这
ELEMENTARY COURSE
ficio and fermanent fortifitation,

THE ATTACK OF FORTRESSES.

Af wine

Pow. all ruvle hipineers 50.14 thine fub. Joreyge sues - XH: \& Freish tent.

f 152 : 2 in gansery. 74 .
Lelog. 10 in Sipteme a 74 A last the . Bec: 74

$$
\begin{aligned}
& 45 \cdot 126 \\
& 152 \cdot 2 \\
& 107 \cdots 10 \\
& =387 \cdots 4
\end{aligned}
$$

$\square$

## ELEMENTARY COURSE

OF

## FIELD AND PERNANENT FORTIFICATION,

## © 1 e attark of jortregers.

By Capt. G. Philips, Royal Engineers, Of the Royal Mititary College, Sandhurst.

## to be obtained only from

BENJAMIN PARDON, PATERNOSTER ROW, LONDON, E.C.;
OR
H. RANDALL, YORK TOWN, FARNBOROUGH STATION, HANTS,


LONDON:
BFNJIAMIN PARDON, PRINTER
PATERTOSTER ROW.


## $\mathbb{C}$ able of $\mathbb{C}$ ontents.

## ADDENDA.

Pages $20^{*} 21^{*} 22^{*} 23^{*}$. Tables of heavy tifled ordnance, projectiles for rifled guns. Snider and MartiniHenry Rifles, Penetrations of ditto in varions substances.
./ $54^{*} 55^{*}$. Shelter Trenches, Gun Pits, Charger Pits and Shelter Pits, with Plate A. in illustration.
., $154 a 154 b 154$ e $154 d$. Details of Single and Donble Lever Spar Bridges, with Plate B. in illustration.

## ERRATA.

Page 66, line 2, for "alteruately as headers and stretchers" read "alternately as rows of headers and rows of stretchers," and alter Figs. 146, 148, accordingly.
" $70, \ldots 17$, for "in conrses of alternate headers aud stretchers" read "in courses alterately all headers and all stretchers," and alter Figs. 160, 162, accordingly.
" 72, , 33 , for 212 , read " 211 ."
", 98, "17. Afler Fig. insert "376."
". 105, ", 3 and 4. Omit these lines here and in Index.
". 114, ", 25, for Fascinesi read "Fascines."
", 117, Fig. 263. Move letter $b$ on left, to the angle 100 yards to the right.
". 137, bottom line, for 294, read "293."
" 143, line 20, for buoy, read "bay."
" 152 , " 18 , for B C, read " D c."
", 171, foot-note, for F C, read " B c."
". 178 , line 11 , for 32 , read " 23 ."
178, line 11, for 32, read "23." (dotted) ought not to oross the ditch behind the tenaille.
191, line 25, for "in the centre," read " at the left."
," 26. Omit the words "the left."
"" "" 27, for " 18 inches within," \&c., read " 3 feet, by throwing the earth that distance beyond the tracing tape."
," ," 35 , for " 5 ' wide" read " 41 ' wide," and alter Fig. 363 accordingly.
", ., 40. After words "first relief," read " 4 feet, making it 3 " 5 " deep at the rear ; they cut away 18 inches of the berm left by the first relief to a depth of 18 inches for the front step of the parallel," and alter Fig. 364 accordingly.
., 192, , 1 , for $7^{\prime}$ read $6^{\prime} 6^{\prime \prime}$.
". 195, Fig. 372. The terminatiug slope at left of Battery is shown by dutted, instead of continuous lines.
" 198, bottom line, for 8 ' to 10 , read " 8 " to $10^{\prime \prime}$ ".
202, line 9. After the word "placed," add "the tape is shifted 3 feet to the rear, in order to mark the cutting line of the trench."
., , , , 10 , for $1 \frac{1}{2}$ ' read 3 '.
.. 205, , 27 , for $(a, a, \& c$.$) , read "(\mathrm{~b}, \mathrm{~b}, \&<\mathrm{c}$.$) "$
". 211, ", 29, for Trenches, read "Breaches."
,, 236 , ", 41,42 , for l l r, read "l l r. ${ }^{3 "}$ "

## $\mathbb{C}$ able of $\mathbb{C o n t e n t s .}$

## SECTION I.

Gunpowder, Artillery, \&c.
SECTION II.
Practical Geometry, Geometrical Drawting, \&c. ..... 21
SECTION III.
FIELD FORTIFICATION.
Chap.
I. On the Profiles of Firld Works ..... 39
II. Obetacles ..... 55
III. Revetments and Revetting Materials ..... 65
IV. Descriptions of Field Works ..... 71
V. Detatls of various kinds ..... 93
VI. Defitade ..... 104
VII. Exroution of Fibld Works ..... 111
ViII. Lines of Intrenchment ..... 115
IX. Bridge Heads, \&o. ..... 120
X. Defenge and Attack of Posts, \&o. ..... 123
XI. Adaptation of Works of Defence to Irregular Ground ..... 131
XiI. Military Bridges ..... 137

## SECTION IV.

## PERMANENT FORTIELCATION.

Снак. ..... Page

1. Of the tabious parts of the Profile of Permanent Works ..... 159
II. The Works Composive a Bastioned Front ..... 168
III. Vauban's First System ..... 176
IV. Tife Attack of Fortresses ..... 179
V. The French Modern System ..... 212
II. Vautied Works ..... 219
VII. Occashonal Wories ..... 225
Viil. Minitary Mining ..... 231
1X. The Pulygonal System ..... 240

## PLANS.

## Priate

I. Vauban's First System

To Face Pagr
11. Difto, Attaok in Advance of the Third Parillel

III. Modern Frenoh System ..... 213
IV. Attaok on the Modern System in Advance of the Third Parallel ..... 218
V. The Polygonal System. Front of the Great Enceinte of Antwert ..... 250

# TABLE OF CONTENTS 

# COURSE OF FORTIFICATION. 

## SEOTION I.-ARTILLERY, EIO.

2. p. 1. Grinpowder, its composition, action when fired, how used to propel projectiles ; object of granulation, size of grains in powder for cannon and small arms.
3. Cartridges for Cannon, how made up.

7, p. 2 and p. 20." Cartridges for small arms, how made up.
8. \& B. Ordnance, three divisions of: of what metal formed.
15 Names of different pieces of S. B. Ordnance and their respective uses.
19 Names of principal parts of a S. B. Cast iran gun.
22. Modes of serving Gums and Mortars, difference in the.
23. Chambers, their nature, objeet, in what pieces used.

25, p. 4. Definitions, Axis, Calibre, Windage, Line of Metal, Line of Sight, Line of Fire, Angle of Elevation for a Guon and for a Mortar Range; Point Blank; Point Blank Range. Velocity, Initial; Final or Remaining.
26, p. 5. S. B. Projectiles. Shot, Solid, Red-hot, Hollow, purposes for which used. Grape-shot and Case-shot or Canister, nature, action on being fired; extreme effective range.
30, p. 6. Shell, Common, object, bursting charge, fuze, sabôt. Grenades, Hand; nature, use, weight, length of fuze. Shell, Shrapnel; nature, object, in what manner fired; Shell, Martin: nature, object, how used.
34, p. 7. Carcasses, nature, object, from what pieces fired.
85. Light Balls, object, how fired; two kinds, action of each kind.
36. Smoke Balls, nature, use.

37, p, 7. Fuzes, object of ; two general classes, nature of each.
40, p. 8. Charges, Service; Fieduced, in what cases used.
41. Tulies, object of; three kinds of'; the kind which is in general use; why?
45. Portfires, what used for, of what composed.

46, p. 9. Quick match, Leader; Slow match, purposes for which nsed.

48, p. 9. Rifled Ordnance. Chief defects of S. B. Ordnance. Inccuracy of fire; to what causes due; Shortness of range: to what due; why large S. B. Guns range farther than smaller ones; object gained by rifling guns; principal effects of riffing; (a), bad effects of windage (if any); of irregularity in shape, or eccentricity of projectile are neutralized; (b), coincidence of axis of gun and projectile ; (c), steadiness of flight of projectile; reason why accuracy is principally due to (a) and (b), and long range to (e). Advantages of elongated projectiles, both solid and hollow.
59, p. 12. Service Rifled Ordnance. Metal used; built up; eylinders, how made.
Breech-loading and Muzzle-loading guns, relativy advantages of each. The two kinds of B. L. Guns. System of rifling B. L. Guns, shot chomber, powder-chamber, grip. Parts of a Screw B. L. Armstrong gun, Barrel, Vent-piece, Breech-screw. Made of closing breech in the Wedye guns. Muzzle-loading guns, shunt principle of making the studs on the projectile take the grooves when fired.
67, p. 14. Projectiles for Rifled Ordnance. Shet, Common Shells, Seyment Shells, Shrapnel Shells and Case Shot; general description of each kind.
72, p. 15. Rockets; nature of a rocket, cause of its motion, rocket-stick. Signal Rockets, Congreve Rockets, and Hale's Rockets. Tube for firing. Advantages of rockets.
76, p. 16. Artillery Carringes : two general classes of.
78, p. 17. Kinds of Artillery Fire. 1st, as regards direction and object, Direct, Oblique, Reverse, Enfilade, Flanking and Cross; 2nd, as regards elevation, Horizontul, Vertical, Ficochet, Plunging and Pitching.
79, p. 20. The Infantry Rifle: description (general) of the Enfictl Musale-loading rifte, and of the Enficid Snider Fiffle.
p. $20^{*}$ The ammunition nsed.

## SECTION II.-GEOMTIRICAL DRAWING, ETC.

81, p. 21, Use of drawing instruments : to protract an angle; use of marcuois scales and triangle.
85, p. 24. Problems in Pructical Geometry. (1.) To bisect a line and an angle.
(2.) To erect or let fall perpendiculars to lines under all circumstances.
(3.) To draw a line parallel to a line.
(土.) To make an angle equal to a given one.
(5.) To divide a straight line into a required number of equal parts.
(6.) To reduce a given figure to a triangle of equal area.
(7.) To construct a pentagon, hexagon, and petugon.
(8.) To draw a line tangent to a virele, of phe veris\%.

95, 1n 25. 2tegil knole in proccical qumations. Clowe hitehe 8inghe bowlime, Single and Doudle ahiot bewls, fieff svols.
100, p. 29. Scoles; deffinition; their rymetenbative fraction; comparntive sonle; calunlutiona for seales; manner of dividing scales: how to fivd the ropresentative fruction of any sente.
104. po 31. Diagonol pailes: their mature und use.
106. p. 34. Menauration; triangle, retanigh and trapesoid.

107, p. 35. Sloper, inelinations of: how expressed by fractions; how to construct a required slope, and to measure an existing elope.
108. p. 36. Geometricat Aroroing, Projection, Orthogrophtic ditto, Plan, Elevation, Soction, Profile. How to conatruct a Plans hrom a given profile; also Section and Elevation.

## SEOIION III.-FIELD FORITFICATION.

## CHAPTEIS I-PROTHES OF EIETD WORKS.

114, p. 39. Fidd and Armanent Fortifieation, difference from each other; main objecte of all defencos. The dillerent cosditions under which Field and Permunent works are msuilly erected.
120, p. 40. Object of the Parupt ald Ditch.
121. Conaramel: do, of Fire and of Observation. Relief.
122. Comurnd of field works on lovel ground; when it

98, must be wcronsed or may be decreased.
, p.41. Uses of Trenclies, with or wilhout Ditches; their advantages and defeots.
126, p, 42, Zhichuess of a purapet; on what depeudent.
198, p. 48. Banquatte, use, breadth for one and for two rauks.
Slope of banquette, use, ustal inclination, when replaced by rovetted steprs.
199. Iritcrior slope, of Parapet: why made steep, usual inolination.
130. Superior slope, its object, usual inclination, greatest ditto, its defect.
Glacis, zature and uses of; its superior slope, how regolated.
181, p. It, Interior crest, or Crest; the magistral line, why.
182. Orest jlane in musketry-proof parapets,
183. Exterior alope, wsual melination; when made more steep, or more geutle. Erterior crest.
185. Borm, olject of, usual dimensions; defeots and adrantages.
156. Ditoh, ita two objecta, one only properly fulfilled.
197. Encarp, why made as steep as possible.
136. Bottom of ditch to have driniage slope to the front.
130. Depth of ditch, its neual limits in field works.
$1 \neq 0$, p. 45. Countrrsoarp, uaually steeper than escarp, why.
Wiath of ditch, minimum in field works, why.
111. Ditch, triangular in section, its advantages.

144, p.46. Profile, eelection of a proper; as regards corimand, thichoness of parapet, and depth of ditch.
145. Remblai and Devlai defined.

Caloulations intolved in determining the profile of a work ; why only approximate.
151, p. 49. Sandbay loophotes on superion slope, uses of, how made. Substituteg for.
$132, \mathrm{p}$, 万0. Stochouls, nature, nse, adyantages aver earthen para-
154. Wrata; how to prevent enemy closing on.

156, D.51. Hodgen, their advantrges for defence; modes of preparing them for defence under various conditions, of time arailable, des, and with or without a ditch on one kide.
$160, \mathrm{p}$. 23. Haw to draw a profile to हcale on eloping ground, with calculations for the sume.

## ORAPIER II.-OBSTAOLES.

102. p. $\overline{0}$. Ohetucies, why ppeesaruy in field works; oonditions they should fulfil.
100, गu 38. Poliscules, naturo, construction: usual positione for.
103. 104. 37. Fraikes ditto ditto asual position dito.
1. Checiaves de frice, how made, and commented in lonethes, nami dimensions; ordivery uses of; deferts; liow ueed as a gate.
 conpenling it from ezomy'h view. Heat wouds to une,

170, p, 60. Trous-de-loup, the two usual sises of: mode of arrangement on ground; use of stake.
171. Enlanglement, how made.
172. Pointed Stakes, use of.
173. Crow's Fect, hory formed, and for whit used.
174. Common fougusses, usual depths, requisite charger : Common fougusses, usaral depths, requisite charges :
how loaded, threo modes of firing.
175, p, 61. Shell fongass, object, two kinds of, how oach acts.
176. Stone forguss, aljoct, mode of construction, usual charge, weight und size of stones used, offect when fired: time and labour required.
177, p, 62. Self-acting fougass, construction, mode in which ignition takes place.
178, p, 63. Inundations, depth, at shallowest end; breadth and leagth, on what dependent. Mode of rendering shallow inuadations unfordable.
179 Dams, manuer in which constructed; earth for construction, from where oltaiued; use of puddling; usual thickness and slopea.
180. Waste weir, its use, position, and construction.

181, p. 64. Shuice gates, use of.
182. Best position for an inundation, with reference to a line of intrenchment.

## GHAPTMR MIT,-REVETMENTS.

183, p. 65. Revetments, use of: the four kinds in general use in field works.
184. Sods, dimensions for cutting, average height of course when built up; labour required to cut with spades; mode of laying sods in each suecessive course; of socuring several courses: slope of revetment: number of sods required; advantages and defects of sod revetments.
185, p. 66. Gabions, brushwood, usual dimensions, mode of making: pickects, their length, number, on what dependent: arrangement in the ground. Waling, how performed, rumber of roils used, to what height carried: mode of finishing at top and bottom with puiring-rods and wilhes; substitutes for withes.
186, p, 67. Men, tools, and time required to matie a gabion; ite average weight,
187. Gabions, iron, sheet; how formed, weight, advantages, defect.
188. Gabions, iron, land; number and dimensions of bands, how pint together, number ot piokets, weight of gabion, adrantages and defect.
189, p.68. Gabiom revetment, how to build, olyject of the intermediate courses of liscines, supporting slope; advantages of gabion revetments.
190. Fascines, usual dimensions. Fascine trestles, how to set up, number required.
Fascine making, how to arrange the brushwood, number of fastenings (either of withes, rope-yarn, or wiré) ; nature and use of the oloker. Men, time, and tools requived for fascine-making; average weight of fascines.
Fascine pickets, use, dimensions, number required.
191, p. 61. Fascine roudment, how to build, uso of anehoring pielots, supporting slope, deflects of revetments entively of fascines. other usen of farcimes.
192, p. 70. Sandbrys, dimeusions, empty; comtente when filled; why pratially filled for revetting:
Sandlay revedment, how built; retaining alopo; num-
ber of bags required. Advantages of sandbags for revetting; their defect.
198.
194.
195.

196, Cosks, how built in revetmont.
Plimks, ditto ditto.
Hurdlea, how made and built in a revetment.
Loose stone wedls, when used for revetments.

## CHADTER TV.-DESCRIPMONS OF FIELD WORKS.

197, p. 71. Defintions:-Siliont Angle; Ae-entering Angle: Flavil: Line of Defence; Angle of Defence; Outline of a work; Faces: Gorge; Capital; Open Works; Closed Works.
198, p. 72. Principles to be olserved as regards the outline:-

1. Length of crest line, on what dependent, and how regulated.
2. Adaptation to ground occupied.
3. Reciprocal defence: how obtained.
(Reason Why Principles 2, 3 may clash with 1).
199, p. 73. 4. Long lines of parapet, in what direction traced, as regards enemy's position.
4. Size ior re-entering angles: reason.
5. Size for salient angles: reason.
6. Lines of defence, maximum length; reasons for.

## Open TVorlics.

200, p. 75. Redren, shape, ordinary size, plêche. Weak points of redans, usual modes of strengthening them.
Double Redans and Triple redans, their shape and advantages.
201. p. 76. Lunett, shape, ordinary size of: flank8, how traced;
202. Fositions of lunettes, how remedied.
202. Fositions suitable for open works.

## Closed Works.

203, 1.77. Redertbis and Forts defined: defects of all closed works, why less felt in large than in small works.
203, p. 78. Ordinary mimimum size for a redoubt: reasoz,
206. Maximum size, why difficult to fir.
207. Size of a redoubt, on what dependent.

Shape of dilto,
ditto.
Garrison ditto,
ditto; object of a reserve.
208. Defects of redoubts: how to obtain a fire on the capitals.
209, p. 79. Kaponier, of what constructed; conditions regulating its length, breadth, and height: usual shape in plan; gallery of commumication: ditch round salient: adrantage of sinking floor, defect of ditto. Positions for Kitponiers, when at an angle, or in middle of face. Mode of arranging kaponiers so as to be secure from enemy's artillery fire.
210, p. 81. Counterscarp Gclleries, where placed, their dimensions in profile, dofect and adrantages.
211, p, 82. Circular Redoults, why not nsually used.
212, p. 83. Entrance into closed works, how visually made.
218. Blockhouses, usual shape, of what constructed, width when used as barracks; interior height. Mode of construction to resist artillory: when shaped like a cross; when built in two storejs.
214. p. 84. Forts, why larger than redoubts,
215. Advantages of parapet Hank defence over availiary flank defence in field works.
216. D. 85. Btar Forts, how to trace when regular; also when irregular. Amount of dead ground in ditches: defects of Star Forts.
217, p. 87. Double Star Forts, their trace; advantages over simple star forts.
218. Bastioned Forts, advantages obtained from their trace.
31, p. 48. Construction followed on each exterior side. Technical terms in bastioned forts. Esterior siite, Perpendicular, Lines of defence; Faces; Flanks; Curtain; Bastioned front of fortification, Bastion: garge and demi-gorge of ditto: the Flanked Augle of Bustion: Shoulder Angle ; Angle of defence, or Flanking Angle; Curtaint Angle, or Angle of the I lank; Diminisiced Angle.

Perpendicular its object, why mado $\frac{1}{10}$ in a square fin a pentagon, and $\frac{1}{6}$ a hexagots or a superion
polygon.
220 p. 88. Eicterior sides, maxiroum and minimum, reasons for
each. each.

222, p. 90. Manner of tracing fire of the entire flank.
222, p. 90. Manner of tracing an irregular bastioned fort.
Manner of obtaining an increased length of flank,
223, p. 91 . Demithont inereasiong the perpendicular.
suitable for.
224.

Reduits, object of: trace, on what dependent. Rela-
tive command, if an earthwork. Varions tive command, if an, earthwork. Various works
suitable for reduits.

## CHAPTER V.-VARIOUS DETATLS.

225, p. 93. Artillery fire from field works, two modes of obtain226. Embrasures, object of. Direct or oblique. Sole, Sill Oheeks, Genowillère, Nircct, Mouth, Sue, Solay, Merlon.
Width Width of neck for Field Guns and Howitzers, height of Genouillère in difto: mode of revetting cheeks.
Use of raw hides in ditto. Use of raw hides in ditto.
227. p. 94. Advantages of direct over oblique embrasures. Hurter, its use. Sloping and countersloping embrasures.
230, p. 95. Defects of embrasures generally. Suitable positions for: use of montlets.
231. Barbettes, nature and use of. Placed either on a face or at the salients, why usually the latter. Dimensions for a single gun.
233. The Ramp; its use, breadth, and slope.

To draw a barbette for one gun, either on a face or at a salient.
237, p.97. Advantages and defects of barbettes; suitable positions for: modes of obtaining musketry cover for gun detachments.
239, p. 98. Traverses, objects of: various kinds of
240 .
240. Splinter-proof Traverses; thickness at top, slope of sides, height.
241, p.99. Traverse to cover entrance, its distance from main parapet, its length, how determined; why given a
banquette. banquette.
244, p.10. Traverses for protection from enfilade; conditions regulating thickness, length, and slope of sides.
45. Parados, object of; condition" regulating height: passages through them; magazines or bombproofs
inside them. inside them.
246. Powider magazines why made small, suitable positions, mode of construction for rectangular and for triangular magazines.
249. p.102. Platforms, nature of; why not usually required with field guns.
250. Barrier Gates, width for artillery. Chemenar de frvise as a substitute. Gate for infantry in small numbers.
253. Bridges aver ditches of Field Works; width of roadway for field suns, usual dimensions for baulhs. planks, ribbands, and racklashings: uses of each. Supporting trestle: when required.

## CHAPTER VI.-DEFILADE.

254, p. 104. Defilade, object of; Plan of Defilade, how determined: Tangent Plane, use of.
256, p. 105. Mode of determining the cormmand of a line of parapet; of obtaining cover by sinking the terre-
258. Hein. Height of planes of defilade above terreplein ; on what dependent; least height of ditto.
259, p. 106. Mode of defilading an open work from the front, and from one or more hills.
202, p. 107. Cases in which Purcilas are required in open works: how to find their length.
264, p, 108. Mode of defilading a closed work from all sides, with parados.

Eenglit anil airention of pmodus; how detormined, thioknuza and slopest. pissuges round its enda, bow protentod; puissages thorough it, magazimes, suat btandigus in it.
26: , I- 10a. Eriw to defilade a dosed work from one side only, mithent a porados.
265, p.110. D. finnle of Lines: priaciples followed. Atuonet of cover reguired, on what dependent: cisus in wlioh coner frum view is the chiof req̧uiaite.

## COSFTEE FH-BXECOTION OF FIBLD WOREB,

270, p.111. Operitions to be succeasively performed.

1. Oultine to be Ifirminod; oi what dependent.
2. Gramand, thictriess, and other dimensions of the poynite of the sceural foces to be atpurately determineal.
3. The nork to be traced and profiled.
4. Tlim tourting jarty to be posted, and work begun.

Trowing. Magistral line; how traced. Prufles, object of; munner in which they are erected. Obivique profites, object of. What limes are required to be marked on the ground.
272, p.112. Forking Party. Diggers, one xow of, at what distanee ordiuarily ayant: minimum distance, inconxenience of.
Showellero, their usual proportion to Diggers.
Rommers, ditto ditto.
Tools roquired for Diggers, Shovellers, and Rammers.
Pesitions of the Torkmen at commencement of work.
278, p.118. Uitches dug loy successive layers, or depthe, with rertinal sides; why: usual depth of ench layer; slopes of escarp and counterscap, in what manner autimily formed.
Mode of employing a double row of Dingers in one esuatation; in what soil used; whyonly at beginruing of work; depth for the two rows of diggers to dis.
274. Tine required to condruct o work, on what dependent; when trace of work has no material influence on time; why. Easy soil, aud Dificull soil; meaning of these terms. Quantity of ent to be exeavated in each kind by diggers. How to calculate "Time Fecyuiral" approxizaately.
275, p.114. Why there is an excess of earth at salients, and a deficuency at the Fie-entering angles: usual modes of remedying.
Drazing, importance of; how usually effected.

## CHAPTRIB VIL.-CTMES OR INTRENCHNEST.

276, p.115. Livas, defined; Continueus and Broken Lines, or Limes with hidervals.
Intreached Comp: Linies of Circumvellution, and of Contruvallation; Introwehen Positions.
27. Lives, whell usptolly resorted to $;$ aulvantages gained to the dofance ly a good acrangernent. Defects of long Cuntinuous Lines. Cases in which Confimoous Linss might be used.
278, p, 116. Tuuban'r Redan Like, trace of; its defects; alteratione to aliove trace.
279. Termills Line trase; preat acfect of.
280. Vruloid Line or Cremeifliere Line, how traced; Eranchios and Erutchefe, Hlanking axigles. Alvantage of the trace, in what positions applicable; Wher fursud of simplo tranchos ; mode of traeing merasa at ralluy.
241, p, 118. Badioned Cinem, tome and defects.
292. I'melim of purely Continuous Lines to be stroug; why-
Live wet fativoala. Low the warke nee usially dratioul probiles shopg, reabot fors Advantugen compursel wilth Cortimoun Linea of equal Hout Warda cmimeuted by trenclues. How a double liny of woelces may be amranged; melyawced
line, open works, how tracod; rear line, elosed works, mode of tracing. Whes rear line may be replawod by a singlo work.
285, p.119. Posifions of quas for defence of broken lines ; principles on which the armanounts of field worls are buserd.
286. Double line of slosed works, rear parapots of udvanced lime to have low ass thin parapets; why.
287, p.120. Single line of closed works, conditions to be fulfilled.
ghapter ix.-bridge heids, etc.
288, p.120. Bridye Head, single and double; object of. Single Bridge head, best position for defence; reasons. Number of bridges; on what denendent; usual arrangement of works.
289, p. 121. Conditions to be fulfilled in a single bridge head.
290. Aetion of a current in a winding stream, with referewce to direction and velocity of current, to depth of water and to steepness of bank; why disadrantageous for a Military Bridge.
Precautious necessary to protent a bridge from injury by floating bodies.
291, p.129. Fords, their probable position in winding and in straight streams; depths fordable by the three arms: how to pass a ford; method of reeonnoitring a ford.

CHAFTER X.-DEFENCE AND ATTACK OF POSTG, ETC.
292, p.123. Defence of Intremehed Positions. Positions for guns, light and heavy; of reserves; communications for lattex, \&e.
293. Defence of a Field Work. Surprise, haw to guard against; defenders, how allotted to the varions parapets; the reserve, its dnty; its strength, how regulated, Hand grenades and shells for throwing into the ditech. Loophales of various kinds on parapets, Improvement of existing obstacles, or construction of fresh ones. Coxmmemicutions with the rear.
295, p. 125. Defence of a House. Advantages and defects of buildings nccupied for defence; conditions of site, shape, and construction, farourable for defence; operations to be performed; loopholing walla; lateral communications; retrent to upper floors: precautions against fire; barricading doors and windotrs; improving or creating flank defences: obstructing enemy's approach; communications with reax.
Tambours and Machicoulis Galleries, nature, object, and mode of construction.
298, p. 127. Defence of a Filloge. Rechrit, ehaice of; main line of defence; lateral commmications, direct comemunications to reduit; streets barneaded; minor operations.
300, p. 128. Athuelk on Field Works, usually by Assauit; Why. Two modes of assanlting works.
301. Attack by surprise, when undertakea, favourable time.
302, p.129. Attisk by Open Force, directed on more thas one point, False attacks, object of; When converted into real attacks.
Composition of sa assaulting columge.
Sharmishero, their duty.
Storming party, ditto. Gumers and Sappers to aceompany.
Reserve, difto
Positions for Artillery sexisting the attack: mode of divecting their five; manner of givive the wanult: line of advance; how to entor the ditch, if flanked.
\#hy-bugs, der, to partially fill ditch, if doop\% scaling lahlowe, how carriet nuid placed.
303, p, 130. Attuck in u llomse. Outline of opurations.
30t. Destroyting or paraing Wilitiory Ubitactan in im ussuuts;
eqeecial party for the purpose ; to what particular purposes their efforts are divected.
Details for priparing, carrying, firsing and firing explosion bage: quantity of powder required for different obstacles.

## CHAFTER XI.-ADAETATION OF WORKs to freegular sites.

$305, \mathrm{p} .131$. Object of a field wowk may ho either offensive or defensive ; difforences of profile and trace in ench crase.
307. Best ground to occupy for defence; conditions it should fulfil; why very high ground is not very good for defence: when ground becomes unfavourable for defence.
$308, \mathrm{p} .132$. Morle of ocrupying the crest of a gentle stope with a line 309. Ditto porapet ; advantages of such a position. Ditto ditto of a slope, convex in section ; 310. disudvantages of this kind of slope.

Beason why steep slopes are less favourable than gentle ones, Usual mode of occupying summits of stecp slopes.
311. p. 139. Ditto sible dilto of slopes, so steep as to be inucussible to un exieny; advantages of such a position.

## Ezanflies iy Illustration.

312, p. 133. (1.) A salient angle placed at the top of a gentle slope.
$313 . \mathrm{p}, 104$. (2.)
Ditto at top of a slope convex in section.
p. 185 (3). Summit of a hill oceupied by a redoubt,
p. 136 ( $\pm$ ). Ditto ditto by a fort.

1. 137 (5). Ditto of a larger hill ocoupied by a suitable binution of works.

## CHAPTER XII,-MILITART BEIDGES.

317, 1. 137. Militany Bridges, defined, The component parts of ordinary bridges; how replaced in military bridges.
Piers, object of; two distinct methods of forming.
Buulks, object of; in what direction laid; substitutes sametimies used.
Planks on Chesses, object of; in what direction laid. Thibiands, where placed; two oljects of.
S18, p.138. Trestle Bridyes, when applicable; sort of stream unsuitablo for.
Construction of a Trestle with four legs; nse of additional legs.
319, 1. 189. Formation of Trestle Bridge: in shallow water; also in water too deep for men to stand in : without boats to assist.
320. Pile Bringis, nature of; to form a pier, cap-plate, braces; distance apart of piers:
Cases in which pile bridges are suitable or the reverse.
Use of piles to form breakwaters. Piles, how driven.

## ienating bridges.

329. p. 1.10. Blansliard's Pontoon Eridese. Raft, composition of; how carried on land: length of bridge formed by; number of men to ench raft.
Contonns, shape, dimensions, internal construction, water-tight compartments, pump-holes, sunken haudles.
Sinddes: object, length, breadth, how secured to pontoons, iron pins of saddle.
bualks: Number, leugth, object, how secured to saddles.
Chesses, whole; haw formed, cleats.
Chesses, Half: how formed, objeet.
Outriggers, how formed, use of, how sechred.

324, p. 142. Formation of the Bridge, from the ehore by independent rafts ; how effected, disadvantage of the
method.
325, p. 143. Formation.
carried of Booming Out, how commenced and carried on; ehesses, how carried and placed; racking down, how effected, object of. Brenst lines :
where fastened. where fastened.
Adyantages of the mode of forming bridge by
hooming out.
326.

To break up a complete bridge into rafts: unracking, how effected; chesses of bays; how liftec, and
where placed; bavilis of bays; how where placed; baullis of bays; how unpinned, and where placed; outriggers, where and how secured; breast lines, when cast off; reserve rafts (without anchors), to what position temporarily moved, Weighing anchors by mooring rafts; cables bent; Which anchor first weighed. Positions of men in rowing; mode of steering pontoon rafts.
Mooring and reserve divisions, relative positions in rowing.
327, p. 144. To forma the bridye from rafts, order of the successive operations.
328, p.145. Gap in Bridge, object of, how to form.
The three orders (or iutervals of pontoons) of the bridge ; capabilities of bridge with each.
329. Pontoon raft for heavy artillery, how formed.

The Infantry Pontoon Bridge, in what details different to large bridge ; number of pontoons carried in a carriage.
330, p. 146. Usual mode of putting together on land, and lawnohing ; manner of passing it down a steep bank or counterscarp; intervals (central) of pontoons :
weight of bridge.
333. Blansiard's Pontoons, advantages and defects arising
from their shope and construction from their shape and construction.
Feason why boat-shaped pontoons are more stable than cylindrical oues.
334, p. 147. Bridyes of Boats, when used; size of boats, intervals apart, with large and small boats; saddle or trestle in lieu; how constructed; mode of laying baulks; improper ditto; greatest immersion of boats; how regulated and why; anchoring and otherwise securing boats.
335, p. 148. Cask Bridges: casks, large; why preferable to small ones; size used at Chatham.
Barrel Pier, how to form ; gunwales, slings, braces, their nature, use and position.
Raft of casks, how formed ; transoms, use of.
336, p.150. Raft Bridges, adrantages and defects of timber rafts as piers of bridges; shape for piers in non-tidal rivers; illustrations of raft hridges.
337, p.151. Flying or Swinging Bridges, nature of; cause of theiv motion; length for cable; most suitable kind of boats: cable, how supported, if long; where fastened to boat.
Mode of using two flying bridges in brond rivers.
Ditto a flying bridge in very rapid currents,
338, p. 152. Double Ladder Bridge, mode of forming ; when available.
339. Bridge made with ladders, auting as beams.
$340, \mathrm{p} .158$. Bridge of logs, illustration.

## SPAR BRTDGES.

341. Single Lever Bridge: Spars; how connected on shore, and got into final position; baulks and planks, \&e.
342, 1. 154. Single Lever Britge, improvement on, when long spars are available; advantages obtained.
342. Double Lever Bridge, construction; disadvantage.
$3 \pm 4$. Colculations for Flouting Military Bridyes: Conditions of buoyancy, and sirength of banllis:
343. 

pressure on eache pier; on what depeudent.
Maximum weight brought on a bridge by Infantry four deep, by Cavalry in file, and by Fixidd Arvilicyry four deep, by Cavalry in file, sud by fistributed : why.
36.p. 153 . Pruygame of a doted body; haw detorminerl.

S veridabe broyatucy of urea naself, how determined.
How to determine uminlobe buoymacy of a pim it the lanefle of bay has bees fixed.
How tonletermine the kangth of bay when the buoyancy of each pior has been firsed.
367. Streceylis if beama ns regnuds breadth, depth, and levigh, two differont straise to baulks of bridges; why artillery exert a more trying strain to the banalks thau on pqual meight of eavalry or infontry: Safo berring wcighte and breaking weighta of buams.
345, p. 157. Examples of calculations.

## SECTION IV.-FERMANENT FORTIFICATION.

MIAPTER I.-FROEINES OE NERACATENT WORKS.
349, p. 159, Ancind Fortinications, walls of; their terreplein and purapet wall ; machicnnlie, use of; fomers ; distance apart; height, Sor; Dithh, when used; Kerp, object of.
Causas of the atrength of anciont defonces.
Revolution in dedence, cansed by introduction of artillery, Walls (esoarps), necessity of concealing; terreplein and parapet, alterations to.

FBOFILE OF MODERN POBTIFICATIONS.
153, p. 160. Bompmer, natare, object: height, on what dependent; braulen, how regulated: terreplein, use of, condition fixing its breadth; usual breadth on main rawparts: when made narrower: slope of terveplein, amount, object: rear slope, object of, inclination; When replaced by a wall.
354, p. 161. Purapet, height above terreplein; thochress of, in new work; superinor slope, uaval inclination: exterior slope, usual inclination: interion slope, usual inclination. Masonry parapets, thicknees, great defects
of, when used. Iron parupets, when used, advautages,
355. Fscarp, object, hav covered, proper height for enceintes: whem not used.
Ditch, uses of, pariety of dimensions for. Counterscarp, why revetted usually, when not revetted.
356, p,102. Grecred Miay, in what manner formed; terreplein, depth umier mrest, breadth of; width (usual) of covered way, why. Uses of covered way; its great advantages. Paliswdes, object, where placel.
357. Glacis, object; superion slope, how regalated.
357. Arsizlery fire from rampart, its proper action of works in front.
Mudkelry ditto ditto ditto ditto.
Esearp, covared from distant fire; how: reason for making dry ditches deeper and narrower than hitherto. Nutual dependence of command, width of dituh, covered may, and slope of glacis.
359, p. 163. Plone of sito, equalization of remblai and deblai.
360. Intches of Fortresses, three kinds of, their respective adyuntages and defeets. Cenettes, nature and use. Alvantages of deep and narrow dry ditohes.
361, p.164. Retaining Wralls, two kinds of. Cordon, मature, use. Solid revetments, four kinds of, respective advantages.
362. p. 165. Counterforte, rature, object, usual intervals; the three forms of: names of parts.
363. Escurps, thiree lands of; respective adrantages and defocte.
Tomer-liroic, mature and defects ; obsolete.
365, p.167. Counder-arched revelmento, Lature, usis to which spplied, adynntayes of.
345. p.168. Casemates, nuture and olject: for details of, see p. 219 .

31ifon. 108. Futurman of in fortroas: Fromt af Worlifieativin: Sigateme To Mortinioution. Bustioned Sy tem: Fnlyyonal Systim. Moden of tlanking the ditches in ruch.
 of comtani, on what deqoseleat: line of defence, on
what depumdent.
365. Body of the Place, or Enceinte, Mrain Diach, Outworks, Adrunced Works, and Delached Morlis defived,
369. Priciple of determiniug a Bastioned Front, when the relief of the Flanks is first settled: two mades of fixing length of thees of bastions: maximum lengtiss for lines of defence of fortresses, both formerly and at present time.
371, p, 171. Construetion of a bastioned front from the exterior side; extevior and interior polygon; exterior and interior sides: full and hollow, or emphy bustions.
Counterscorp of main ditch, how traced, reason for.
872, p.172. The Ravelin, its shape, position, and principal object; its counterscurp how fraced: other uses of the ravelin: reasons why large ravelins are preferable to small oney: originally made small.
378. The Tenaille, kind of relief, situation. Principle determining its relief. Uses of the tenaille, defect of ditto.
374, p.178. The Covered May, its situation in plan: its two enlargements.
Salient Pluces of Arms, where and in what manner formed: varions uses of them.
Re-entering Fluces of Arms, situation, faces of, angle for when straight; if eurved, for what objeet. Iwo principal uses of the R. P. of Arms.
975. Branches of the Covered Way, where situated.
975. Troverses in Covered Way, object of, why built as parapets, length of. Position of traverse nearest to S. P. of Arms, ditto for that nearest to R. P. of Arms; when intermediate traverses would be used. Passages round ends of traverses, two kinds of.
Double crotehet passage, how formed, its special defect and advantage.
Single crotchet (or Cremaillere) passage, how formed, its advantage and defect.
Defects common to both methode very great.
376, p.174. The Glacis, its ordinary height and base.
377. Communientions of Fortresses, two kinds of.

Siege communicutions, conditions required in their situation and construction.
378. Postern, wature, minimum breadth and height, greatest permissible slope: position in a bastioned front: how its slope is determined in wet and dry ditches.
379. Capanvicres, object of.

Double caponniere, how formed, superios slope how regulated.
Single or demi-coponvière, ditto ditto
380, p. 175. Ramps, nature of, usual breadth aud slope: positions in a bastioner front, advantages.
881. Masoary steps (Pas-de-souvia), usual width, length and height, why sometimes commenco is feet above ditch: great defects of.
359. Solly Ports, nature, position, shape, slope: how
383. Peace or Civil Communications, limited in number: on which frouts placed; gemeral arrangement of gateways, drawbridgus, and fixed bridges.

CHAPTER III.- vAUBAX'S EMSY BY:TEAF.
384, p. 176. Fomarks conceruing Vubhan's great skill and experieuce both is the coustruction and the attack of Fortcesses,
285, 12.177 Tirat System. Conatruction of Encrivid. Baterier Side limits of ; Peymuricualar, lengthe tor; levesther v/ fiees: bruce of juniks; of moin Chuatersourge.
387. drawn ; counterscarg of ravelin, how drawn,

Tenaille, fuces, gorge and end walls, how drawn; centre face or curtain.
388. Cowered Way, cres of, how triced. Re-cntering Places of drms, leugth of demi-gorge, direction of their faces. Base of slope of glacis.
Traverses in Coveced Way, thickness, position of those at the salient, and near the re-entering angles; passuges round them.
389. Sally-ports, number and position, breadth, two
390. methods of tracing:
291. Dovble Caponniere position and dimensions,
392. 1.178. Commands and Reliefs of the System.
392. Oommunications of a Front, positions, de., of the Posterns, Caponnicire, Steps, Ramps, and Sally-ports. Defects of Vauban's 1st System.

## CHAPTER IV.-THE ATTACK OF FORTHESSES,

394, p.179, Reasons why Fortresses can seldom bo attacked de vive force: desperate nature of such an attack, whether effecter by day, or, as a suxprise, by night: conditions justifying such a mode of attaok.
395, p. 180. Bombardment, its nature; when undertaken, in what eases likely to fail, and to succeed. (Seo Note 1, T, 18x.)
396. Blockade, its nature and object: its success, on what 397. Sepeudent, when undertaken. (See Note 2, p. 189.) Siege, to be effective, should be carried on with
398. Vigour. Outline of operations of a regular siege. security, how caloulated. (2.) To resist a Siege, additional troops requisite.
399, p.181. Armument (Artillery) of Fortresses. (1.) For immediate security, how ealeulated. (2.) To resist a Sioge, extra pieces requisite, why dependent in number on size of fortress.
400. Strength of Besieging Armuy, usual proportions to garrisons of different strengthis.
Working Parties, strength of, on what dependent,
Guards of the Trenches, strength of, on what dependent.
General duties (camp, pickets, escorts to convoys, \&c.) on what dependent, why impossible to estimate correctly beforehand. Assumed strength for purposes of ordinary calculation.
Reliefs (or number of relays of troops) proper for. (1.) Guards of Trenches. (2). Worting Parties and also General Duties; why the two latter requive longer repose from duty than the former.
Length of retief (or number of hours' actual ituty), for (1.) Guards of Trenches, (2.) Working Parties.

Cavalry, when required in the trenches, where posted, proper strength of.
402, p. 182. Ordnance for the Attack, why usually inferior in number to those of the defence.
Siege Train, strength for, according to Sir John Jones.
403, p. 183 Materials for carrying on a siege, when possible to estimate probable quantity.
404. Causes of the superiority of the Attack over the Defence. (1.) From the faulty construction of Fortresses. (2). From improved weapons of attack. (See Note 3, p. 189)
Operations of a Regular Siege, both for the Attack and for the Defence, during the following periods:
405, p. 183. From the Investment of the Fortress to the Opening of the Trenches.
406, p. 184. From the Opening of the Trenches to the Formation of the 2nd Paxallel.
407, p. 186. From the Formation of the 2nd Parallel to that of the 3rd Parallel.
408, p. 187. From the Formation of the 3rd Parallel to the Crowning of the Covered Way.
409, p. 188. From the Crowning of the Covered Way to the Capture of the Place.

NOTES EXPLANATORY OE THE OPERATIONS OE THE ATTAMR AND DEFENCE,
Note 1, p. 188. (410). Description of the bambardraent Flushing, 1809.
Note 2, p. 189. (411). Blockade of Pampeluna, 1813, outline of.
Note 3, p. 189. (412). Siege purposes.
Note 4, p. 189 purpozes.
Note 4, p. 189. ( 413 ), Artillery and engineer purles, nature and
use.
Note 5, p. 190. (414). Outline of irregular siege, termed the
Note 6, p. 190. (415). Sap rollers, nature, use, dimensions,
Neight, and labour required to make,
Note 7, p. 190. (416). Parallela and demi-poralle?
190. (416). Parallela and demi-parallels, other name for; their nature; general direction and object; other uses to which put; when fresh parallels become necessary ; extent of parallels towards Hanks, how regulated: Hlanks, how protecter.
417. Distance of first parallel from salients; how regulated in past sieges; why dependent on position of ricochet batteries; probable position in future ; why not dependent in future on position of the first batteries.
418. Trace of 1st parallel, by whom and in what mannex effeeted.
419. p.191. Working parties for trench work; in what manner told off; how superintended; tools required ; mode of posting them along the tape ; distance apart of workmen; rate of extension; how each man commences his portion of trench.
420. Execution of lst parallel; number of reliefs (relays of men) required in difficult and in easy soil; work done by each; drainage, how effected. Profile given to ist parallel; ditto suitable for marshy soil.
Note 8, p. 192. (421). Approaches, why in rigzags ; usual posi tion; in what direction traced, Redurns to zigzags object of; other convenient uses of. Approuchies, why made deeper than parallels; why usually on the capitals of the works which have to be crowned.
Note 9, p. 192. (422). Conering Parties, object of; how posted.
Note 10, p. 192. (423). Siege Batteries; nature, construction, \&cc.
Buttery, meaning of term; how named according to their intended fire, and their profile.
Elevated, Sunken, and Hal $j$-Sunkien Batteries, defined; profiles of each.
424, p.193. Height of cover given in batteries : interior slope for guns and for mortars ; superior slope ; exterior slope; thickness of parapet, usual berm; object of ditch, how excavated.
Breadth of trench for gun batteries; why shallower in rear than in front.
Length of a Battery; on what line measured; how determined; use of extru hulf-merlon.
Eparlment, object, length, thickness, and direction.
425, p. 194. To trace an Elevated Battery. The two lines actually marked; what points are marked along the building line; mode of rounding the shoulder of all batteries.
426. Worlomen for Blevated Butteries. Per gun or mortar portion in eusy soil, and with Gubion revetiment extra diggers in difficult soil; extra worknem if Fascines or Sandluys are used.
Time required for construction of Elevated Batteries at Chathom : probable time at a Siege.
427, p. 196. To trace a Suntien. Battery. What lines are marked: reason for partial ditch in front.
428. Number of workmen per purtion of a Stuken Rattery, for Gabion, Fascine, aui Sanilbag revetments respectively; time required.
429, p. 197. Trace of a Half-Smdim Butlery.
What lines are marked; number of workmen, per portion ; time required.
430. Comparative alvantaqes of the three aunt of Singe Bitteries. Elerated Rotteries; deftects of tiome to construct, and size of parupet exposed to firo:
nidraotegers of simplicity of constrnction. of inninags; truxerons and plutforme, convenience of layzug.
Sonder Datherion, ulvuntrice in timo, of convenience of formation in existing trumbens; defects of drainage, ot guan binge diose to nutumal ground, inownvemunco of construction, mud od layiag platforms.
IFil-5oniten Patteriel, nilvantagea nud defecto similar to Sunkes Ruitterica; crowleil atate of wollanem.
FSL. Splanfir-prowi Imarreme for Siege Batteries, thiokDise at 200 ; siles, why rusutted rery steenly; leseth; when jowed to paripets; weual proportion to piease al urimumes in buttery.
432. p. 108. Mannsinces fir Sige Batteries; surrice pattorn; general dimensions aol arrangement of body, Eudrowies, paseaye, nud ramps; roof, of that formed; druionge, how effeeted.
Quartity of powior containued; sdvantages of the survina putform: prechution titkas as regurds ver-timal firs; atumber of nagquives required; nise of Lathoratory Mraquaine; positions of magusines.
Gencral ilesmintion of the Lema-to or Triengutar Mingeine formerly used.
488,p.199. Fint focms for guns und mortars; natare nud names of the rarious component parte.
Gun Platformu, lenfth, breadth, and glope; reason for the slope; the sleperce, number, in what manner laid; inturvnls between, how filled, for What reason; the plankis, when and how laid; the rillamite, where placed und how secured,
4st. Mertar Placforms, lent th, brealth, why laid level, Why stronger thin gun platiomens; mode of laying the sureral parte.
Advanthges for Siage purposes of these gun and nortar platforme.
$485, p-200$. Puaitions of Butteries; direction, as regards the lone of size.
Enflowing Zattcria, where placed with reference to olject; distance from olject if S, B. Ondnance are used for ricochel fire: use of moxtary ; number of pieces required; arrungement of the rarions pieces in the battery; four great advantages of enfilaling
Cunter Batteries, where pisced with reference to object; advaituge of connter batteries; their great defecte compared mith enfilading batteries ; cuses at nigers in which they are requisite.
Note 11, 1. 201 . (437). Truererdes on tatpparts, soits required.
Note 12, p. 201. (438). Conuter-approuches, their nature, usual nosition; how compeoted with covered way; their alject.
Note 13, p. 201. (439). Mode of macsling embrastues.
Note 14, 1. 201. ( $4+0$ ). Fifle Pva, by whom formed; manner of torming; suitable dimensions; uses of the pits; mode of couverting a line of pits into a trench.
Note 15. p. 201. (4t1). The nd parallel, situation, and extent; differultien attending the construction; by what
method exeouted.
449, p. 202. Frymen Sip, object of: distance apart of the workmoin in $18 t$ retief: mode of commening and continmuin the work, 2 nid and 3rd reliefs; nt what distmoce apart workmen are placed; cliinf difficulty in Tlying Sapt: virious modees of cormmencing the
warle. worle.
Nob 16. p. 202. (443.) Nocosity tor communication round rear
Solto 15. 1. 202, ( 441 ). Whfocta of live in a parallel.
202, (444). स4foots of large shells om earthen

Nom 10, 1. 202. ( 106 . Two purpoute for whicherrasition.
 what thes would first forzo.
Nian 20. p. 20. + tit. sypuime delined. When it has to be



crowning fascines; brigule of sappore; use of sap fliggots, or sand hags in tien ; sup forks, use of: nutura; Sap travel, by whom widened.
449, p. 204. Principle of sumping; on what depends tho progress made; timo required to place and fill a fresh gabion.
Stranding simph Sap, number of sappers to execute ; worle flone by each; advantinge of the sup.
Mode of protocting the heal of a sap while in pro-
t50. Contibiuation of flying and full (regular) sap, sometimes practicable.
Note 21, p. 204. (451). Difficultios attending the commencement of the 3xil prablel; advautages to bosiegers atter completion of the sud parallel.
Note 22, p, 205. (452). Crowning Coveral Way by Aseanult, objeofions to the operation; when it would be undertaken ; preparatory mensures to take; execution of the assault; necessary extent of the lodgments.
Note 2y, p. 205. (453). Circular portions, where and how formed: naes of.
Note 24, p. 205. (454). Double Sap, when resorted to.
Jehk's Direct Double Sup, advantage of ; number of hrigades of sapperers used; work done by each brigade; by which sappers the traverses are formed; number of sap rollers used; rate of advance of the sap.
Double sap without traverses, when suitable; dimensions of trench.
Note 25, p. 206. (455). Trenche Cavaliers; their nature and object, position and direction; return or epaulment, object of; profile of cavalier.
Note 26, p. 206. (456). Diffieult conditions under which lodgminents on crest of glacis have to be formed.
Note 27, p. 206. (457). Cormort Batteries on Creet of Glucis, position for ; object of; when can be used as hreaching batteries.
Note 28, p. 207. (458). Dreach, position of ; usnal extent.
Breaching Eattery, position of; great difficulties attending ita construction; to what causes due; mode of supping out the embrasures.
$459, \mathrm{p}, 20 \mathrm{~s}$. Node of forming a breach by artillery; quantity of ammunition required; on what lependent.
Note 29, p. 208. (460). Descent into the Ditch, when made as a Great Gallory or acia Blinded Gallory : disadvantage of the latter; cleur dimensions of the galleries: ordinary slope.
Usual mode of commencing the descent; slope, how regulated; frames for the blinded gallery, Low connected and roofed over.
461, 1. 209. Blowing in the Counterscarp, how effected, object.
Note 30, p. 209. Fusage of the ditch.
403. To pass a dry ditch h haw commenced and continued, enemy's fire how kept down : sorties to be guarded against : cramped situation of besieger's workmen.
463. To pass a wetd dithe without a current. Sort of cauzeway to be formed, use of a donble gallery of descent.
404. To prass a vel difch which has a curvent. Difficulty of the operation: either by floating bridges or by canse ways with oponiugs ; difficulty of anchoring bridges. General Pasley's proposed mote as tried by uxperiment.
Noto 31, p. 210. (40i.) A Pranilt of a breach. Variable nature of the difficulties, to what causes duo ; disadrantages of assunlting from distant trenches, of not being able to silonce the defensire fire; ulvautiges attendrig the assault when the tronches are curvied the breach, und the fire from the fortress io well kept down.
Note 32, 1, 210. (466.) Forming a Ladqment by Satp on a Brouch. When the oporation cam be atterapted. Vuuban's roodo of effecting it.
Nute s3, E. 211 ( 167.$)$ Deffice of it Brauch. Reasons why Iremches in the enceinte are not urually dofendeni.
 defence of the breach.

## OHAPTER V.-THE FRENCH MODERN BYSTEM,

468, 1. 212. Title appliad to shecessive Bastion Systems from Vuuban's time.
469, Construction of enceinte. Exterior side, limits of; perpendicular, length of; faces of bastions ; flanks, puain counterscarp, reason for its direction.
470. Ravelin, salient of, how determined; faces, how

47I, drawn; counterscarp, ditto.
Reduit of Pavelin, faces how drawn, breadth of ditch; flanks of reduit, object, length, how to draw them; gorges of ravelin and its roduit,
472. Teraille, breadth of, how separated from flanks and curtain: small flanks to, length and object.
Reduits of R. P. Arms. Onter fuce how traced, inner face ditto, width of ditch: use of small flank at end of inner face; gorge walls towards ravelin, how traced, for what reason.
474, p. 218. Glacis of R. P. Arms, why curved; how drawn. Width of covered way.
475. Coupure retrenchment of ravolin, object of, trace of, width of ditch.
476. Gorge wall of coupure, how traced, why,
477. Traverses in covered way, some 18 feet thick, others 10, reason; pathway at inner end, for what purpose ; traverses, how placed in front of bastion and of ravelin.
478. Commumications round traverses, how traced ; pan coupé at S. P. of Arma of Bavelin.
479. Traverse in ditch of Ravelin, object of, haw drawn.
480.

Covalier Retrenckment not part of System; its command, faces and flanks, how drawn; width of ditch; coupures in face of bastion, why each is broken.

## RELIEFS OF MODERN SYSTEM.

481, p. 214 . Reasens for not having the whole of main ditch defended by the flunks.
482, p.215. Relief of enceinte, of glacis, slope of latter.
483. Telief of ravelin and its reduit, slope of glacis, relief of ditto, level of ditch of ravelin, reasons.
484. Bottom of ditch of reduit of ravelin; height of its escarp.
48j. Reduit of R. P. of Arms: command, depth of ditch, height of esearp, relief.
486. Relief of Tenville, how determined, actual calculation; why flanks may be higher than centre.
487, p.216. Plane of site, how determined.
488. Tuble of Reliefs, as determined.
489. Communications, on what principle arranged.

490, p.217. Details of communications.
491. Revetments, what kinds may be used.
492. Comparisou of advantages of Moilern System over Vauban's First System: illustrated by the operations of the attack in advance of the 3rd Parallel.
494, p. 219. Defeets of the System. Exposure to enfilade, want of bomb-proof cover; communioations not good for an active defence.

## OHAPTER TI.-VAULTED WORKS.

495, p. 219. Casemate, or bomh-proof, nature of, thickness of arch, and of earthern covering, increased use of casemates; various kinds of oasemated buildings.
496. Casemated Barructes, neual position of ; details of those in some of English Forts ; breadth, on what dopendent, height of pier walls, rise of arch; gallery of communieation in rear, use of.
497, p.220. Casemated Gunt Butteries, ordinary construction; position in which placed, in land and sea defences; sole kind of firo to which guns are exposed,
498. Defects of gnu casemates of old pattern, as regazds (1.) Ventilation. (2.) Form of embrasures.
499. Ventilation, how provided for in modera works.

500, P. 221. Embrasures in the masonry walls of old casemates, two prineipal defects, to what causos due.

301,
502.

Improvenents introduced by the dmeriems.
Ditto in England by use of Tibbed racers: conserquent reduction in size of embrasures; defeet still tuxist-
503, p. 222. ing im masonry embrusures.
503, p. 222. Casemates with iron shields, the masonry piers and arches, covering to latter; shield, thickness of
$504 . \quad$ how supported; size of embrasure.
Adrantages to be secured by being ablo to elevate or depress a gun on any required centre of
motion. $505, \mathrm{p} .223$, Mortar
positions for ; diffienlt construction of, suitable
506. Hoxitions for; difficulty of silencing mortars.

Haxo Casemates, nature of; portion of front wall exposed; positions suitable for; when used singly
507 to act as traverses.
507. Casemuted Kaponiers, nature and object; details in
508. Chap. IX.

Blindage, nature and use of, Leaning, Blindage, or Single Blindage, how formed.
509, p.224. Gun Blindage, usual construction of, suitable positions, serves as traverse.

OHAPTER VII.-OCOABIONAL WORKS.
510, p.225. Four groups of accasional morks.

## 1. THOSE USED IN THE ENCEINTE.

511, Citadel, nature, position, and usual objects. Esplunade; which fronts of citadel are stronger than the others.
512, Cavalier, natiure and object; usual position ; advantages and defect of one in a bastion.
513, Retrenchments, nature of ; their two objects ; permanent or temporary; various shapes of.
514, p.226. Straight retrenchment, its advantage and defect ; precaution to be taken in all retrenchwents.
515, Tenaille retrenchment, its shape, position when used.
j16, Bastion retrenchment, ditto ditto
517, Caralier retrenchment, shape, construction.
518, Coupure retrenchent, to what works applicable; how to apply to an empty bastion.
Objects to be fulfilled in Choumara's proposed retrenchment.

## 2. THOSE USED AS OUTWORKS.

519, p.227. Tenaillons ; shape; object for which constructed; great defects of; why obsolete.
520, Demi-Tenailloms; shape; defects.
521, Counterguard or Couvre-face; shape and profile; its relative command; usual object; how traced in front of both bastions and ravelins; has a command of observation over glacis; why. Defects of counterguards.
522, p.228. Hornwork, its shape, object, suitable positions, defects.
523, Crownuork, single, double, de.; objects, de., as for horuworks.

## 3. THOSE USED AS ADTANGED WORKS,

524, p.229. Alvanced Works, cases in which they mar be nsed; usual kind of work employed; mode of arrangement; when advanced wovks may be valuable, or the reverse.

## 4. THOSE TSED AS DETACHED WORKS.

525, Why independent warks are used; when a chnio of detached forts is used; Futreached Comp, uses of: two principal objects for which deticebod forts awo constructed; moilo in which each is ellected.

527,
$526, \mathrm{p}, 230$. Conditions to be fulfilled by the forts.
Why ouly apphied to large und important fortressua?
Advantages to the defocee secmed by intruachod camps when appliad to large furtresaes; to what prinepally due.

## 

 rogured; how lined temporarily and permanently:
182. Dimensions given to Shafts and three sorts of Gollirner; whon lined with timber; eliape for ditto in Nulth.
The two methode of lining with timber.
 plank usod; numes of difforent parts.
प्रो) pu2a2. To sink it shift; direction of centre line: mode of Jlaning buch casen
sise. To drive a Gallery frome buttom of a Shaft; fixed frame shupe; dear breudth; object; mode of fixing a case in a gallery.
25UL Caning a! open order, whon and in what manner und.
334. Dress how placed in sloping palleries: mode of clanging the slope of a gallery aus its direction horixontally.
630.p.283. Frumber imd Shectiong, when used; dimensions of Shinjt and Gallery Framea; Slueting Planks.
256. Skupf to Sink in: Intervals betiveen frawes; top frame, how placed; scoond frome, ditto; battens, use of; eheeting planks, how driven and wedged out: object of the medges; mode of placing a fresh trawe.
is7, [2 234. To drive a Gallery from bothom of Shaft; fixat frame, how placed; sheetiag for roof; when required for sides: fresh frame, how placed.
thio glowe shating when and how used; fulse frame,
230- nljeect of, how tied.
च07 Chambir, object, position ; charge of powder, how Chamber, object, position; charge of powder, how,
placed in chamber in dry, damp, or very wet soil; boxec for large charges: bolk oceupied by powiler.
-14. Tramping; object; how effected; distance to which ermiel: charge for on untamped mine.
212 p-23in. Powidn Floss two nanal sizes; wooden trough; filze, how connectrad to hese.
S43. Simultminemes Explosions, how effected with powder
544. Minimy Tools required; push pick, use of; canvas hucted and miner's truck, dimensions and use; miner's bellows, how worked; tin tubes; floxible joints.
Tisa, Morlacen requived in shafts and galleries.
46, pidalt. Churye of Mines. Effects of a mine, on what deprevient, orater, when formed: Puali of Ruptrum. Fiadive of Crater and of Explosion: Line of Loast Renidance: One Tinal: Two kined (or other Tinal) Crutere; Common MPines; Whder-charged and Over-charged Mines, or Gloles of Compression; Dinumaions, Sc., of a Two-linad Crater eharges of powler, why proportionate to the LILR ${ }^{3}$ for similne cruters; chargess for Two-lined, Thrcelimel nud Etix-lined Craters.
Camonflet, mature und object.

## COUNTRFMINED SYSTEMS.

万iti, p. 23EL Conivermines, natore and object.
Alughiani, Aronch, Listening, aud Envelope Golleries: diancosione naual for Brauch and Jistering Gal-
legies.
ith. Fringpul conditions to be fulfilled in a system of I4 Conatemminer. Dusfur' Countirmines upplied to Froneh modern Fafori mlof jurtione of a front are mined; rensoles for sut mining the ghesis of the bastions.
Tratuile of Eallories vador glamis of Pavelia.
 of thei miens ; chamhers, has reuched.
 moule is sligh they uro arranged; object of
doulite row ot chaubors.
sis2, p.239. Junctions of galleries, how formod: rentilating hales, doors, grooves in wulls, cesspools, \&o.
553. Attack of Countormines. Uhargos uaed in the attnck and in the defence: adrantages on the part of the attacels.
Ontlino description of the mode of attack on comutermines: great delay to the attack caused by countermines.

## CHAPTER EX,-TEE POLYGONAL BYSTEM,

544.p.240. Gradual rise of German or Polygonal System; its chiet dillerence from the Bastionch Syatem.
55․․ Improvements in new works which are not part of any System.
55bi. Polygonal System, from its adaptability to varions conditions, renders it difficult to select a type for a frost.
Compazison betweon the Polygoual and Bastimed Systems, with refereace to four important points.
307. Flank Deferer. Conditions that a flamk should fulfil; the varions kinds of fire to which a bastion Hank is exposed, both distant and close; the canses of the security of the grans in Kaponiers from these fires,
5558, p. 242. Number of Guns in a Flank; on what dependent; disadvantages attendiog an increase of length in a bastion flank; also of adding to the number of guns, by casemating the flanlis; why each or bothe of these modes may bo resorted to in a Polygonal Front,
559. Reasons for the flanking fire from a Kapomier being more ufficient than that from a Bustion,
560, p, 243. Security of Enceinte from Emflade. Reasons why the enceinte of 4 large fortress is more secure from enfilade than that of a smaller one on the same system; why enceinte of a Polygonal Fortress is more secure than that of a Bastion Fortress on a similar polycon.
561. Detailed account of the defensive disadvantages arising from a line of work being enfiladed.
562. Length of Eaterior Sides. Maximum length of exterior side; on what dependent in all systems; how fixed in the Polygronal nud in the Bastioned System: why greater in the forruer.
568, p. 244. Effect on the maximuam length of exterior side that a short curtain has in a bastioned front; adyantages also gained; defects in a bastioned front att ndant an a short curtain, from the necessary connaction of the relief und the trace.
564. In the Polygonal System, traco and relief are not dependent; very short exterior sides (or fronts) can be used.
365. Difficulty of fising minimum length of exterion sides for a bastioned front; defects attending small bastioned frouts,
566. Long faterior sides, cases when they would be desiratle.
Short erterior sides ditto ditto
507. Short extervor sides ditto Nivect Firc on Fied of Attach Namber of guns able to bear on exterior ground; on what dependent in a given system; with similar polygons, why greater in amount with the Eolygoual than with the Bustioned System; ditto as regards direct fire on the capitals.
$56 \mathrm{~B}, \mathrm{p}, 245$. Ilustrations of Polygonal System from existing Wonks recently constructed.
569. Fortress of Avturerp, its stitnation, purpose for which constructer, its probable gawison in ease of attack; why its work ufford a good type of a syalum: the two diatinct sots of works in the fortress.
580, p 246 . The Enceinte, number of fronts in: their nvamge leugth: position of the two citarlila; which fronts are mulo wenker thim the ofleers, will for whit reason; the atrong tronts, their numabor. general direolion; weakost purt of exceinter hows fifrengthened; length of cnceintes

The Detached Forts, their number, distance in advance of enceinte, average central intervals. Length of front of the Introncked Camp. General construction of the Eorts. For defensive adyantages of the Intrenched Camp, see Art. 527, p. 230. The wurlis composing a front of the Linceinte.
572. The Body of the Hace. Defensible Barrack. Curtains, number ; First Flanks, number and object ; Second Flanks, number and object; Faces and Orillons, number of each. Place of Assembly, where situated.
The Kaponier, Flanks, Head and Wings, number of each; tiers of guns in the flanks ; which of them is casemated.
The Couvre Face. Branches, gallery in its countersearp (gorge) wall; palisades, or low escarp in lieu. The Ravelin, Braaches, Crotchets, number per branch. Reverse Battery, Great Traverscs, where placed, with what provided.
573. Construction of a Front. Esterior side, maximum and minimum length; rampart of enceinte, when coincident with exterior side, when slightly brisured inwards. Salient of Kaponier, where fixed; Curtain how determined; First flank and Sccond flank ditto.
574, p. 247. Defensible Barruck, length of head, wings and gorge; the gorge how occupied. Parapet on roof of head and wings, command of; number of men accommodated in the casemates.
575. Wings of Kaponier, how traced; Court of the Kaponier, dimensions of; Casemates of Kaponier, number of; how they may be used as mortar casemates; communications through the Head, counter arches in ditto, object of the Kaponier wings; ditch of Kaponier how flanked.
376. Gouere foce; Salient how fixed, direction of faces; principal object of the work; guns in its salient; advantage of its dry ditch; galleries of mines under ito salient; its dry ditch, how flanked.
577, p.248. Ravelin: salient, how fixed; direction of faces; width of ditch, Orotchets in ravelin, object of; Casemated battery in its salient, for what purpose constructed, how protected. Ditch of ravelin, how flanked. Low battery in ditch of ravelin, various reasons for its low level : direction of its magistral line; its outer flank how protected; how made to act as a reduit to the R. P. of Arms.
578. Covered Way, breadth for enceinte and for ravelin; why not traversed; crotehets in front of ravelin, number and length. Re-entering Place of Arms, traverse in, its object. Bonnette in the S. P. of Arms of ravelin, its command and objects. Blockhouses in the Places of Arms.
579, p.249. Cavalier in the enceinte, position, shape and command, guns in its faces and flanks ; casemated traverses on its terreplein.

Profile of the works, Great command given to enceinte, small command to ravelin, for what purpose.
582 . the fire en barbette.
Increased width to terreplein of main rampart: inclination of exterior slopes; of escarp und counterscarp ; berm, width for enceinte and
ravelin. ravelin.
583, p.250. Communications, on what prineiple arranged. Muin roadways to each front, their breadth, adrantage of their situation.
584. Supplementary roads, their position; rolling bridges, where placed, Ramps, their breadth in enceinte, couvre-face, and ravelin.
585. Defensive powers of a Front. Remarks as to the difficulties attending a siege of the enceinte of Antwerp in each of its suecessive epochs.

## DETACHED FORTS ROUND THE ENGLISH DOCKYARDE.

586, p.252. Principal object of the Eorts, their distance in advance of the place, on open ground; when made at a less distance. Usual central intervals between the forts, on what dependent.
587. Conditions to be fulfilled by each work; general shape, trace of the faces, and flanks; additional face on eapital, when used; length of various faces, how determined.
588, 1. 253. Command of the works, haw regulated. That given when casemated barracks are placed under the ramparts. Flanks, why not given casemated barracks; their usual cornmand. Traverses on the terreplein, to what uses applied.
589, p.254. Depth and width of ditches; changes in their dimensions from former custom, reasons for them, and for command of glacis; Covered way and Qracis on what portion of the works used: communication to covered way. Escarps, usual profile; the chemin-des-roniles, breadth, how flanked; Clounterarches in escarps and counterscarps, uses to which placed.
590, p.255. Kapponiers, number of tiers of fire; details or a Kaponier for one tier of guns and one of loopholes above. Ordnance suitable for the Kaponiers ; usual positions of Kaponiers, why extremely secure from enemy's fire, their flank defence. Communications to the Kaponiers.
592, p. 256. The Keeps (or Reduit), objects with which constructed, their nature, and usual shapes. CourtJard. Command given to front portion, conditions fulfilled by this command. Relative level of the rear portions. Ditch of keep, how flanked. Communications to Kaponiers. Escarp of keep, how covered from pitching fire. Ditch of gorge of fort, how traced, for what reason.

## ELEMENTARY

## COURSE OF FORTIFICATION.

## SECTION I.

GUNPOWDER, ARTILLERY, \&c.

Limited eatent of the subject treated.-Gunpowder: its composition and action; object of gramulation; castridges for connon and for small arms.-Artillery, S.B. Ordnance : divisions of; metals used; guns, shell guns, howiteers and mortars; chambers, use of"; lechnical tems.-Ammunition for S.B. Ordnance: Shot, solid, hollow, red-hat, grape, case, or canister; Shells, common, hand grenades, Shraphel, Martin; Carcasses; Light balls, ground and suspended; Smalie balls; Fuses, fime and percussion; Charges, service and reduced; Cartridges; Tubes, connmon, detonating, friction; Portfires; Qucickmatch; Slow-mateh.-Ripled Ordnance: General explanation of the Rifle system, advantages gained by its adoption; Service rifled ordnance, B.L. and M.L. gens; their mode of rifling; Table of service rifled ordnance.-Projectiles, ete. for Rifled Ordnanoe: Shot, common shells, segment shells, fuses, time and percussion. - Rockpts, Signal and Congreve. -Carralaes for Ordnance, two general classes of - Various Krids of Artillemry Fire, nirect, oblique, enflade, veverse, flomting, cross; horisontal, vertical; ricochet, plunging, pitching.-The ENFIeld Rifle and its ammunition.

1. The following general description of gunpowder, artillery, \&c., will serve to convey a sufficient knowledge of the power and action of the fire-arms in use, to enable the student in Fortification to comprehend their influence on the general arrangement, and on the various details of works constructed for defence and for attack.
2. Gunfowner is a mixture of nitre (saltpetre), sulphur, and charcoal; the proportions of the several ingredients in the powder used in the British service being for every 100 parts -75 nitre, 10 sulphur, 15 charcoal.
3. When a burning body is brought into contact with gumpowder the latter takes fire, and, owing to the nature of the ingredients, and the intimate manner in which they are mixed together, the combustion spreads through the mass so rapidly as to be almost instantaneous, and the result is the sudden production of a quantity of an elastic gas in a highly condensed state.
4. The force exerted by this gas in expanding in every direction at the moment of its formation, is used in fire-arms for propelling the various projectiles in use. Being confined by the metal of the gun from expanding in any direction but that of the bore of the piece, a charge of powder, when fired in a gun of any kind, acts in a twofold manner-viz., by forcing the projectile in one direction out of the bore of the gun, and by causing the gun itself to recoil in the opposite direction.
5. Gumpowder is granulated in order to allow the flame of the explosion of one portion to spread rapidly through the mass, and so cause the rapid explosion of the whole charge.

The grains in cannon powder are made coarser than those in the powder used for small arms; for in large pieces, owing principally to the large size of the charges used, the combustion of the powder is required to be more rapid than in small arms, and this is effected by using more coarsely grained powder. In ordinary cannon powder the grains vary in diameter between $\frac{1}{\frac{1}{2}}$ and $\frac{1}{10}$ of an inch, while in the Enfield rifle powder they vary from $\frac{1}{15}$ to $\frac{1}{y^{2}}$ of an inch.
6. Cartridges for Cannon are made up in flannel or serge bags, separate from the projectile.

Flannel is used because it is not liable to leare burning particles in the bore of the gun, and because it withstands well the effects of transport.
7. Suatl Abar, of Rifll Cammages, contain both the charge of powder and the bullet. The charge is contained in a thick paper cylinder, which forms a complete bag, and the bullet is rontained in a thin paper bag enclosing the powder bag. The paper which surromds the bullet is coated with beesswax, in order to prevent the barrel from fouling after repeated discharges.

In londing the rifle, the powder is poured into the barrel from the bag; the bullet, with the paper coreling and beeswax, is then inserted in the barrel and rammed lome, after the powder bag has been separated from it and thrown away.

## ARTILLERY.

8. Shooth-bore Ordnazce.-Ordmance is divisible into three kinds,-viz., Heavy, Medium, and Light Artillery.
9. Heayy Artmesty includes the guns, and other pieces of ordnance, that are used in Foriresses, Coast Batteries, and in the Nayy, where the appliances available for serving them, nllow the heaviest and most powerful pieces to be used.
10. Mediuar Abtilleriy includes the pieces that are used in the attack of fortresses and for wher purposes, where considerations of transport forbid the use of the heaviest guns. Medium guus differ from heavy guns in their weight only; the same calibres are used in each.
11. Light Armbleay includes the pieces that accompany, and move with, an army in the field.
12. Heavy and Medium S. B. Artillery are made of cast-iron ; Field S. B. Artillery of bronze. Two varieties of heary S. B. guns, lately introduced for naval service, are made of wrought-iron; (see Table, page t.)
13. Bronze is used for S. B. Field Pieces in order to be able to have as light a gun as possible ; for although bronze is specifically much heavier than cast iron, yet, owing to its superior tenacity, a much less weight of metal will suffice than would be required in a cast-iron gun of like calibre.
14. Cast-iron guns may be fired as rapidly as possible, and are much cheaper than bronze guns, which latter cannot be fired rapidly for a continuance, as, when heated, they tend to droop at the muzzle, that is, the gun bends by the muzzle dropping downwards. This peculiarity of bronze prevents its being used as a material for Siege Ordnance, which should be capable of sustaining a rapid and continuous fire.
15. The pieces of S. B. Ordnance in use are-Guns, Howitzers, Mortars.

In Fig. 1, 2, 3, and 4, the comparative dimensions of the different natures are shown, as the figures represent pieces of the same calibre, or diameter of bore.
16. Guns are subdivided into two groups-viz., Solid Shot Guns and Shell Guns.
17. Solm Shot Guns (Fig. I) are constructed of a strength sufficient to withstand the effects

Fio. 1.
F. A.-Cascahle.
A. B. Fist Reinforce
B. C. Second do.
C. D.-Chase.
D. E.-Muzzle.
A. E. Length of Gun.
c. d. Lreech.
a. b. - Dispart.

of large charges of powder with solid projectiles. Their length is sufficient to exhaust the uccelerating effect of charges of from one-fourth to one-third of the weight of the shot. They are " 68 -pounder cast-iron gun, of 95 ewt."
18. Shesl Guvs (Fig. 2) are designed to project shells and hollow shot horizontally, at a

Fio. 2.

high velocity, with smaller charges than are required for solid shot guns of similar calibre. They are therefore made of less strength, and are also shorter than solid shot guns of similar calibre.

Shell guns are named from the diameter of their bore (calibre) in inches. There are two varieties of shell guns in the service-viz., the $10^{\prime \prime}$ and $8^{\prime \prime}$ shell guns.
19. A smooth-bore cast-iron or bronze gun is divided into five principal parts-viz, THE Cascable, the first reinforce, the second reinforce, the chase, the muzzle.
20. Howrizers (Fig. 3) are similar in their general construction to shell guns, but are much shorter and fire a smaller charge of powder. They were originally intended for fring shells at low angles, but they are so much exceeded in range and accuracy of fire by shell guns, as to be almost superseded by them.

Iron Howitzers are distinguished by their calibre ; there are two varieties-viz., the $10^{\prime \prime}$ and $8^{\prime \prime}$ howitzers.

The Bronze Howitzers are named from the weight of the solid shot which fit them, althongh

they do not fire solid shot. There are three varieties-viz., the " 82 -pounder," the " 24 -pounder," and the " 12 -pounder" howitzers.
21. Mortars (Fig. 4) are very short pieces of ordnance, designed to throw shells at high angles of elevation (generally $45^{\circ}$ ). They differ from guns in having their trunnions at the breeeh, instead of being near the centre of the piece.

Mortars are made of cast-iron and of bronze: the former are intended for Fortresses, Siege Trains, Naval purposes, \&c.; the latter, which are of small calibre and very light, are chiefly employed in the attack and defence of Fortresses.
22. The modes of serving guns and mortars are essentially different. With guns the charge of powder is, as a rule, constant, and only elevation snfficient to enable the projectile to reach the object is given to them; while with mortars, the elevation is, as a rule, fixed $\left(45^{\circ}\right)$, and the charge is varied for the different ranges.
23. The bores of Shell Guns, Howitzers, and Mortars, which fire comparatively small charges, are provided with Chambers, which are a contraction of the bore at its extremity. The general form in use, is that termed the Gomer Chamber (Fig. 2, 3, 4), which is a frustrum of a cone, with a spherical end.

Chambers have the adrantage of concentrating the charge of powder and increasing its useful effect; they also cause the shot when rammed home to fit the bore, thereby reducing the bad effect of windage, or space left between the bore and the projectile, and causing the centre of the shat to coincide with the axis of the gun.

## 24. SMOOTH BORE ORDNANCE.

TABLE OF WEIGETS, ETG, OF THE PRINCIPAL PIECES.

| Nature of Orduance. <br> Built up, Wroughttron, Orduance. <br> $150-\mathrm{Pr}$ | Weight. $\qquad$ <br> Cwt. | Calibre. | Leugth. |  | Charge |  | Ranges |  | Remarks |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Built up, Wroughttron, Ordrance. 150-Pr, ............. |  | Inchers. |  |  | 1 lbs. | P. R. | 19 | $8^{\circ}$ |  |
|  |  | $10 \cdot 5$ | 13 | 3 | 85 | 315 | 635 | 2095 |  |
| 100 ". .......... | 125 | 9.0 | 10 | 3 | 20 |  |  |  |  |
|  | 87 | $10 \cdot 0$ |  | 4 | 12 |  |  |  | 600 yds . with <br> 450 , $52^{\circ}$ elev. |
| $10^{\prime \prime}$ Shell Gun | 65 | 8.05 | 9 | 0 | 10 | 320 | 660 | 2220 |  |
| $8^{\prime \prime}$ " | 59 |  | 8 | 0 | 8 | 290 | 580 | 2080 |  |
| $68-\mathrm{Pr}$. | 95 | $8 \cdot 12$ |  | 0 | 16 | 320 | 700 | 2540 |  |
| 32 " | 58 | $6 \cdot 375$ | 9 | 6 | 10 | 400 | 820 | 2610 |  |
| 38 " A. | 50 | $5 \cdot \ddot{82}$ | 90 |  | 88 |  | 747 | 2443 |  |
| 24 " | 50 |  | 96 |  |  | $360$ | 750 | 2230 |  |
| 18 | 42 | $\begin{aligned} & 5 \cdot 292 \\ & 10.0 \end{aligned}$ | 90 |  | 8 | 350 | 690 | $\begin{aligned} & 2130 \\ & 1500 \end{aligned}$ |  |
| $10^{\prime \prime}$ " "Howitzer. | 42 |  | 5 | 0 | 6 |  |  |  |  |
| $\dot{\alpha}\left(18^{\prime \prime}\right. \text { Mortar. }$ | 22 | 8.0130 | $\begin{array}{ll}4 & 0 \\ 4 & 4 \cdot 8\end{array}$ |  | 20 |  |  | 1227 |  |
|  | 100 |  |  |  | 4400 |  |  |  |  |
| $\dot{\infty}^{\prime}\left\{10^{\prime \prime}\right.$ " | 52 | 10.0 | 3 | $9 \cdot 6$ |  | 9.5 |  | 0 ह |  |  |
| ゅ் $\left[13^{\prime \prime}\right.$ " | 36 | 13.0 | 3 | 3.6 | 9 |  | 0 \} |  |  |
| ¢ $\left\{10^{\prime \prime}\right.$ | 18 | 10.0 | 2 | $7 \cdot 5$ | 4 |  |  |  |  |
| $78^{\prime \prime}$ | 9 | 8.0 | 2 | 1:2 | 2 |  |  |  |  |
| Bronze Ordnanoo. |  |  |  |  |  | P. B. | $1{ }^{\circ}$ | $6^{\circ}$ |  |
| 12-Pr. Gun. | 18 | $4 \cdot 62$ | 6 | $6 \cdot 6$ | 4 | 300 | 700 | 1800 |  |
| 9 ", | 181 $\frac{1}{2}$ | 4.2 | 6 | 0 | $2 \frac{1}{3}$ | 300 | 680 | 1750 |  |
| 6 :. | 6 | $3 \cdot 66$ | 5 | 0 | 112 | 200 | 620 | 1600 |  |
| 3 " ${ }^{\prime}$ | 21 | $2 \cdot 91$ | 3 |  | 10 oz . |  |  |  |  |
| 82-Pr, Howitzer. | $17 \frac{1}{2}$ | $6 \cdot 3$ | 5 | 3 | 3 | 300 | 500 | 1400 |  |
| 24 " | $12 \frac{1}{2}$ | $5 \cdot 72$ | 4 | $8 \cdot 6$ | $2 \frac{1}{2}$ | 270 | 520 | 1520 |  |
| 12 ", | $6 \frac{1}{2}$ | $4 \cdot 58$ |  | 9.2 | $1 \frac{1}{4}$ | 200 | 420 | 1290 |  |
| $4 \frac{2}{5}$ inch ${ }^{\text {a }}$ | $2 \frac{1}{2}$ | $4 \cdot 52$ |  |  | - 1 |  |  |  |  |
| $5 \frac{1}{3}$ inch Mortar. | $1 \frac{1}{4}$ | $5 \cdot 62$ |  |  | $7{ }^{2} \mathrm{oz}$. |  |  |  |  |
| $4 \frac{2}{5}$ inch $\quad$ " | $\frac{3}{4}$ | $4 \cdot 52$ |  |  | 5 oz |  |  |  | The Coeliorn ${ }^{\prime \prime}$ |

25. Definitions in Artillery.-The Axis of A Gun is an imaginary line passing through the centre of the bore (F, E, Fig. 1)

The Cafibre is the diameter of the bore, in inches.
Windage is the difference in diameter between the bore of the gun and that of its projectile.
The Lise of Metal is the visual line joining the highest points on the base ring and the swell of the muzzle. It is marked on guns by a couple of notches, and it gives a line vertically over the axis of the gun, the trunnions being level.

The Line or Sight is the visual line passing through the tivo sights (at any elevation) and the object.

The Line of Fire is the axis of the gun produced.
of sight; that of a mortar is then of a gun is the angle formed between the line of fire and the line of sight; that of a mortar is the inclination of its axis to a horizontal plane.

The Range is the distance from the muzzle of a gun to the second intersection of the trajectory with the line of sight. In practice, the range is usually measured from the muzzle of the gun to the first graze of the projectile.

A gun is said to be laid Point Blank on an object, when its axis produced passes through the object. A gun may therefore be laid point blank with reference to an object, and yet have several degrees of elevation or depression with reference to a horizontal plane.

The Point Blank Range of a gun is the distance from its muzzle to the first graze of the projectile, when the gun is fired with the service charge, and directed with its axis parallel to the ground, which is supposed to be level.

Inifial Velocity is the velocity with which a projectile issues from the bore of a gum.
Final or Remaining Velocity is the velocity at any given range.

## AMMUNITION FOR S, B. ARTILLERY.

26. Projectises. - The projectiles fired from S. B. Ordnance are Solid and Hollow Shot, Grape Shot, Canister (or case) Shot, Common Shells, Shrapnel Shells, Martin's Shells, Careasses, Light Balls and Smoke Balls.
27. Solm Shot are spheres of cast-iron,* having a diameter a little less than that of the bore of the gun. They are fired from all guns (not shell guns) in the service, and may be used at all ranges. They are most useful against troops in masses, for destroying buildings, dismounting guns, and breaching revetments, for which latter purpose shells would be of little service.

Red-hot Shot are fired against shipping, buildings, and anything combustible which it is required to set on fire.

Hollow Shot are simply common shells fired without a bursting charge, their fuze-holes being closed with a metal plug; formerly special projectiles were made.

They are fired from shell guns, and were introduced for Naval service against wooden ships, in the sides of which, at moderate ranges, they make large apertures and form destructive splinters.
28. Grape Shot (Fig. 5) consists of a number of cast-iron balls, arranged in three tiers, by means of three circular cast-iron plates, and a bottom plate of wrought-iron; the whole is secured by a wrought-iron bolt which passes through the centre of the plates, and is provided with a head at the lower end, and a screw on the top to receive a nut.

The number of shot in each tier varies from three to five, according to the nature of the gun, for which the grape shot is intended.

When fired the shock of the explosion fractures the cast-iron plates, and the shot are thereby set free from one another, and spread as they proceed onwards.

Grape Shot are very destructive up to ranges of 800 yards, and can be employed with considerable effect on open ground up to 600 yards.
29. Common Case Shot, or Canister Shot (Fig. 6), consist of a cylinder of tin filled with small iron balls, the number and size of which vary with the calibre of the gun. They are provided with an iron or a wooden

> Fia. 5. Grape Shot. $32-\mathrm{pr} .-\frac{1}{6} \quad$ Crc. 6. Case Shot. $32-\mathrm{pr}-\frac{1}{6}$.
 bottom, according as they are intended for use with iron or bronze ordnance.

The cylindrical case is broken by the shook of the discharge; the bullets are thus liberated and proceed onwards, and spread over a considerable space.

Case Shot is most destructive when the ground is hard and the enemy's front considerable. They are effective at all ranges under 300 yards.

[^0]30. A Comas Sirell (Fig. 7) is a hollow sphere of cast-iron, having an opening termed the fuse-hole cut through the metal for the insertion of the bursting charge, and afterwurds of the fuse. When used, the shell is filled with powder, which is ignited at the required moment by means of the fuze. A common shell weighs about two-thinds of a solid shot of the snme diameter.

Shells fired from guns, shell guns, or howitzers are provided with wooden bottoms or sabots, altached to the shell by means of a rivet opposite the fuze-hole.

The sabot serves to keep the fuze in the axis of the gun in londing, and perhaps lessens the rebounding of the shell within the bore.

Mortar shells do not require sabots, owing to the shortness of the bore of the piece.
A shell is broken into a number of splinters by the ignition of its bursting charge; the
 violence of the explosion is so great as to cause the splinters to fly to considerable distances. Splinters of $13^{\prime \prime}$ shells have sometimes flown a distance of 600 yards from the spot where the shell burst. A $10^{\circ}$ shell fired horizontally will scatter its fragments 2,000 yards.

Shells are used either to do damage by their splinters, as when fired against troops; or to destroy earthworks, buildings, de., by fixst penetrating them and afterwards exploding in them. In the former case they should burst a little before they reach the oljject; in the latter case, just after reaching it.
81. Hand Grenanes are small shells intended to be thrown by hand among an enemy, either in the attack or defence of worls; they are provided with if fuze which burns seven seconds. They weigh, when filled, 11b. 18oz, each, and can be thrown by hand a distanee of about thirty yards.

Hand Grenales are also thrown, in numbers at a tíme, from mortars.
32. Shrapnet Shellis are shells intended to have the effect of case shot at long ranges. The most improved pattern is the Diaphragm Shrapnel, invented by Lieut.-Colonel Boxer, R.A. It is shown in fig. 8 .

The metal of the shell is made only thick enough to withstand the shock of firing, in order that a small bursting charge may break it open, without violently bursting. To facilitate this object, the shell is provided with four geoves in its interior surface, which form 80 many weak points. The interior of the shell is divided into two chambers by a wrought-iron partition, or diaphraym. The smaller chamber contains the bursting charge, and is termed the powier chamber; while the larger one, termed the bullet ohamber, is filled with bullets. The interstices between the bullets are filled with coal dust, to prevent motion among the bullets.

Shrspnel Shells are always fired at high velocities; when the bursting charge is ignited, it breaks open the shell and liberates the bullets, which proceed onwards, spreading out in their flight, at a velocity which depends on that of the shell at the moment of bursting. To be effeetive, the shell should have a high remaining velocity when it is burst, which should take place when the shell is about 50 yarda short of the object fred at, in order to allow the bullets to spread, without losing too much of their velocity. Move nicety is required in firing Shrapnel Shells than with any other projectile.

Shrapnel Shells are used against troops, especially cavalry, at ranges exceeding one-third of a mile.
33. The Marrin Sheld is intended as a substitute for red-hot shot, when fring against wooden shipping, \&e. It is a cast-iron spherical shell, lined with a nou-conducting coating, formed of loam and cow-hair. When required for use, it is filled with molten iron, which quickly sets at the filling hole; this latter need not, therefore, be closed with a plug. The metal of the slell is thin at the sides, but thick at the top and bottom ; extra thickness is given at the top, so as to afford a long filling-hole, and to cause the molken raetal to set there quielily; and at the bottom to withstand the shock of firing.

This shell is intended to break on passing through the side of a ship (or building), and therely liberate the molten iron, which would be scattered over the dock of the ressel, und produce conflagration, besides causing ingury to the defenders.
34. A Carcass (Fig. 9) is a cast-iron spherical shell, having three vents or fixe-holes in its upper hemisphere. The metal is thicker than in common shells, as the vent holes weaken it.

Carcasses are filled with an incendiary composition of a highly inflammatory nature, the flame from whieh issues with great fury through the vents, and burns, according to its nature, from 3 to 12 minutes. Three holes are made at each vent into the carcass composition, and are filled with ordinary fuze composition.

Carcasses are fired ehriefly from mortars, but are also used from guns and howitzers.
Their object is to set fire to houses, shipping, or anything combustible.
They are chiefly used in the bombardment of towns.
35. Lighm Batis are projectiles containing a combustible composition, which burns with a brilliant light.

Their object is to enable the position, occupation, and numbers of an enemy to be discovered at night.

They are principally used at sieges.
There are two varieties-viz., the Ground Light Ball, and the (Boxer's) Suspended, or Paraclute Light Ball.

The Ground Light Bail consists of a cylindrical wrought-iron skeleton (Fig. 10), which is filled with the composition, and covered with canvas. Fuze composition is driven into holes made in the light-ball composition, to facilitate the ignition of the latter.

Ground Light Balls are thrown from Mortars to moderate distances. They burn from 10 to 20 minutes.

The Suspenden, or Parachute Light Ball, consists of a shell of strong pasteboard, out into halves and secured together by a linen band glued on to them. In the lower half is placed a hemisplerical iron case containing the composition, and in the upper half is a large calico para-

Fig. 10.

$$
\text { Ground Light B. Inll Skeleton. } \frac{1}{6}
$$



Fic. 11. Fic. 11.
Pettman's L.S. Percussion Fuze.


Etr 12.
Comanon Puze.- -1.


Section.

chute packed into another iron case, and attached to the composition case by a small chain. There is a small bursting charge of powder placed between the pasteboard and iron cases, with a fuze attached.

These Light-balls are fired from mortars at an elevation of about $75^{\circ}$; the fuze should be arranged so as to burst the shell, when over the object. The pasteboard shell is thus opened, the composition is ignited, and the parachute spreads out and supports the case containing the burning composition by the chain. The light continnes to float along, gradually descending, and the composition burns with great brilliance for about three minutes.
36. Smoke Balls are pasteboard shells containing a composition which, upon ignition, evolves a large volume of smoke.

They are thrown from mortars, and are employed to drive out an enemy from mines or other confined situations ; and also to conceal one's own position from an enemy.
37. Fuzes.- Fuzes are used with shells for the purpose of igniting the bursting charge at the
required moment. There are many varieties of fuzes in use at the present time, but they form two classes-viz., Time Fuzes and Percussion Fuzes.
38. A True Fuas consists of a case of wood or metal having a cylindrical hollow in its interior, into which is pressed (by hydraulic pressure) the fuze composition, which burns regularly at the rate of 1 inch in 5 seconds, so that any length may be given to it, to correspond to the time of flight of the shell, by boring a small hole through the case into the composition, thus making a commonication for the flame of the fuze into the bursting charge of the shell, when the fuze composition shall have burnt as far as the small hole. The fuzes are ignited by the flame from the discharge of the piece, which, in S. B. Guns having windage, envelopes the shell. The top of the fuze composition is primed to facilitate its ignition. In loading, the fuze of the shell is kept in the axis of the piece, and points towards the muzzle.

Fig. 12 shows the Common Tine Fuze.
39. Percussion Fuzes are fuzes containing detonating composition, arranged so as to be ignited by the shock sustained by the shell in passing through a substance that offers a considerable resistance, such as the side of a ship.

In percussion fuzes two distinct and successive actions are requisite to effeet the intended purpose of bursting the shell; one of these is caused by the shock of the discharge of the piece, the other by that of striking the object,

Pettman's (Land Service) Percussion Fuze (Fig. 11) is the only one now constructed for smooth bores.
40. Charges.-For land service there are certain fixed charges termed sowice charges, for all guns and howitzers, which are shown in the table, page 4, and with which, as a general rule, the guns are fired.

Reduced Charges are used in ricochet firing, and in firing red hot shot, Martin Shells, light and smoke balls.

Cartridges for land service are made of serge secured with worsted. Serge is used because it is not lisble to leave sparks in the gum, and also because it packs well.
41. Tubes are used to fire the charges of ordnance. A tube consists of a barrel of quill, paper or metal, about 3 inches long, driven with mealed powder damped with spirit. A hollow is made down the middle of the composition, so that the whole length may be ignited at once, when the flame strikes down the vent and reaches the charge. At the top of the barrel is a cup or
 head, the construction and priming of which varies with the nature of the tube. Quill tubes are used for naval service, metal tubes for land service.
42. The Comnon Tube (Fig. 13) consists of a barrel of quill or metal, provided with a cup at the top, which is primed with mealed powder.

This tube is fired by means of a portfire.
43. The Detonating Tube (Fig. 14) has a barrel of quill, with a small quill cross-piece passing through it close to the end, and containing detonating composition.

This tube is fired by means of a blow from the hammer of a pereussion lock, which is fitted on the gun. It has been chiefly used in the Navy.
44. The Copper Friction Tube (Fig, 15) has a small copper tube, called the nib piece, soldered on to the barrel close to its end, A hole is made from the nib piece into the barrel. A small piece of copper (a Fig. 15), termed the friction bar, having its sumface roughened, and one end made in the shape of a ring, is placed in the centre of the nib piece. A small patch of detonating composition is placed above and below this friction bar, and the nib piece is finally compressed on to it.

Friction tubes are those in general use ; they are fired by means of a cord, termed a lanyard, laving a hook at one end. The hook is placed in the ring of the friction bar : a smart pull draws the friction bar out, and igaites the detonating composition, and thus fires the tube.
45. Pormpiras are used to fire common tubes; they are each composed of a paper case,
about 18 inches long, which is filled with a composition which burns at the rate of one inch in a minute.
46. Qurckatch is composed of cotton thread, coated with a composition of mealed powder,
and water. gum and water.

It is used for various purposes, such as firing trains of powder, rockets, \&o.
It burns, when not confined, at the rate of 1 yard in 13 seconds; and when enclosed in a tube called a leader, it explodes simultaneously.
47. Slowmatci is made by boiling hempen rope in water and wood ashes. It burns at the rate of ubout 1 foot in an hour,

Its general use is to afford the means of obtaining a light; it smoulders slowly, without a flame.

It is also used as a substitute for a fuze in setting fire to a train of gunpowder for mining or
purposes. other purposes.

## RIFLED ORDNANCE.

48. Before describing the present service riffed ordnance, a short explanation will be given of the principles of the Rifle system, and of the causes of the great superiority of rifled over smoothbore artillery (or small arms), for almost all purposes of war.
49. The chief defects of smooth-bored ordnance are:-
50. Inaccuracy of fire.
51. Shortness of range.
52. The causes of inaceuracy are due to-
53. The windage (or difference in diameter between the bore and the projectile) given to the gun.
54. The eccentricity of the projectile,
55. The irregularity in the shape of the projectile.
56. The effects of windage on the flight of the projectile are as follows :-After the piece is loaded the shot rests on the bottom of the bore, and the whole windage is then between the upper surfaces of the shot and the bore. When the charge is fired, there is an immediate loss of force, as a considerable quantity of gas escapes through the windage; also, the action of the gas thas escaping is to press the projectile downwards at the same time that it begins to be propelled forwards through the bore; this downward pressure is of course followed by a rebound upwards, until the projectile strikes the upper surface of the bore, when it again rebounds, and strikes some other part. This bounding of the projectile from side to side continues until it leaves the bore, which it will do in a direction, not coinciding with the axis of the piece (the line of fire), as ought to be the case, but in an accidental direction, which depends chiefly on the position of its last impact against the bore.

At the same time the projectile is given an irregular rotatory motion, from its friction with the surface of the bore, which affects its after-flight. Thus, should the last impact of a shot, when fired from a smooth-bore gun, be on the bottom of the bore, as shown in Fig. 16, the shot will be deflected upwards, and it will at first move through the air above its proper trajectory; but it receives a rotatory motion, as shown by the arrows, the front part of the shot moving from above downwards, the effect of which is to deflect the shot gradually downwards, so that the ultimate deflection, at considerable ranges, will not be upwards, as might be assumed, but downwards, causing a loss of range.

Similar reasoning will show that against whatever part of the bore a shot last strikes, its ultimate deflection, unless at very short ranges, will be to the same side as the part struck; that is, should it last strike the upper part of the bore, the range will be increased, on account of the ultimate deflection being upwards; or, should it last strike against the left of the bore, it will range to the left.

Thus it may be assumed that a projectile never issues from a smooth-bore piece in a direction coincident with the axis of the piece, while it always must have an uncertain and irregular rotatory motion imparted to it, which injuriously affects its after-flight.

These three bad effects of mindage-viz., partial loss of the force of the powder, irregular movement of the shot along the bore, and its uncertain rotation in the air-account for much of

Fro. 16.
(Vertical Sectiva.)


Fig. 17.


Lhe inacouracy of fire of smooth-bore guns, as they are variable and uncertain, and cannot, therefore, be allowed for in laying the gun. They are variable, on account of the variation in both size and shape of different shot, as, probably, no two shot are exactly of the same diameter, or exactly spherical in shape.
52. A further cause of inaccuracy of fire arises from the eccentricity of the shot-that is, from the centre of gravity not coinciding with the centre of the shot. This eccentricity arises from want of homogeneity in the mass of the projectile, and, as bodies rotate round their centres of gravity, it causes the shot on leaving the bore to rotate in a direction dependent on the accidental position of its centre of gravity after the gun is loaded.

If Fig. 17 represent an eecentric shot, the centre of gravity of which, $G$, is below the centre of figure $F$, when the gun is fired the powder will act on a larger surface above $G$ than below $i$ t, and will give the shot a rotation, as indicated by the arrow, and the result will be a deviation of the shot towards the side on which lies the centre of gravity. In the case under consideration the deflection would, therefore, be downwards, and the range would be decreased.

Experiments have proved the above, for in loading guns with eccentric shot, the centres of gravity of which were placed in known positions, the deflection of the shot was always towards the side of its centre of gravity after loading.

This effect, on the range, of eccentricity of the shot can be taken advantage of to obtain an increase of range, by placing the centre of gravity of the shot in loading sbove its centre of figure, whenever it is possible to load so carefully as to be able to place the centre of gravity in any required position. But for ordinary purposes of firing, where the centre of gravity of the shot is not known, and neither time nor the necessary appliances are available for such careful loading, eccentricity in a shot is simply a cause of inaccuracy of fire, in addition to those already mentioned, as arising from wiudage.
53. Lrregularity of Form in the Shot, already mentioned as affecting in a certain degree the actual amount of windage, also affects the flight of the shot, as it causes the shot on rotation to experience a varying resistance from the atmosphere.
54. All these causes of inaccuracy of fire from smooth-bore guns may in any single case be combined to cause deflection, either towards one side or the other of the object, or to increase or decrease the range, while it may happen that they partly neutralize one another; they are, however, sufficient to account for the well-known fact, that if a number of shot be fired from the same gun, with equal charges und elevations, and with gunpowder of the same quality, the gun carriage resting on a platform, and the piece being carefully laid before each round, very fen of the shot will range to the same distance, and the greater part will be found to deflect considerably to the right or left, unless the range be very short.
55. Siroriness of Range in a smooth-bore gun is due to the spherical form of the projectiles, which canses a rapid loss of velocity as the projectile moves through the air.

This loss of velocity arises from the comparatively small weight or mass of a spherical projectile in proportion to the surface that it opposes to the atmosphere in its passage through it ; for the power of a projectile to overcome the resistance of the atmosphere is mensured by its weight, while the amount of resistance, for equal velocities, may be measured by the area of its
section. An example will illustrate this: If a shot with a diameter of 8 inches is fired under precisely similar conditions of elevation and initial velocity to one with a diameter of 4 inches, the 8 -inch shot will range farther than the 4 -inch shot; for while the 8 -inch shot has a greater resistance from the air to overcome-viz, in the proportion of $8^{2}$ to $4^{2}$, or of 4 to 1 -it has a still greater power in its weight to overcome that resistance, because the respective weights of the two shot are in the proportion of $8^{3}$ to $4^{3}$, or of 8 to 1 .

Therefore, with smooth-bore guns, those of large calibre have longer ranges than those of smaller calibre (elevation and initial velocity being the same in each), because their projectiles lose their velocity at a less rapid rate. It is for this reason that a long range smooth-bore gun necessarily must be one of large calibre, and therefore of great weight.

The accompanying table has been computed from Dr. Hutton's formula, and it exhibits the actual loss of velocity in solid shot of different diameters, occasioned by the resistance of the air in passing over a distance of 50 feet,
56. In a rifled piece, the bore is provided with a number of grooves, running in a spiral direction throughout its length, with the object of giving to the projectile, which fits into them, a rotatory motion on an axis which coincides with that of the bore. The rotation will be more

| Nature of Gun. | $\begin{gathered} \text { Initial } \\ \text { Velocity. } \end{gathered}$ | Velocity lost in 50 feet. |
| :---: | :---: | :---: |
| $\begin{gathered} 68 \\ 32 \\ 32 \\ 24 \\ 12 \\ 12 \\ 9 \\ 9 \end{gathered}$ |  |  | or less rapid, according to the degree of twist given to the grooves.

57. By the applioation of rifling to guns the following advantages over smooth-bores are acquired-
58. Owing to the rapid rotation * given to the projectile in a known direction, the causes of deviation arising from windage, and from the irregular shape and eccentrieity of the projectile, are almost entirely abolished.
59. Since the projectile fits the bore when the gun is fired, + it issues from the gun with its long axis coincident with the axis of the gun; that is to say, it commences its flight in the required direction. These two advantages are the principal causes of the accuracy of fire of rifled guns.
60. The projectile being given a rapid rotation on an axis coinciding with that of the gun (or the line of fire) does not turn over in its flight, but passes through the air in a manner similar to that of an arrow, with its head to the front. $\ddagger$
This permits the use of elongated in place of spherical projectiles, thereby allowing an increase of weight without an increase of diameter, or of the surface which is opposed to the atmosphere during flight: it also allows the fore-part of the projectile being made of the most favourable form for passing through the air with the least resistance.

Owing to these causes, rifled projectiles lose their velocity at a much less rapid rate than is the case with those of smooth-bore guns, and to this result is principally due the long range of rifled pieces.

Long range can be obtained equally from rifled pieces of small, as from those of large calibre; for in both cases there can be maintained the same proportion between the length and diameter

[^1]of the projectile, and therefore between its weight and that part of its sumface whioh is acted on by the atmosphere.

The use of elongated projectiles leads to the further ndvantages of great weight of projectile when solid ones are nsed, and also great capacity for holding $a$ bursting charge of powder when shells are used, which greatly increases their destructive effects, more especially when used against earthworks.
58. Considerable difference of opinion exists as to the best form for a rifled projectile, and also as to the best form, number, and twist to be given to the grooves of the bore of the gun. Almost every new gun that is tried differs from preceding ones in all, or mostly nll, these points.

There is also considerable variety in the methods followed for causing the projectile to fit the groores when the gun is fired, and so acquire the desired rotation, but a description of those at present adopted in our service will alone be given in the present work.

## SERVICE RIELED ORDNANOE.

59. The service rifled ordnance are constructed of wrought iron, which is made into cylinders, or coils, of various sizes to suit the partioular gun ; these cylinders are shrunk one on to another, in numbers proportioned to the strength required, so as to obtain at the different parts of the gun a strength proportioned to the strain to be experienced.

From the nature of their manufacture, the term "built-up" has been applied to ordnance thus made.

A coil is made by heating a long bar of wrought iron and twisting it round a mandril, so as to form a rough cylinder, which is then welded, turned and bored to the required dimensions. The cylinders thus made directly from the coil do not exceed three feet in length; any increase in length is obtained by welding two or more coils together.

The breech and the trumnions require a special mode of formation, for the mass of metal at those parts.
60. There are two classes of service rifled ordnance, viz., Breech-loading guns, and Muzsleloading guns.

The advantages of loading at the breech are, that projectiles slightly larger than the bore

Fig. 18.
12-pounder B. I. Fifled Gun, 8 cwt - Scale $\frac{1}{12}$.

can be used, thas insuring the stability of their axes during their passage through the bore; the gun can be loaded after being run up, thereby exposing the gumners to a less extent; while the gun oan be worked in a smaller space than a muzzle-loading piece. The bore can be also more readily cleaned.

Muzzle-loading guns are generally considered the best for very heavy artillery, as they are stronger than breech-loading guns of equal weight, and are more simple in construction.

The breech-loading gins are also subdivided into two classes, on account of the different modes of closing the breech; they are-Screw B. L. rifled guns, and Wedge B. L. rifted guns.
61. Rifled guns of $7^{\prime \prime}$ calibre and upwards are distinguished by the calibre and weight of gun, thus- $T$-inch M. L. gun, of 140 cwt R. ; while those of less than $7^{\prime \prime}$ calibre are distinguished by the weight of their projectile and weight of gun, thus- $40-\mathrm{pr}$. B. L. gun, of 35 cwt . R.
62. The system of rifling in all the breech-loading guns is as follows:- The projectile is coated with dead, and is a little larger in diameter than the bore of the piece; at the lower end of the


$$
\begin{array}{ll} 
& \text { A A. } \\
\text { B, C, \& } & \text { Barrel. } \\
\text { P. } & \text { Coils. } \\
\text { T. } & \text { Breech piece. } \\
\text { Trunion ring. }
\end{array}
$$

V. Vent piece.
E. Tappet ring.
L. Lever ring.
S. Breech screw.
bore, the diameter is enlarged to form a shot chamber (b Fig. 19), and behind this is a powder chamber (a), which is not rifled, and has a diameter equal to that across the bottom of the grooves of the bore. The bore is also very slightly enlarged to within about a calibre in front of the shot chamber ; the intervening portion (c), which has a less diameter than any other part of the bore, is termed the grip. The diameter of this grip is the calibre of the gun.

In loading either the screw or the wedge gun, the projectile and cartridge are inserted through the breech into their respective chambers; the breech is then closed, and on the gun being fired, the force of the explosion drives the projectile through the bore, compressing its soft lead coating into the grooves, and so imparting the rotatory motion.
63. The principal parts of a screw B. L. Armstrong gun are shown in Figs, 18 and 19.

The barrel or inner tube contains the bore, the shot chamber, and the powder chamber.
The vent piece is of iron or steel. When it is dropped through the vent slot or opening in the top of the gun, to its position, and pressed by the breech screw tightly against the end of the powder chamber, it effectually closes the bottom of the bore.

The breech screw fits in a thread cut in the breech piece, and is worked backwards or forwards by a lever, so as to release or press home the vent piece. It is made hollow, so as to allow the charge to be passed through, in loading the gun.
64. In the Wedge breech-loading guns, a slot passes through the breech from side to side, and the parts which close the bore are inserted or withdrawn from side to side, instead of at the top. They are wedged up by a peculiar arrangement.
65. In the Muzzle-loading guns, the projectile has projecting copper studs on its exterior, which on loading fit loosely in the grooves. In loading a rifled gun from the muzzle, the projectile on passing down the bore presses against one side of the grooves, but, on passing out of the bore, it presses against the other side. Advantage of this is taken,
 by contracting the grooves near the muzzle on the driving side, so that the studs of the projectile in passing out of the bore fit tightly into the contracted part, as in Fig. 21, where they are slightly compressed, and the stability of the axis of the projectile is thereby secured.

B6. The following table shows the weights, charges, \&o., of the principal service rifled ordnance:-

| Nature of Orinance. | Weight. | Cailitre. | Length. | Charge. | Weight of Pro jectile | No. of Groaves. | Ranges. |  |  | Remarks, |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | cwt | inches. | ft. in. | Ibs. oz |  |  | $1{ }^{\circ}$ | $9^{\circ}$ | $8^{\circ}$ | N.B.-The |
| $7^{\prime \prime}$ Screw B. L. Gun. | 81 |  | 10 9 9 | 120 | 110 | $\begin{aligned} & 76 \\ & 76 \end{aligned}$ |  |  |  | ranges given here are the |
| 64 Pr . Wedge | $63 \pm$ | 64 | 92 |  | 64 |  |  |  |  | distances to |
| 40 Pr. Screw | 35 | 4.75 | 10 1 | 50 | $41 \frac{1}{7}$ | 56 | 590 | 990 | 3080 | the second in- |
| 20 Pr . $\quad$, | 16 | 3.75 | 80 | 28 | $20 \frac{1}{3}$ | 44 | 520 | 920 | 2730 | tersection of the projectile |
| 12 Pr. | 8 | 3 | 60 | 18 | $10 \frac{1}{4}$ | 38 | 590 | 1020 | 2860 | with the line |
| 9 Pr . $\quad$ | 6 | 3 | $5 \quad 2$ | 12 | 8 : | 38 | 570 | 930 | 2600 | of fire. |
| 6 Pr. | 3 | $2 \cdot 5$ | 50 | 012 | $5 \frac{1}{2}$ | 32 |  |  |  |  |
| $9^{\prime \prime}$ M. L. Gun. | 248 | 9 | $\begin{array}{ll}12 & 3\end{array}$ |  |  | 3 |  |  |  |  |
| $7^{\prime \prime} \quad, \quad$ L. S. | 140 | 7 | 1110 |  |  | 3 |  |  |  |  |
| $7^{\prime \prime} \quad \# \quad$ S. S. | 130 | 7 |  |  |  | 3 |  |  |  |  |
| 64 Pr . | 65 | $6 \cdot 4$ | 93 | 80 |  | 3 | 410 | 770 | 2560 |  |

In addition to the guns in the above table, there are other rifled guns of large calibre, which are not yet approved as service guns. The $150-\mathrm{pr}$. S. B. has been rifled, and carries a projectile 300 lbs . in weight ; there is also an experimental $13^{\prime \prime}$ rifled gun, which carries a projectile 600 lbs . in weight, and weighs 22 tons.

## PROJECTILES, ETC., FOR RTFLED ORDNANCE.

67. There are three kinds of projectiles for rifled ordnance, viz., Shot, Common shells, and Segment shells.

These projectiles are elongated, and are cylindro-conoidal in form, the shells being flattened at the apex to receive the fuze. Those for B. L. guns are coated with lead, while those for M. I. guns have three spiral rows of studs to fit the grooves of the bore.

The shot and common shell are used for similar purposes as the spherical projectiles of the same name.

The segment shell is intended to act as a shrapnel, but can be used as a shot or as case-shot. The segment shell is the only projectile used at present with the 12 -pr. Armstrong and the lighter guns, although shot are issued to those guns for practice.
68. The Shot are solid masses of cast-iron, cylindro-conoidal in form.

Fig. 22.

62. The Common Shein (Fig. 29) is a hollow cast-iron projectile, the metal of which is thiel
enough to withstand the shock of the discharge of the gun. The head or apex of the shell is flattened and provided with a fuze hole.
70. The Segment Shell (Figs, 23, 24) consists of a thin cast-iron shell, inside which are placed a number of rows of cast-iron segments round a cavity which contains the bursting charge.


The interstices between the segments are filled with lead. The interior surface and the head of the shell are provided with grooves to cause it to burst easily. The bottom of the shell is a separate casting, and is pressed in after the segments have been inserted.

When the shell is burst, the segments fly outwards, owing to the centrifugal force due to the rotation of the shell, and thus produce an effect similar to that of a Shrapnel shell. Segment shells are burst about 20 yards short of the object.

The 20 -pr. and lower natures of segment shell are usually fired with both a time and a percussion fuze ; the time fuze is screwed in the fuze hole, with the percussion fuze inside, so that, should the time fuze fail to act, the shell is burst on ricochet by means of the percussion fuze.
71. Fuzes.-There are four different fuzes for the shells of rifled guns, two of which are time fuzes, and two are percussion fuzes.

In both the time fuzes (Boxer's and Armstrong's) there is a percussion arrangement by which the shock of the discharge of the gan ignites some detonating composition, and thereby sets fire to the fuze composition, which is arranged according to the time of flight.

This percussion arrangement is necessary with the time fuzes, owing to the absence of windage, for the flame from the explosion of the charge of the gun cannot be used to set fire to the fuze composition.

In the percussion fuzes there is a double action. The shock of the discharge of the gun, by breaking wires in the fuze, sets the percussion arrangement free to act, when it receives the second shock which is caused by the impact of the shell on the object.

## ROCKETS.

72. A Rocker consists of a cylindrical case of paper or metal containing inflammable composition ; to one end of the case is attached a head usually of a conical or cylindro-conoidal form ; the other end is closed, but has one or more vents or holes in it, for the escape of the gas of the ignited composition. There is a conical hollow space in the interior of the rocket, extending nearly throughout the length of the composition. The object of this hollow in the interior of the rocket is that a large surface of composition may be at once ignited, and the gas be thereby generated more quickly than it can escape through the vents ; the result is, that the gas becomes condensed inside the rocket and exerts a pressure in every direction on the interior surface. The pressures on the sides of the rocket neutralize one another, but the pressure on the head exceeds that on the base, in consequence of the escape of the gas from the vents. This excess of pressure on the head over that on the base causes the rocket to move in the direction of the head, slowly at first, but with an accelerating motion, owing to the continued generation of fresh gas, and its escape through the vents, which increases until the resistance of the air is equal to the force of progression, or until the composition is consumed.

The motion of a rocket is in reality a continued recoil, differing from that of a gun in being caused by a continuous force which acts during $a$ great part of its flight; whereas the recoil of a
gun is caused by an impulsive force, which ceases to act on it as soon as the projectile has left the bore.

A stick or long rod is attached to the bnse or side of the rocket to guide it in its flight.
73. There are two descriptions of rookets used in the service,-viz., the Stanal Roomer, and the Conamevs Rocket. The former are used as signals at night, the latter as destruetive projectiles.

Th. The Sraval Rocmet (Fig. 25) has its onse and heud of paper; the latter contains the Fio. $2 \pi$.
Signal Rocket.-

composition for the stars; the bottom of the case is choked, so as to form a single vent in the axis; the stick is attached to the side of the rocket case.

Signal rockets are fired vertically, or nearly so. When the composition is consumed, the bursting charge explodes the head and ignites the stars, which in falling produce a brilliant light that can be seen from a considerable distance.

Rockets between $1^{\prime \prime}$ and $2^{\prime \prime}$ in diameter ascend between 450 and 600 yards in height, and are visible within a cirenit of from 35 to 40 miles.
75. Congreve Rookets (Fig. 26) have a sheet iron case, with a hollow iron head, which is

Fig. 26.

cylindro-conoidal in form, and can be used as a shell by filling it with powder, but is left empty when intended as a shot; the base is of wrought iron, and contains 5 vent holes, with a hole in the centre, in which the stick is screwed.

The larger varieties of rockets ( 24 -prs, and 12 -prs.) can be used as carcasses, by substituting for the ordinary head a conical one, having six vents, which is filled with carcass composition.

Congreve rockets are fired from an iron tube which rests on legs, and has a suitable arrangement for giving the required elevation. They may also be fired from the ground, the head of the rocket being slightly elevated. A number of the smaller rockets placed in a row and fired in this manner, may be used with advantage against cavalry.
Congreve rockets are

Congreve rockets are employed both in the land and sea services, to set fire to houses, shipping, de, in the bombardment of towns.

Rockets have the advantage of containing within themselves their own propelling power, and they may therefore be used in many situations where it would be impossible to employ artillery, but they have the defect of being extremely irregular in their flight.

## ARTILLERY CARRIAGES.

76. The carriages on which ordnance are mounted are divided into two general classes,-the one class including all those upon which the gun travels, or is conveyed, as well as worked in action ; the other class comprising all carriages upon which ordnance is mounted when placed in permanent or fixed positions, but whieh are not intended to be used in their transport.
Ship Gunt Carriages, Traversing Platforms, and Mortar Beds.
77. Figs. 27, 28, represent a Field Gun Cariar Beds.

With it, and also with Siege (or Travelling) Carriages, the gun an Armstrong 12 -pounder Gun.
Figs, 29, 30, represent a Garrison Gum Carriages, the gun fires over a height of $3 \frac{1}{3}$ feet. height of $9 \frac{1}{4}$ feet.

Figs. 31, 32 , represent a Mortar Bed for a $10-\mathrm{in}$. mortar. When the bed rests on a level surface, the mortar has an elevation of $45^{\circ}$.

A Traversing Platform consists of a strong frame provided with trucks, which traverses in any required arc of a circle. A gun carriage, similar to a garrison carriage, but without trucks, works on the traversing platform.

A casemate dwarf traversing platform is shown in position in a Haxo Casemate, in the Chapter on Vaulted Works.

## VARIOUS KINDS OF ARTILLERY FIRE.

78. The fire of artillery may be, as regards the direction and position of the object, either Direct, Oblique, Reverse, Enflade, Flank, or Cross ; and, as regards the elevation used, it may be either Horizontal, Vertical, Ricochet, Plunging, or Pitching. (Figs. 33, 34.)

Direct fire is that of which the direction is perpendicular, or nearly so, to the line of the object (whether formed by troops or by a line of fortification) fired at.

Field Carriage for 12 -pounder Armstrong Gun.-Scale $\frac{1}{25}$.


Fig. 27. Elevation.


Onrreue fire is that of which the direction is oblique to the object.
Emitude fire is that which is directed along a line fired at; the gun requires, therefore, to be posted in the prolongation of the line to be enfiladed.

Reverse fire is that which is brought to bear on the rear of the object, which is then said to be taken in reverse.

A Flanerag fire is a defensive fire, which is directed along the front of, and parallel, or nearly so, to the line to be flanked. It is thus named, because an enemy, when attacking the work, would have his own flank exposed to the flanking fire.

A Cross fire is that which is obtained when the lines of fire of two or more guns, in different positions, cross one another on any particular ground.

FYo. 29.
Garrism Carriage for 8 -inch Gun. -Elevation.


Erf. 31.
$10^{\prime \prime}$ Iron Mortar Bed.-Plan.-Seale at.


Fro. 30.
Plan.-Scale $\frac{1}{\text { tw }}$.


Ftc. 32.
$10^{\prime \prime}$ Iron Mortar Bed,-Side Elevation,-Scale $\frac{1}{2 n}$.


Horizontal fire is the general term applied to the fire of guns or howitzers, which pieces, being fired with service charges, are only given the elevation requisite to allow their projectiles to attain the object.

The effect of horizontal fire is principally due to the horizontal velocity of the projectile at

Vertical fire is the term applied to the usual fire of mortars, which are fired generally with an elevation of $45^{\circ}$; the projectiles so fired fall at a much steeper inclination.

In vertical fire the striking velocity is due almost entirely to the force of gravity.
Ricochet Fire.-Fire from guns is so named when the projectile makes a series of rebounds at short intervals. To effect this a low velocity is necessary, and a reduced charge with an increased elevation are given to the gun.

Fig. 33.-Plan.


Ricochet fire is generally combined with enfilade fire, for the purpose of searching into a line of work which is screened from direct view by some intervening work. In this case the guns are placed on the prolongation of the line to be enfiladed à ricóchet; and on being fired with the proper charge and elevation, the projectiles ought just to clear the intervening work, and make

several grazes and rebounds along the line, dismounting and destroying any guns, \&ce., they may strike.

The usual charges for ricochet fire vary from one-half to one-tenth of the service charges, and the augles of elevation from $5^{\circ}$ to $10^{\circ}$.

With this kind of ricochet fire, it is almost nnnecessnry to remark that the object is unseen from the guns.

Ricochet fire is uncertain, on account of the low velocity of the projectiles. At 600 yards not more than from one-half to one-third of the rounds fired will take effect; at 400 yards about two-thirds take effect.

Ricochet batteries for S. B. Guns should therefore be, if possible, within 400 yards, and not further than 600 yards from the object.

With rifled ordnance, shells filled with powder, and having percussion fuzes, would be used, so as to burst the shell on grazing. Much greater damage would be effected in this manner than by the rebounding of the projectile after grazing.

Plungisg fire is that obtained from guns situated at a considerable elevation above the object, and fired with service charges. It is the least effective fire.

Pitching or Curved fire is used to strike directly an object, which is concealed from view, as an esoaxp wall in a fortress. It is obtained in a similar way to rioochet fire, so far as regards using a decreased charge and an increased elevation, to enable the projectile to clear the intervening obstacle at a sufficient angle of descent to reach the object, but, of course, no rebounds take place. This fire is so fur uncertain that the effect of each round cannot be observed, so as to allow of corrections in the aim and elevation being made.

## THE ENFIELD RIFLE.

79. The Enfield Rifle, with which the infantry are principally armed, is a muzzle-loading* piece, rifled with three broad and shallow grooves, which have a twist making one complete turn in a length of $6 \frac{1}{2}$ feet: it is sighted up to 800 yards.

Its principal dimensions and weights are :-


Length without bayonet, 4 feet 7 inches.
Ditto with fixed bayonet, 6 feet $\frac{1}{2}$ inch.
Weight without bayonet, $9 \mathrm{lbs} .2 \frac{1}{2} \mathrm{oz}$.
Ditto with ditto, 10 lbs .
Charge of powder, 22 drams.
Diameter of bore, 0.577 inch.
Ditto of bullet, 0.55 inch.
80. The Enfield rifle bullet (Fig. 35) is cylindrical in form, with an ogivale head; it has a conical hollow at its base, which is closed with a wood plug, partly filling the hollow.

This bullet is easily loaded on account of the windage, but expands by the action of firing sufficiently to fit the grooves of the rifle, thus doing away with the windage at the moment of firing and giving the bullet the requisite rotation.

The expansion of the bullet at the moment of firing is due to its inertia, which allows the powder, when ignited, to slightly crush its base before its point moves.

This effect is most probably assisted by the wood plug being driven inwards by the explosion, and so forcing the lead outwards into the grooves; but such is not the object of the hollow and its plug, for it is found that a solid bullet of the same external dimensions will expand, or, rather, be "upset," by the action of firing sufficiently to fit the grooves.

The object of the hollow in the bullet is to throw forward its centre of gravity, and so favour its steadiness of flight; and that of the wood plug is to prevent the sides of the bullet from collapsing, as it leaves the barrel, which would otherwise be the case, and would cause the shape of the bullet to be much distorted, and its flight injuriously affected.

[^2]
## ADDENDA TO SECTION I.-ARTILLERY, \&c.

$60 a$. B.L. Rifled guns are, for general purposes, in course of being superseded by M.L. Rifled guns, not only as regards heavy ordnance, but also for Field Artillery.

The existing stock of B L. guns will continue in use, but no new B.L. guns have been constructed for some time. It will probably be many years before our Field Artillery, at present composed of breech-loaders, is entirely composed of muzzle loaders; but all Heavy Ordnance of $8^{\prime \prime}$ calibre and upwards are now muzzle loaders.
B.L. Guns will, however, always be most suitable for certain special purposes, such as for use in ships' boats, in the embrasures of flanking kaponiers, \&c.

The following table shows the dimensions, \&c., of the principal M.L. Guns in the Service ; the details of B.L. Guns remain as stated in the table, p. 14:-

| Nature and Weight of Gun. | Length of |  |  | Number,Depth, andWidthof Grooves |  |  | Charge. |  | Rifing. |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  | Gun. | Bore. | Rilling. |  |  |  | Service. | Batter ing. |  |
|  | ft. in. | in. | in. |  | 1 bs . | cwt. | 1bs. | 1bs. |  |
| $13.05^{\prime \prime}$ of 23 tons | 141 | 141.5 | 126. | $\begin{array}{ll}\text { N } & 10 \\ \text { D } & 1.2 \\ \text { W } & 1.5\end{array}$ | $\}_{600}$ | .. | 50 | 70 | Woolwich |
| $12^{\prime \prime}$ of 23 tons F.. | 14 31 | 145 | 127 | $\begin{array}{lr}\text { N } & 9 \\ \text { D } & 2 \\ \text { W } & 1.5\end{array}$ | 600 | . | 50 | 70 | Do. |
| $10^{\prime \prime}$ of 18 tons F.. | $14 \quad 2$ | 145.5 | 118. | $\begin{array}{rrr}\text { N } & 7 \\ \text { D } & 2 \\ \text { W } & 1 & 5\end{array}$ | \} 400 | 8 | 40 | 60 | Do. |
| $9^{\prime \prime}$ of 12 tons F.. | 128 | $125^{\circ}$ | $107 \cdot 5$ | $\begin{array}{lcc}\text { N } & 6 \\ \text { D } & -18 \\ \text { W } & 1.5\end{array}$ | \} 250 | 5 | 30 | 48 | Do. |
| $8^{\prime \prime}$ of 9 tons F .. | 11 4 ${ }^{\frac{1}{2}}$ | 118 | 102. | N D D W W 18 | \} 180 | 4 | 20 | 30 | Do. |
| $7^{\prime \prime}$ of 7 tons F .. | 11 91 | 126 | 112.5 | $\begin{array}{cc} \mathrm{N} & 3 \\ \mathrm{D} & .18 \\ \mathrm{~W} & 1.5 \end{array}$ | , 115 | 3 | 14 | 22 | Do. |

The general mode of construction (which is officially termed the "F construction") is as follows:-

The bore is composed of a solid-ended steel tube, which has been forged from a cast ingot, bored out and toughened by being plunged, when heated to a high temperature, into oil. It thus parts slowly with its heat (oil not boiling under $600^{\circ} \mathrm{F}$.), and is toughened as well as hardened. The remainder of the gun is built-up of double or triple coils shrunk over one another.

A donble coil is made by winding a bar of red-hot iron over one previously coiled in the reverse direction, and then welding and preparing the mass as a single coil.

A triple coil is similarly formed, three bars being wound, one over the other.
The trumion ring, which at first was shrunk on, is now welded to the breech-piece.
The inner steel tube, in heavy ordnanee, is prolonged to the rear by the cascable serew, which is a cylinder of solid forged wrought-iron, screwed into the breech-piece.

The Woolvich system of rifling hus grently superseded the Shunt system.
In the Woolsich system, the grooves are broad and shallow, being for all guns of $7^{\prime \prime}$ calibre and upwards $1 \cdot 5$ inches broal, and from 18 to 20 inch deep.

The number of grooves varies (from 3 to 10) with the calibre; the projectiles love projecting studs, which fit loosely into the grooves, and which rub rgainst one side of the grooves, when being loaded; and when fired, they press ayninst the other, or driviug side, and force the projectile to assume a position in which its axis, or central line, coincides with the axis of the bore of the gun during its passage ulong the latter.

70a. Boxrr's Shrapnel Shell for Rifled Guns consists of a thin, cast-iron, elongated shell, having a wood head, which is covered with sheet iron; the bursting charge is placed in a space at the base of the projectile, from which a hollow iron tube, in the axis of the shell, leads to the fuze at the head. The bullets are packed round this hollow axis, in the space between the bursting charge and the head of the shell; the interstices between the bullets are filled with yesin. The interior surface of the shell is provided with six grooves, so as to enable a small bursting charge to break open the shell and liberate the bullets, without violently dispersing them.

The size and number of the bullets vary for the different calibres, as also do the details of the projectiles in minor points. 'The weights, \&e., of the Shrapnel Shell for the 7 -inch B.L. Gun are-

| Shell, empty |  |  | lbs 58 | ${ }^{18}$ |
| :---: | :---: | :---: | :---: | :---: |
| 860 ballets, mixed metal, at 14 | per 1b. |  | 26 | 12 |
| Head, disc, woud, resin, \&c. | . |  | 11 | 5 |
| Total . . | .. |  | 46 | 13 |
| Bursting charge | $\cdots$ |  |  |  |

70b. Casa Suot for Rifled Guns are very similar to those used for S.B. Ordnance. Eheh projectile consists of a number of small bullets in a cylindrical case. In the latest pattern the case is of tin, with a double bottom of sheet-iron ; there is also an inner lining or case of sheetiron, which is divided into three segments, in order not to be any impediment to the dispersion of the bullets; these latter are packed in coal dust,

71a. Boxer's time fuzes for MiL. Ordnanee are of two kinds, one is termed the 9 seconds fuze, and the other is termed the 20 seconds' fuze; they are respectively available for times of flight from 1 to 10 seconds, and from 10 to 20 seconds. They are both of wood.

71b. Boxer's 20 seconds' time fuze contains 4 inches of fuze composition, which is separated from the wood case by a paper eylinder. At the bottom of the composition, a hole is bored transversely through the fuze for the reception of a pellet of mealed powder, pierced like a tube. The head of the fuze is closed by a gam-metal plug, which is sorewed into the upper part of the is looped a bore. From the centre of this plug, a copper pin projects downivards, and round it are provided in the side of the head, for the which are passed through two eseape holes, which Quickmatch is laid in a gronve round the for the escape of the flame of the burning composition. and is protected by a strip of sheet copper, covered by a tape connection with the escape holes, being exposed. The eopper band is stripped off, when the shell is pone end of the copper band (triped off, when the shell is placed in the bore of the gin.

Moblece. I.
A reed is observed to frojed qie from the toh of the water ui a rapiia riven at rightaugles. it is also otseroed that when the wird blows the reed will the strew that-theitit exactly coucedes with the to 10 of thw cuater at a desturce 5 ft . from the bugival posilion. Requeved the despthe of the water. Inqwisil Su/p eosition The reed muot be a furfetly riofid one.

$$
\underset{\text { mind }}{\text { diuclim }} \rightarrow
$$

$$
\text { do: } 5 \text {-luam } \Longrightarrow
$$

Cet $A B=\mathrm{reed}$
$A C=$ pos above cualen
$C B=x=$ deple of water 1 is uquired.
$D=$ prins of civmersios
foin $A D B D B$.
זaw. $B A D=\frac{C D}{A C}$

Note!
Shis solution orla halds for a prenfelly ugio read in the case of a comm. read a deffenent bolutain wonlos he requinas. using for BD $\frac{\text { th }}{}$ cumer if a paratiolos and in thi cas $c \rightarrow$ wored a len, thatis: the poiver of unussion - dicielar hearer the/uiken-
I. $\tan B A D=10+\log 60-\log 9$

$$
=10+17781513-964+2425
$$

$$
=10.8239088
$$

$$
=\tan 81^{\circ} 28^{\circ} 9 \cdot 3^{\prime \prime}
$$

$$
\begin{aligned}
\therefore \angle B A D & =81^{\circ} \cdot 28^{\prime} \cdot 9 \cdot 3=B D A \\
\angle C D A & =90^{\circ}-B A D=8^{\circ} \cdot 31^{\prime} \cdot 51.7 \\
\alpha \angle C D B & =\angle B D A F \angle C D A \\
& =72^{\circ} \cdot 56^{\circ} \cdot 7^{\circ 6}
\end{aligned}
$$

now. $x=C D \cdot \tan C D A$.
$\therefore x=16^{f t} \cdot 347^{2}, \% c:=$ leugth of $x$ or depth of ire.ins.

$$
\begin{aligned}
& \therefore \tau_{x}=Z \cdot 60^{a}+E \operatorname{taw} 72^{\circ} \cdot 56^{\prime} \cdot 17^{\circ} C-10 \\
& =1.7781513+10.512857+0000732-10 \\
& =1.291087^{2}=195.4727 \mathrm{im}=16.2394 \mathrm{H}
\end{aligned}
$$

The fuze is provided with one row of side holes, spirally disposed like those of Mortar fuzes, and numbered from 2 inches downwards. The side holes are plugged with rifte powder.

On being fired from a gun, the quickmatch becomes ignited and sets fire to the fuze composition, which burns out of the two escape holes; the further action is the same as that of the common time fuze.

The head of the fuze is plugged in front, and the escape holes made in the side, (1) to prevent the extinction of the fuze when striking end on, (2) to prevent the acceleration of the rate of burning, which would be caused by the pressure of the air on the head.

Both the " 9 seconds" and the " 20 seconds" fuze are available, without any preparation, as percussion fuzes against ships or earthworks, the fuze on impact being driven into the shell, and thus exploding it.

71c. Boxer's wood time fuzes for B.L. Ordnance are similar to those for M.L. Guns in all respects, except the method of lighting the fuze, which is effected by a percussion arrangement in the head. A metal plug is suspended by a cross wire, which is broken by the shock of discharge of the gun, and thus brings the metal plug into violent contact with a patch of detonating composition, the flame from which ignites the priming of the fuze.

These fuzes are also serviceable, without preparation, as pereussion fuzes against earthworks, ships, \&e.

79a. The Enfield Rifle has been converted into a breech-loader on Mr. Snider's principle. Its principal dimensions and weights remain practically unaltered from those given in Art. 79, page 20. The converted arm can be fired with ease from 6 to 8 times in a minute.

80a. Cartridges for the Enfieid Skider Rifle have a case of thin sheet brass, which is covered with thin paper. Into the head of the case is choked the bullet, which is 573 inch diameter. The lower end of the bullet is provided with 3 cannelures (or hollow rings), which contain the bees' wax, with which this portion of the bullet is coated. The bullet has a hollow in the base, with clay plug, like that of the Enfield in Fig. 35. It has also a hollow in the head, which is filled with wood, so as to adjust the position of the centre of gravity. Between the bullet and the powder is a small quantity of cotton wool. The charge of powder is $2 \frac{1}{2}$ drams. The base of the cartridge has a percussion cap fixed in its centre. The base rim allows the cartridge case to be withdrawn from the chamber after firjng, by the extractor of the rifle, which aets when the moveable breech-block is drawn back; it is thus impossible to load the rifle with more than one cartridge at a time.

This ammunition is perfectly waterproof, and the peculiar distribution of its lubrication (the bees' wax) makes it absolutely non-fouling. By its adoption, the accuracy of the converted arm has been rendered much superior to that of the unconverted arm.

80b. The Martini-Henry Rifle is the breech-loading arm that has been proposed (by a special committee) as the future weapon for the infantry, and will gradually replace the Suider Rifle, to which it is superior in accuracy, initial velocity, flatness of trajectory, and penetration. Its name is due to the fact that its breech mechanism is the Martini, while its barrel is the Henry. each of which is considered the best of its kind.

The barrel is of steel, the calibre is 45 inch, the grooves are seven in number, and are polygonal ; that is to say, the bore has 7 sides which circumscribe a circle, the diameter of which is 45 inch. Along each angle of the bore there runs a raised rib, which projects inwards as far as the (imaginary) 45 inch circle, and thus forms each groove into a double one. The rifling has a twist of 1 turn in 20 inches.

80c. Cartridges for the Martini-Henry rifle are ealled Boxer-Henry, as they consist of the metal case of Colonel Boxer, as used with the Snider rifle, the mode of lubrication being that of Mr. Heary.

The case, with its percussion cap in the centre, is similar to that for the Snider, but is longer, in order to suit the swaller calibre.

The bullet is solid, cylindro-conoidal in form, 45 inch in diameter at the base, and tapers rery slightly towards the apex. Its length is about $1 \frac{1}{4}$ inch, and it weighs 480 grains. It is made of lead bardened by tin, and is provided with a single cannelure for securing it to the cartridge.

The lubrication consists of a wad of bees' wax between thin cardboard wads, placed between the powder and the bullet.

The charge of powder is 85 grains.
80d. The following table gives the trajectories of the Snider and Martini-Henry rifles for A range of 500 yards, supposing the gun to be fired from the ground, and aimed at the foot of the objeet-


The comparative penetrations of the Snider, and of the Martini-Henry rifles are illustrated by the following statement of the results of experiments :-

Fired through $\frac{1}{2}$ " elm planks, $\mathbf{1}^{\prime \prime}$ apart.
$\begin{array}{lllll}\text { Snider } & 577 \text {-Average penetration } & \text {.. } & \text {.. } & 8 \frac{1}{3} \text { planks. } \\ \text { Martini-Henry } & 45 \text { - } & \text { ditto } & . . & \text {.. } \\ & 14 \frac{1}{2} & "\end{array}$
Fired through $3^{\prime \prime}$ baulks of dry fir timber, placed close together. Snider 577 -Stopped by 2nd baulk at .. 50 yards range. Martini-Henry 45 -Penetrated 8 baulks easily at 50 "

Snider $\quad .577$ - Failed at (four thicknesses of $3^{\prime \prime}$ rope).
Martini-Henry 45 -Penetrated at 350 , and not at $\quad 50$ yards range.
Fired against an ordinary gabion, filled with earth from a clay soil.
Snider $\quad 577$-Failed to penetrate.
Martini-Henry '45-Penetrated at 10 and 25 yards. Failed at longer distances.
Fired at a Sandbag, containing one bushel of Sand.
Snider 577 -Failed to penetrate.
Martini-Henry 45 -Penetrated at 10 and 25 yards. Failed at longer distances.

## SECTION II.

PRACTICAL GEOMETRY, GEOMETRICAL DRAWING, sc.


#### Abstract

Use of Drawing Instruments-Compasses, protractor, Marquois scales and triangle. Problems in Plane GeometryBisection of a line and of an angle : construction of perpendiculars; to draw a line parallel to a line; to make an angle equal to one given ; to divide a straight line into a given number of equal parts; to reduce a rectilineur figure to a triangle of equal area; construction of regular polygons on a given line; to draw a tangent to a given circle. Knots, useful in tracing works on the ground; clove hitches; single bowline; single shicet bend; double sheet bend; reef lnot. ScalesMethod of construction, examples of calculation necessary ; diagonal seales; table of English and Foreign linear measures. Mensubation, - Areas of rectangles, triangles, and trapezoids; inclinations of slopes, how expressed by fractions. Geometrical Deawivg.-Projections, orthographic ; plan, elevation, section, and profile; how to construct a plan, a section, and an elevation.


81. A knowledge of the elements of geometrical drawing is desirable in the study of Fortification, both for the purpose of comprehending the various drawings by which works and buildings are represented on paper, and also for the purpose of tracing, or marking out on the ground, the necessary details of defensive works.

The drawing instruments in use at the Royal Military College are the following:-
82. A Patr of Compasses having a movable leg to admit of a pen or pencil leg being substituted for it, so as to allow of circles being drawn in ink or pencil.

A Suall Compass with a Pen Leg, for drawing smaller circles than can be described conveniently by means of the large compasses. These are called bow sweeps; they should not be used for circles which require the legs to be opened to a greater angle than about $30^{\circ}$.

Ftg. 36.


A Pen Leg and a Pencir Leg to insert in the place of the movable leg of the large compass.
A Drawing Pen.
83. An Ivory Protractor, to set off angles, and having on it various useful soales.

To set off an angle by means of the protractor.- Let CA (Fig. 36) be the given straight line, C a poin in it, and $40^{\circ}$ the angle required to be set off. Place the centre mark on the lower edge
of the protractor at C , and move the protractor round until the line marked $40^{\circ}$ on the radiated edge coincides with CA . Draw the line CD along the edge; DCA is the required angle. If the point D , through which the straight line, forming the angle of $40^{\circ}$ with the line CA , is to pass, be not in the straight line, the protractor is placed on the line C A with the centre point and the mark $40^{\circ}$ coinciding with that line, and it is moved along the line CA in this position until the edge CD coincides with the point $D$.

When the line CA is not long enough to admit of the above construction, place the lower edge of the protractor on that line (Fig. 87) with the centre on C ; then make a mark against the upper

Fig. 37.

edge at the line indicating the required angle (D), and draw D C. The protractor should not be used for setting off angles the lines containing which are required to be accurate for a greater length than $1 \frac{1}{2}$ or 2 inches.

The scale marked CHO on the protractor is a scale of chords.
To set off an angle by means of it.-With centre C(Fig. 38) and radius equal to the distance from Fie. 38.

zero to 60 on the scale (because chord of $60^{\circ}$ is equal to the radius), describe an arc AD cutting CA in A; and with centre A and radius equal to the distance from zero to $40^{\circ}$ (or other given angle), describe an are intersecting AD in D. Join CD. DCA is the required angle.

The scale on the edge of the face of the protractor, and those on the back marked $30,35,40$, \&c., are plain scales, an inch being divided into the number of parts indicated by the figures.

The protractor has also on it a diagonal seale. The principle of the diagonal scale is fully explained in the Chapter on Scales. The scales generally given are either inches divided into hundredths, with half inches similarly divided on the right hand side, or half inches divided into hundredths, with quarter inches on the right hand side. To take off a given distance, let the distance be 4.35 units. Look along the horizontal line marked 5 (for five hundredths), place one point of the compass on the point where this horizontal line cuts the oblique line from the point 3 (for three-tenths), and the other point of the compass where it is intersected by the perpendicular from the point marked 4 (for four units).
84. A box of Marquors Scales.

The Marquois seales consist of two rectangular rulers and a right-angled triangle. On each edge of the rulers there are two scales; the inner one is the natural scale, in which an inch is divided into the number of parts marked in the centre of the scale. The longest side, or hypothenuse, of the triangle is 3 times the shortest side. Let A BC (Fig. 39) be a position of the

triangle, FG the ruler. The ruler remaining fixed, let the triangle be moved from ABC to $A^{\prime} B^{\prime} C^{\prime}$; it is evident that the perpendicular distance $A^{\prime} E$ between the parallel lines $A B$ and $\mathrm{A}^{\prime} \mathrm{B}^{\prime}$ bears to the distance $\mathrm{A} \mathrm{A}^{\prime}$ which the point of the triangle has moved, or to $\mathrm{D}^{\prime} \mathrm{D}^{\prime}$ its equal, the same proportion which the hypothenuse AC does to the short side BC. A'E is therefore $\frac{1}{3} r d$ of DD'. If the scale on the edge of the Marquois ruler be compared with the inner, or natural scale below it, it will be found that each large division is 3 times the division on the inner or natural scale : thus the proportion between the scales is the same as that between the sides of the triangle.

To apply this principle, let it be required to draw two parallel lines $\frac{1}{3} \mathrm{rd}$ of an inch apart. On the scale of 30 , one large division (or 10 small divisions) will be equal to $\frac{1}{3} \mathrm{rd}$ of an inch. Place the bevelled edge of the triangle carefully against the given line, and make the star point on the triangle agree with the zero point on the scale of 30 . Then slide the triangle down (the ruler being held firm with the left hand) until the star point coincides with the division on the outer scale marked 10, and draw a line along the bevelled edge. It will be, as required, $\frac{10}{20}$ ths, or $\frac{1}{3} \mathrm{rd}$ of an inch from, and parallel to, the given line.

To apply the Marquois scale to the construction of a given rectilinear figure at a given scale. Let ABCDEF (Fig. 40) be the given figure of the dimensions marked, to be drawn at a scale of 20 feet to 1 inch. Lay the bevelled edge of the triangle along AF. Then draw $b c, e e^{\prime}, d d$ parallel when the star point coincides with $3 \frac{1}{2}, 6$, and 8 divisions on the scale of 20 , and slide the triangle up far enough to draw D D' at right angles to AF by the short side of the triangle. Turn the rulers round, make the bevelled

Fig. 40 ,
 edge of the triangle coincide with $\mathrm{D} \mathrm{D}^{\prime}$, and set the zero and star points together. Then move the triangle up, marking $\mathbf{E}$ at 12 divisions, $\mathbf{F}$ at $18(12+6)$; next move the triangle down, marking C at $1 \frac{1}{2}$, B at $6\left(1 \frac{1}{2}+4 \frac{1}{2}\right)$, and A at 18 (or $6+7$ ).

Join $\mathrm{AB}, \mathrm{CD}, \mathrm{DE}$, and E F , to obtain the required figure.

## PROBLEMS IN PLANE GEOMETRY.

85. The following are some of the problems of most general applisation in Geometrical Drawing, and also for tracing on the ground the outlines and necessary details of works of defence.

For the compasses may be substituted a cord fixed at one end when describing arcs on the fround, and is measuring tape or line when setting of distances.
s6. Problex I. To bisect a given straight line.-Let AB (Fig. 41) be the given
Fien 4 I.
 stragght line: with A and B as centres, and with any convenient radins, $\mathrm{A} C$ (greater than $\frac{1}{2} \mathrm{AB}$ ), describe circles intersecting in the points C and D ; join these points by a line intersecting the given line in E. A B will be bisected in E.
N.B.-CD is perpendicular to A B.*

To apply this construction practically, double a rope so as to be able to take hold of its centre, and while its ends are held to the points A and B , the points C and D can be fixed by moving the rope until both its halves become tight. The point E can then be obtained.

When the given line is too long for the above construction, set off from each of its ends $A$ and $B$, equal distances as marked by the figures $1-2-8$ (Fig. 42); a convenient length to biseet, as $3-8$ will thus be obtained, the middle point of which C will evidently bisect A B.

When the given line AB is of known length, it may be bisected by measuring from either of its ends one-half of its length to obtain its point of bisection C.

$$
\text { FIG. } 42 .
$$

## 87. Problem II. Ta bisect a given angle.-

 Let D A C (Fig. 48) be the given angle ; make AC equal to AD ; then from D and C as centres, and with equal radii, deseribe ares intersecting in E ; the line A E being then drawn, bisects the angle as required.OBs. - The triangle DE C must be isosceles, but need not be equilateral.
To bisect an angle traced on the ground by pickets, or other marks, as D A C, fix a mark at any point $C$ in the line $A C$, as far from $A$ as possible, and another at $D$ in tie line $A D$, making the distance A D equal to C A; double a cord so as to find its centre, and stretching it from $O$ to $D$, mark the point equidistant from $C$ and $D$, then the line bisecting the angle will pass through this point.

It may here be observed that any straight line traced in this way by piokets, \&e, may be prolonged by placing other pickets so that they may appear to coincide with them; and that the point of intersection of two lines may be found by observing the coincidence with pickets placed in both lines.

88. Problem III. Through a given point, to draw a line perpendicular to a given line.(Eromid I., 19.)
(1.) When the point $P$ is in the given straight line $A B$, and not near either end of $i$, as in Fig. 44, set off equal distances P C, P D, in AB; from C and D as centres, with any equal radii, describe arcs intersecting in $\mathbf{E}$; join P E which is the perpendicular required.
(2.) When the point P is not in the given line A B, as in Fig 4s.-From P as a centre, with any

[^3]convenient radius, describe an arc, cutting A B in C and D; from C and D as centres, and with any equal radii, describe ares intersecting in E (see rules), on the side of $\mathrm{A} B$ opposite to P ; join PE : it is the perpendicular required.

These constructions may be employed on the ground, the point E being formed as in Fig. 43, by doubling a cord.
(3.) When the point P is in the line AB , but very near to one end, as in Fig. 46.-Take any point C , with radius CP describe a semicircle EPD ; draw the diameter E D ; join E P: it is the perpendicular required.

Second construction (Fig. 4\%).-Take any scale of equal parts; then with $P$ as centre, and

Fig. 46.


Fig. 47.
Fre. 48.


radius equal to three such parts, describe an arc cutting $\mathrm{A} B$ in C ; with P as centre, and radius equal to four parts, and with C as centre, and radius equal to five parts, describe arce intersecting in D ; join PD : it is the perpendicular required.

For $3^{9}+4^{2}=5^{2}$, i.e. the square on C D equals the sum of the squares on PC and PD , and, therefore (Euclid I. 48), CP D is a right angle. This construction may be used on the ground, also the one above.
(4.) When the point $P$ is nearly opposite to the end of $A B$ (Fig. 48).-Drav PC at a convenient angle to A B; bisect it in D. From D as a centre, with radius P D, describe an arc entting A B in E. Draw PE. It is perpendicular to AB.

Second construction.-Take any two points, C and D (Fig. 49), at a convenient distance apart, and with radii C P and D P describe arcs intersecting in E. Join P E: it is perpendicular to A B.

Fig. 49.



Fig. 51.

89. Problem IV. Through a given point to draw a straight line parallel to a given straight line.-Let A B (Fig. 50) be the given straight line, and $P$ the given point. From $P$ let fall a perpendieular P C to AB , and from any convenient point D in A B draw a perpendicular D E , making its length equal to PC : join PE to obtain the required line.
N.B.-This is the only construction here given, as it is the most convenient one for practical operations.
90. Problem V. To construct an angle equal to a given angle.-Let B A C (Fig. 51) be the given angle, and P the point in the given line $\mathrm{P} \mathbf{D}$, at which it is required to construct an angle equal to BAC. With centre A, and any radius, A C, cut the lines in B and C; with centre P and
radius $A B$, and with centre $D$ and radius $D E$, equal to $B C$, deseribe ares intersecting in $E$. Join PE, D PE is the angle required.

To set off augles on the ground. - This is most rapidly effected by means of a theodolite or sestant, but if they are not available, it may be done thus, with a cord only: A right angle may be traced as shown in Prob. II. (3). An angle of $60^{\circ}$ is obtained by tracing an equilateral triangle; and a line passing through any one angular point of this figure and the centre of the opposite side, will give an angle of $30^{\circ}$. The angles of $90^{\circ}$ and $30^{\circ}$ being also bisected (see Prob. II.), angles of $45^{\circ}$ and $15^{\circ}$ are obtained; and each of the above angles being added to any of the others, or subtracted from them, by laying them out on the ground with equal radii and adjacent to each other, give a few others : thus we get angles of $75^{\circ}, 105^{\circ}$, $120^{\circ}, 135^{\circ}$, and $150^{\circ}$.
91. Problem VI. To divide a given straight line into any number of equal parts.
(1.) When the number ( $n$ ) into which the line is to be divided is a prime number not greater than 7.

Open the dividers to what appears to be the $n$th part of the line, step this distance along the line from one end, and if it be found either to exceed or fall short of the nth part, correct the opening, and repeat the trial till the exact $u$ th part is obtained.

Obs.- This is the only way of dividing a line that should be used in drawing, and with a little attention it will be found that two or three trials are generally sufficient; but the process may be shortened by attending to the following rule :-

If $n$ oan be resolved into two factors ( $p$ and $q$ ), one of which, $p$, is any power of 2 , as $4,8, \& c$., the line should be first bisected (which can always be done by two trials) ; each part should again be bisected, and so on till the line is divided into $p$ parts; each of these may again be divided into $q$ parts, the qth part of one being obtained by trial as above.
(2.) When the number ( $n$ ) is a prime number greater than 7 , as AB (Fig. 5\%).

$$
\text { Fra. } 52, \quad \text { Frg. } 54
$$



Fic. 53.


Draw A C, making an angle of about $30^{\circ}$ with A B, and through B draw B D parallel to

A C. On AC and BD set off $n-1$ equal parts, each nearly equal to $\frac{1}{n}$ th of $\Delta \mathrm{B}$; join $n-1 \mathrm{C}$ with $1 \mathrm{~B}, n-2 \mathrm{C}$ with 2 B , \&e., to divide A B into $n$ equal parts.
(3.) To divide a straight line into a considerable number of parts by means of the Marquois scales (Fig. 53).

Bisect $A B$ in $C$ and describe the semicircle, $A D B$, and lay off BD a chord equal to $n$ parts or any multiple of $n$ parts on any convenient scale on the Marquois; and setting the triangle on A D, slide off the corresponding divisions on the Marquois scale. In Fig. 53, A B is thus divided into 176 equal parts; and if A B represented a mile, divisions of hundreds and of tens of yards would be thus obtained.
92. Problem VII. To reduce a given rectilinear figure to a triangle having an equal area.-Let ABCDEFG (Fig. 54) be the given figure. Produce AG both ways: draw B $b$ parallel to $A C$; it is evident that a line drawn from $C$ to $b$ would include the same area as the lines CB, BA, because the triangles $\mathrm{AB} b, \mathrm{CB} b$, are on the same base and between the same parallels. Draw $\mathrm{C} c$ parallel $\mathrm{D} b$, and join $\mathrm{D} c$. So also on the other side of D draw $\mathrm{F} f$ parallel to E G and $\mathrm{E} e$ parallel to $\mathrm{D} f$, and join $\mathrm{D} e ; c \mathrm{D} e$ is the triangle required.
93. Problent VIII. To construct a regular polygon on a given line.
(1.) Let A B (Fig. 55) be the side of the proposed figure. By Euc. I. 32, cor. 1, all the interior angles of a rectilinear figure are equal to twice as many right angles as the figure has sides, less four right angles ; or $\frac{2 n-4}{n} 90^{\circ}=x$, the interior angle, where $n$ equals the number of sides. Therefore at A and B make (by the scale of chords) the angles A B D, B A C equal to $x$, and make AC and BD equal to BA , from the ends of which set off the angles $\mathrm{BAO}, \mathrm{ABO}$ equal to $\frac{x}{2}$.

$\mathrm{A} O$ and BO will intersect in O , which will be the centre of a circle, which will also pass through C and D ; set off lines equal to A B round the circle, to obtain the angles of the polygon. This construction is liable to error; the lengths of the sides, or the radius of the circle, will often require correction.
(2.) For a Pentagon.-On A B (Fig. 56) as a base draw a right-angled triangle of which the perpendicular BC is equal to half A B ; produce the hypothenuse till the part produced, CD , is equal to the perpendicular, or to half AB ; with this line AD as radius, from A and B as centres, deseribe arcs to intersect in E . The point of intersection will be the opposite angle of the pentagon, and the two remaining points are found by drawing ares with radius equal to $A B$ from each of the three points A, B, and E.

OBs.-The arcs described from $A$ and $B$ with $A D$ as radius, will pass through the points $F$ and G of the polygon.
(3.) For a Hexagon.-Describe ares with AB (Fig. 57) as radius from A and B as centres ; they will intersect in $O$, which is the centre of a circle passing through $A, B$, and the other angles of the hexagon; then draw the chords B D, D E, \&c., equal to A B.
(4.) For AN OCTAGON.-On A B (Fig. 58) describe a square A B D C, draw the diagonals and produce them until the parts produced, FD, C E, are equal to A B ; through A and B draw lines, AH, B K, parallel to the diagonals and equal to AB: by these means six angles of the polygon are determined, and the remaining two are obtained by drawing lines, EL and FM, parallel to the diagonals of the square.
94. Problem IX. To draw a tangent to a given circle.-(1.) When the point is in the circle. Let BPC (Fig. 59) be the given circle, and P the given point. Let O be the centre of the circle. Join $O P$ and draw $A P$ at right angles to $O P$. A $P$ is the tangent required.

Fig. 58.


Fig. 60.

Fio. 59.


(2.) When the point is not in the circle. Let P (Fig. 60) be the given point. Join O P; bisect it in $D$, and from $D$ as a centre, with radius D $O$, deseribe ares cutting the circle at $B$ and $C$. Ioin P B, P C : they are the tangents required.

## KNOTS, etc., REQUIRED IN TRACING WORKS OF DEFENCE, etc.; ON THE GROUND.

95. A Clove HiroH is shown in Fig. 61. It is used for fastening a rope to a picket, and is thus made:-A loop, $a$, is first made by bringing the part of the rope held in one hand under that part held in the other; a second loop, $b$, is then made in the same manner, and is placed over the loop, $a$, as shown in the sketch $c$; the fastening is then placed aver the post or picket to which it is to be secured and hauled taut, when it appears as sketched at $d$.

Fig. 61.



Fig. 62.


This is a most useful fastening ; it can be made at any part of the rope, and does not form a knot on being slipped off from the picket.

Another clove hitch is shown in Fig. 62. It will frequently be found a useful mode of fastening the end of a rope.
96. A Single Boivline (Fig. 68) serves to throw over a post to haul upon. As it does not slip, it can, when required, be easily jerked off the post, from the other end of the rope. It is thus made:-A loop is first made of any requisite size with the end of the rope, as shown at $a$, Fig. 63.

Fig. 64, Fig. 65.
Fig. 66,

a turn is then given bo as to form the small loop shown at $b$; the knot is finished by passing the end of the rope in the manter shown at $c$, and by the dotted line in $b$, Fig. 63.
97. A Single Sheet Bend (Fig. 64) is used to fasten two ropes together. It tightens itself on being hauled npon.
98. A Double Sheet Bend (Fig. 65) differs from the single sheet bend only in having two turns instead of one given to the rope $a$, round the loop of the second rope. It is useful in joining ropes of unequal thicknesses.
99. A Reef Knot (Fig. 66) is the knot in common use for fastenings of many kinds.

## SCALES.

100. A Scale is a mode of expressing by a divided line or lines the proportion which exists between a drawing and the object which it represents. Scales are used for the purpose of measuring the dimensions of objects represented in drawings.

Fig. 67.


Fig. 67 is the drawing of a room. One side is marked as $12^{\prime}$ long; the actual length of the drawing of that side is $22^{\prime \prime}$.

Fig. 68 is a divided line which expresses this proportion ; for if the distance marked $12^{\prime}$ on this divided line be compared with the corresponding distance on the drawing, it will be found to agree with it, and the line is divided throughout in the same proportion. It is the scale of Fig. 67.

The representative fraction of a scale is a fraction which expresses the proportion to the Fte. 68.


real size of the objects, as regards their linear dimensions, as they are shown on the drawing. Thus, if a drawing is made to a scale of $\frac{1}{0}$, it implies that any line or distance on the drawing is in length actually $\frac{1}{100}$ th part of the real length of the line.

The proportion which exists between the drawing (Fig. 67) and the object which it represents, is that of $12^{\prime}$ to $2 \frac{2^{\prime \prime}}{\prime^{\prime}}$. This proportion would be expressed mathematically by the fraction $\frac{2 \frac{3}{8}}{12 \times 12}=\frac{1}{60}$, which means, that every distance on the drawing is $\frac{1}{00}$ th of the corresponding distance on the object represented ; $\frac{1}{60}$ is the representative fraction of the scale (Fig. 68).

Senles are said to be comparative when they express the same proportion in different units of measnre ; they bave therefore the same representative fraction.
101. A scale is given whem a known distance and the corresponding dimension on the drawing which it represents are given, or when the representative fraction is given.

The object required in calculating a soale is to find in English inches and parts of an inch, the leugth of line which will represent some number of some required dimension, as 1,10 , 20,100 , ©o., miles, yards, mètres, \&o.

To ascertain this it is necessary to work out the following proportion :-
As the known distance
Is to the dimension on the paper by which this is represented;
Or when the representative fraction is given,-
As its denominator,
Is to its numerator,
So are 1, 10, 100, \&e., of the dimensions required to be expressed by the scale,
To the distance by which these $1,10,100$, dc., dimensions will be represented.
Such parts of the third and fourth terms must be taken as will give a scale of about the required length, if the nmmber of dimensions assumed in the third term gives the fourth term too long or too short. The first three terms must be reduced in such a manner that the fourth term shall be in English inches.
102. Having ascertained by this proportion the length of line which will represent a known number of the dimensions required, the line must be divided to show these dimensions.

It will not be necessary to mark the smallest dimensions shown on the scale, throughout its length. Thus, if as in Fig, 68 a line six inches long is found to represent thirty feet, it is only necessary to divide the line into three equal parts to show the three tens, the units being shown by subdividing the left-hand part into ten parts. If, as in Fig. 69, each unit is large, one foot being represented by one inch, the left-hand unit must be divided into the next lower measnce,- in this case, into twelve parts to represent inches, which are the next lower measure to feet.

To find the representative fraction of any scale, make the known distance the denominator of the fraction, and the distance representing it on the scale the numerator of the fraction. Bring both to the same terms, and reduce the fraction to one having its numerator unity.

Scales are to be drawn, lettered, and figured exactly as shown in Fig. 68.
103. Exaniples.
(1.) Required a scale of $\frac{1}{30}$ to measure feet and inches :-

As denominator : numerator :: actual dimension : the length representing it on the scale $30 \quad 1 \quad 1 \quad 1$ foot $\quad 0.4$ inch, the length representing 1 foot 1 foot is represented by 0.4 inch
[on the scale. 10 feet will be " 4 inches 15 " " 6 inches
To draw the scate. Take a line (Fig. 70) 6 " inches in length, subdivide it into 15 equal parts, each of which will represent 1 foot. Divide the left foot into 12 equal parts, each of which will then represent 1 inch. Figure the scale as in Fig. 70.
(2.) Required a scale of yards to a plan, on which a length of 0.51 inches represents 9 yards.


To draw the suate, -Take a line (Fig. 71) 698 inches long, subdivide it into 11 equal parts, each of which will represent 10 yards; subdivide the left division into 10 equal parts, each of which will represent 1 yard. Figure the scale as shown in Fig. 71.

(3.) Draw a scale of Milan miles comparative to a scale of 10 English miles to 1 inch. Onc Milan mile $=1808.81$ English yards.

$$
\text { Fig. 70.-Scale } \frac{1}{30}
$$




Fig. 73.-Scale of $\frac{1}{37 \text { foun }}$


Here the known distance is 10 English miles, the dimension which represents it on the paper is 1 inch, and the dimension required to be expressed on the scale is Milan miles; therefore, as the known distance is to its length on the paper, so is the required dimension to its length on paper:-
10 English miles : 1 inch :: 1 Milan mile : the length on paper representing 1 Milan mile, 17600 yards 1808.81 yards
$\frac{1.908 .81}{17001}=0.1028$ inches, the length on the scale representing 1 Milan mile.
$\therefore 10$ Milan miles will be represented by $10 \times 1028=1.028$ inches; and if the scale is required about 6 inches long, 60 Milan miles $=6 \cdot 168$ inches.

To draw the scale. Take a line (Fig. 72) 6.168 inches long; divide it into 6 parts, each of which will represent 10 Milan miles; divide the left hand division into 10 parts: each will represent 1 mile.

As 1 English mile $=63,360$ inches, the representative fraction will be $\frac{\sigma^{3}, \frac{1}{60} \bar{x}}{10}=\frac{1}{603}, \sqrt{00}$.
(4.) On a Russian map 25 versts are represented by 1 archine; find the representative fraction, and by means of it draw a scale of French kilomètres.

$$
1 \text { verst }=1500 \text { archines, } \quad 1 \text { kilomètre }=1093 \cdot 63 \text { English yards. }
$$

Here the representative fraction will be $\frac{1}{25} \bar{x}^{1} 500={ }^{57 \frac{1}{500}}$.
The proportion to state is similar to that in Ex. 1, viz. :-
denominator : numerator :: aetual dimension : the length representing it on the scale. or as $37,500: 1 \quad: \frac{1 \text { kilomètre }}{\text { : }} 1$ : the length of 1 kilomètre on the scale. (or 1093.63 yards ) (or 39370.58 inches)
$\frac{39375.58}{3,5 \%}=1.0498$ inches $=$ length on the scale of 1 kilomètre.
If the scale be required to be about 6 inches long, as -

$$
\begin{aligned}
& 1 \text { kilomètre }=1.0498 \text { inches } \\
& 6 \quad=6.2988 \text { inches }=6.3 \text { inches nearly. }
\end{aligned}
$$

To draw the scale.-Take a line (Fig. 73) 6.3 inches long, and divide it into 6 parts ; each will represent 1 kilomètre. As each unit is large (about one inch), the next lower measure being mètres, 1,000 of which make a kilomètre, divide the left hand division into 10 parts: each will represent 100 mètres.
104. Dragonal Scale.- It is sometimes necessary to obtain the measurement of a more minute quantity than can be readily taken from a plain scale. This is done by means of a diagonal scale, the construction and use of which will be best illustrated by an example. On a scale of ${ }^{\frac{1}{30}}$ (Fig, 74) let it be required to measure inches. Calculate the scale for yards. Divide the left hand division to show feet. The scale is now a plain scale of the next higher dimension to that required to be expressed by the diagonal scale. Twelve inches being equal to one foot, it

Frc. 74.-Serle of 4o

is necessary by the diagonal method to represent $\frac{1}{1}$ th of the smallest dimensions shown on the plain scale. To do this, rule twelve equidistant lines, parallel to the top line of the scale (making thirteen equidistant parallel lines in all, having twelve equal spaces between them). Through the main divisions of the scale, which in this case show yards, draw perpendiculars to the parallel lines. Join the left hand secondary division (the 2 feet) with the upper left hand extremity of the top line of the scale, and through the other secondary divisions (the 0,1 foot) draw lines parallel to this oblique one.
105. Table of some of the principal Units of Linear Measure in terms of English Feet, Yards, and Miles.

| Locaumr. | Usir, | Fert. | Yabds. | Milies. | Remarks. |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Austria . | Zoll (12 Linien) .... | . 08640 | -02880 |  |  |
| " | Fussor Schuh(12Zolle) | 1.0371 | - 34568 |  |  |
| " | Elle ............... | 2.5586 | -85289 |  |  |
| " | Klafter (6 Fuss) .... |  | 2.0741 |  |  |
| " | Ruthe (10 Fuss) .... |  | $3 \cdot 4568$ |  |  |
| " | Meile ( 4,000 Klafter) |  | $8297 \cdot 0$ | $4 \cdot 7142$ |  |
|  | Meile (Geographische) |  | $8101 \cdot 0$ | $4 \cdot 6026$ | $\frac{1}{15}$ Degree, |
| Baden | Fuss (Foot) . . . . . . | 9842 | -32806 |  | İ Degree. |
| Bavaria.... | Meile (14,815 Fuss) .. Fuss . . . . . . |  | $4860 \cdot 833$ |  |  |
| Bavaria.... | Ruthe (10 Fuss) | $\cdots 9517$ | .8139 3.139 |  |  |
| Berne | Pied (12 Pouces) | $\because 9617$ | -3206 |  |  |
| " | Aune | $1-7832$ | -5944 |  |  |
| Belgium | Perche (10 Pieds). | . | 3'206 |  |  |
| Belgium <br> " | Fuss (11 Zolle) ...... Elle | ${ }^{-9366}$ | -3122 |  | Old Measures. |
|  | Verge.. | 2 240 | 4.9255 | $\because \quad$. | For New, see |
| Chins...... | Tché (Foot) | 1-05 | 49255 -3500 |  | France. |
| Denmark .. | Foot | 1.02975 | -34325 |  |  |
|  | Ell (2 Feet) | 2.05950 | -68650 |  |  |
| England | Inch | . 08650 | 02777 |  |  |
| ," | Yard | 1.0000 | 33333 |  |  |
| . | E11... | 3.000 | 1.000 |  |  |
| " | Fathom | .. | 2.000 |  |  |
| " | Pole or Perch | $\ldots$ | 5.5000 |  |  |
| $\cdots$ | Chain (100 Links) | $\cdots$ | 22.000 |  |  |
| " | Furlong . . . . | ., .. | $220 \cdot 000$ |  |  |
| " | Mile, common ...... | .. . | $1760 \cdot 000$ | $1.000$ |  |
|  | Ditto, Geographical) or Nautical |  | 2025.200 | $1 \cdot 1506$ | a Degree. |
| " | League |  | 5280.000 | 3.000 |  |



| Locauty. | Untr. | Fext. | Yirds. | Miless. | Prmares, |
| :---: | :---: | :---: | :---: | :---: | :---: |
| Turia .... | Piéde (Liprando) .... | 1.686 |  |  |  |
| ", | Auna . . . . . . . . . . . . | 1.9714 | $65714$ |  |  |
| Turkey . . . | Pertica (12 |  | $\begin{array}{r} 674 \\ 1827.0 \end{array}$ | 1.0383 |  |
| Tuscany .. | Braccio | 1.915 | . 638 |  |  |
|  | Canna |  | $2 \cdot 553$ |  |  |
| Venice .... | Piéde . . . . . . . . . . | $1 \cdot 1410$ | -3803 |  |  |
|  | Braccio . | $1 \cdot 95$ |  |  |  |
| Westphali | Stunde ( $\frac{1}{2}$ Meile) .... | ... .. | 6076 | 8.452 |  |
| Wurtemburg | Fuss .............. | . 9383 | -3128 |  |  |
| Zurich .... | 1 ied | . 9842 | -3280 |  |  |
| Anct Egypt. | Oubit | $1 \cdot 4764$ | -4921 |  |  |
| " Greeee | Cubit | 1.4764 | -4921 |  |  |
| " ${ }^{\text {" }}$, ${ }^{\text {ame. }}$ | Stadium ( 400 Cubits). | .. | $196.85$ |  |  |
| ${ }^{\prime}$ R Rome. | Stadium . . . . . . . . . . . |  |  | 1148 | $\sim^{\frac{1}{0} \overline{0} 0}$ Degree. |

## MENSURATION, ETc.

106. The following simple rules are necessary, in order to find the areas of the different parts of the profile of a parapet :-
(1.) The area of a rectangle is equal to the product of the two adjacent sides.


Fig. 75. Area $\mathrm{BD}=\mathrm{AB} \times \mathrm{BC}$, or $\mathrm{AD} \times \mathrm{DC}$.
Note-The area and one side being given, the other is found by dividing the area ly the
wa side. knowa side.

$$
A B=\frac{\text { Area B D. }}{B C}
$$

(2.) The area of a right angled triangle is equal to half the product of the two sides containing the right angle; this is evident from Fig. 75.

$$
\text { Area } \mathrm{ABC}=\frac{\mathrm{AB} \times \mathrm{BC} .}{2}
$$

(3.) The aren of any trianglo is equal to half the product of any side and the perpendicular from the opposite vertex.

$$
\text { Fig 76. Area } \mathrm{ABC}=\frac{\mathrm{AC} \times \mathrm{B}_{\mathrm{p}}}{2} \text {. }
$$

Note.-As by Problem VIII, any rectilinear figure drawn to scale can be reduced to a triangle having an equal urea, this rule affords the means of finding the area of any rectilinear figure.
(4.) To find the area of a trapesoid, add together the two parallel sides, and divide by two to obtain the mean length $\left(\frac{A D+B C}{2}=m n\right.$ in Fig. 77$)$, and multiply by the perpendicular distance between them.

Area $\mathrm{ABOD}=m n \times d \mathrm{~B}$ in Fig. 77.
If the area of a trapezoid, the distance between the parallel sides, and the slopes, be given, the length of the parallel sides may be thus found. Divide the area of the trapezoid by the distance between the parallel sides for the mean length $\left(\frac{\text { Area A B CD }}{d \mathrm{~B}}=m n\right)$. Add and subtract half the bases of the slopes for the lengths at top and bottom.


$$
m n+\frac{\mathrm{Ad}+e \mathrm{D}}{2}=\mathrm{AD} \text { and } \mathrm{BC} .
$$

107. The inclinations of slopes are expressed by fractions in the following manner:- The line of the slope is supposed to be the hypothenuse of a right angled triangle; the sides of the right angle being a vertical and a horizontal line. The vertical line, which represents the height of the slope, is made the numerator of the fraction; while the horizontal line, which represents the base of the slope, is made the denominator of the fraction.

Thus, in Figs. 78 and 79, the dotted lines represent vertioal and horizontal lines, and the slopes of the other lines are represented by the fractions accompanying each.

Frg. 79.


This method of expressing slopes is generally more convenient than by referging to the inclinations of the slopes in degrees, both for drawing on paper or for erecting slopes, and also for measuring the inclinations of existing slopes. For instance, if in Fig. 80 a slope of $\frac{1}{\mathrm{t}}$ is Fig. 80.

Fro. 81.

required to be druwn passing through the point $p$, and meeting the ground line $g g$, the vertical line $p$ a can be obtained by any ordinay plomb-line; and then by measuring the hieight $p a$, and from $"$ setting off the horivontal line ab equal to a $p$, a point $b$ in the required slope will be obtained; the line $p b$ being produced to its intersection $c$ with the ground line, will be the required slope.

Again, suppose au existing slope ( $a \mathrm{c}$, Fig. 81 ) has to be measured; if from uny convenient point $a$ in the slope, the horizontal line $a b$ is set off, and from uny convenient point $b$ in $a b$ the vertical lime $b c$ is drawu mesting the slope, the lines $a b$ and $b c$ being measured, the incliuation of the slope $a c$ will be expressed by the fraction $\frac{b \mathrm{c}}{a b}$; and this will be correct of whatever magnitude $a b$ and $b e$ are taken, provided they are respectively horizontal and vertical; practically, however, the longer these lines are the better.

When the ground is practically level, the bases of slopes may, of course, be measured on the ground itself.

## GEOMETRICAL DRAWING.

108. As remarked in the opening paragcaph of the section, a knowledge of the principles of geometrical drawing is necessary for the student in Fortification. This necessity is really two-fold : first, because constant reference is required to the various drawings (plans, \&ie.) by which works are represented on paper on a scale more or less small; second, because a knowledge of geometrical drawing is requisite in order to be able to mark out on the ground the various works of defence, when the works may be said to be drawn full size.
109. The following short description of the principle and method of construction of the ordimary geometrical drawings is therefore given.

The Proneotron of an object is a representation of it, made by imaginary lines or rays, proceeding from some point in space through every point of the object, and meeting a given plane or surface on which they form the required representation.

If an observer, in a room, sees a landscape through a window, and while remaining stationary himself marks the outline of the laudscape, as it appears to him, on the window, that outline will be a projection of the landscape on the glass of the windor as the plane of projection, the eye of the observer being heve the point of projection.

Thus, every ordinary picture, so far as respects its sketch or outline, is merely a projection of the objects represented; the eye of the artist being the point, of projection, and the paper or canvas being the plane of projection, which is here supposed to be vertical, and to be placed between the eye of the artist and the landscape.

A projection is Orphographic, when the projecting lines are parallel to one another; the point of projection being supposed infinitely distant from the plane of projection.

In the netual draving of Fortification it is not necessary to get every point of the object to be drawn, really projected; for since the object is usually bounded by plane surfaces, those surfaces will be shown by drawing their intersecting lines or edges ; to do which, all that is necessary is to be able to fix the points in which they (the edges) meet, for the lines joining these points will then represent the boundaries of the surfaces, and the spaces between them the surfaces themselves.

Thus, if Fig. 82 represents a triangular pyrumid, it is only necessary, in order to be able to

Fio. 82
 draw it, to fix the four points A, B, C and D correctly; for by joining these points in the manner shown in the figure, the six lines and the three visible surfaces of the figure are obtained.

The Prax of an object is its orthographic projection (in its natural position) on a horizontal plane of projection, which is represented by the drawing paper.

Plans are used in drawing, to bhow the true horizontal lengths and breadthe of the object they represent.

The Trice of a worls is a plan of its guiding or magistral line. In

Field Fortification this line is the highest or crest line of the parapet, while in Permanent Fortification it is the line of the top of the escarp wall.

The Elevatron of an object is its orthographic projection (in its natural pusition) on any vertical plane of projection, represented by the drawing paper; it shows the true heights of the various parts, and it gives an idea of the appearance of the object when viewed perpendicularly to the plane of projection.

The section of an object is the representation of the surface that would be exposed, supposing the object to be cut through by a plane, passing in any required direction. This imaginary cutting plane is usually vertical.

The Proflle of an object is a section made by a vertical plane, cutting the object in a direction perpendieular to its length. A profile evidently shows the true breadths, and heights or depths, and is the only section that does so.

Plans and Profiles of works are the only drawings that are ordinarily required, as by means of them we obtain a correct representation, on any convenient scale, large or small, of the true lengths, breadths, and heights of every part of the work drawn.
110. All these different kinds of drawings-viz, Plans, Profiles, Sections, and Elevations-are usually made on the same piece of paper, and, at first, great difficulty is experienced in endeavouring to comprehend their nature and method of construction. This principally arises from the drawing paper being treated in the Plan as a horizontal plane; while, in Profiles and Elevations, the same paper is considered a vertical plane.
111. In explanation of the foregoing, suppose we have to make the plan of a line of parapet, of which a profile is given in Fig. 83, where the bases and heights are figured. Here the horizontal surfaces covered by the slopes of the parapet are evidently $\mathrm{A} G=6, \mathrm{GH}=4 \frac{12}{2}, \mathrm{HI}=1 \frac{1}{2}$, $\mathrm{IK}=12$, and $\mathrm{KF}=5 \frac{1_{2}}{2}$. The point (D) in the profile, being the highest or crest point, represents the magistral line. Draw a line D D, (Fig. 84), to represent this line in the plan, making

Fig. 8\%,

it of the length required to be shown; parallel to it, and at the distance from it of the bases $\mathrm{K}=12^{\prime}$ and $\mathrm{K} \mathrm{F}=55^{\prime}$ draw the two lines E E and F F , represented in profile by the points E and F ; and on the other side of $\mathrm{D}, \mathrm{D}$, in the plan, draw the lines $\mathrm{C} \mathrm{C}, \mathrm{B}, \mathrm{B}$, and $\mathrm{A} A$ parallel to it and at the distance apart of the bases shown in the profile-viz., $\mathrm{HI}=11^{\prime}, G \mathrm{G}=4 \frac{1}{2}$, and $\mathrm{AG}=6$, to represent in the plan, the lines shown in the profile by the points $\mathrm{C}, \mathrm{B}$, and A .

Suppose now that the line of parapet, here partly represented in plan, is to be terminated at its extremities by slopes of \& and on its right and left respectively. To draw the plan of the slope of 3 on the right, produce D D, making $\mathrm{D} d=1$ D I in profile; through the point $d$ draw the line A F perpendicular to the line of the work: this line A F will be the intersection of the termimating slope of ; with the smface of the ground; from this line set off e $\mathrm{E}=\frac{1}{d} \mathrm{~K} \mathrm{E}$ in profile, $c \mathrm{C}=1 \mathrm{HC}$ in profile, and $Z \mathrm{~B}=1, \mathrm{~GB}$ in profile; join $\mathrm{AB}, \mathrm{BC}, \mathrm{CD}, \mathrm{DE}$, and EF, to complete the figure.

If the line AF terminating the work on the ground had been first assumed instead of the point D , the same result would have been obtained by setting off the four bases $b \mathrm{~B}, c \mathrm{C}, d \mathrm{D}$, and $c$ E, equal respectively to $r$ rd of the heights of the points $\mathrm{B}, \mathrm{C}, \mathrm{D}$, and E in profile above the glound.

To draw the plan of the terminating slope of $\frac{\rho}{T}$ at the other end or extremity of the parapet, a similnt process to the one just mentioned must be gone through, taking care to make the bases $b \mathrm{~B}, c \mathrm{C}, i \mathrm{D}$, and $\varepsilon \mathrm{E}$, one half respectively of the heights of the points $\mathrm{B}, \mathrm{C}, \mathrm{D}$, and E in profile above the ground.
112. We will now suppose that a Sectron of the above line of parapet is required on the line XI (Fig, 84).

This line X Y is here supposed to represent the plan of a vertical plane eutting through the marapet This section line intersects the lines of the plan in the points $l, m, n, a, p$, and $q$. The distances $\ln , m n, n O, o p$, and $p q$, will be the bases of the several slopes in the section.

To draw the section, select any line (X Y, Fig. 85) for the ground or base line, along which mark the hases $l m, m n, n o, o p$, and $p q$ : from the points $m, n, o$, and $p$, erect perpendiculars to the baze line, making them of the several heights shown in the profile (Fig. 83). The angular points of the section will thus be obtained, and by joining these points the section itself will be completed, as shown in Fig. 85, by the shaded portion.

Fig 85.

113. Let us now suppose that, in addition to the section on XY (Fig. 84), AN ELEVATION on the same line is also required to be constructed, as shown in Fig. 85.

In this case it must be imagined that the object to be represented is viewed in directions perpendicular to the line X Y in the plan (Fig. 84), where imaginary lines are shown drawn from the points $\mathrm{A}, \mathrm{B}, \mathrm{C}, \mathrm{D}$, perpendicular to and meeting XY . These perpendiculars intersect X Y in the points $r, s, t$, and $v$.

To draw the elevation, transfer the points $r, s, t$, and $v$ to the ground line of the elevation (Fig. 85) ; from $s, t$, and $v$ erect perpendiculars, making them equal respectively to the lnown heights above the ground, of the points B, C, and D, in the profile (Fig. 83). The angular points of the elevation, in addition to those fixed by the section, will thus be obtained; and by drawing the proper lines through these points, the elevation itself will be completed.

## SECTION III.

## FIELD FORTIFICATION.

## CHAPTER I.

## ON THE PROFILES OF FIELD WORKS.

Object of Fortification; principles to be fulfilled; causes of the difference betueen Field (or temporary) and Permanent Works; object of the Parapet and Ditch; conmmand and relief; command given to field works; object of trenches, as a means af obtaining cover, their advardages anil defects; thichness of parapets, how regulated; table of penetrations; banquette, its use
and dimensions; slope of banquette; interior slope; superior slope; use of glacis; interior and exterior crests; crest plane; exterior slope; berm; ditch, escarp, bnttom of ditch, depth of ditch, counterscarp; triangular profile to ditches; width of ditches ; exanpple of a profile; usual mode of determining the profile of a work; remblai and deblai; two evamples of the calcoutation of a profile ; profile on sloping ground; loopholes on a parapet, and their substitutes; Stockades, their uses and construction; how to prepare walls and hedges for defence.

## Addenda to Chapter I.

Ilustrations of the construction and calculation of the profiles of works on sloping ground.
114. Premminary Observations.- Fortification, or the art of fortifying, as a practical science, has for its object the strengthening of positions held by troops. It has been usually treated in two divisions-viz., Field Fortification and Permanent Fortification; the former (Field) referring to the class of works made during a campaign for temporary defensive purposes; the latter (Permanent), as its name implies, treating of works intended to exist for an unlimited period, which may be constructed to secure the vulnerable frontiers, the leading communications, the arsenals, dockyards, or ports of a country, from capture or destruction.
115. The division of the science of Fortification into the two branches of Field and Permanent, is convenient for purposes of instruction, but it is to be borne in mind that the principles to be followed in each are the same, and it is only the difference of the conditions under which the two kinds are constructed that causes the difference between them.
116. The principles to be fulfilled in every fortification, whether Permanent or Field, are the following:-
(1.) It should cover or protect the defenders from the view and the fire of an enemy,
(2.) It should enable the defenders to see the enemy and to use their weapons with effect, over the whole ground within range of fire, with the least possible exposure to themselves.
(8.) The assailant's access to the position should be difficult and obstructed, in order that he may be kept as long as possible under the fire of the defenders.
Such being the principles to be fulfilled in all defensive works, it is evident that their nature greatly depends on the stature of men, and on the effects of the weapons used both in the attack and in the defence.
117. Permanent Fortipications are usually constructed in time of peace with reference to future wars. From three to five years are required for their construction, for which all the means
at the disposal of the State are available; and the adrautages abtrined ought to be as perfect as the natural strength of the position will admit of.
118. Fiem Worse, on the contrary, are almost invariably constructed in haste, often in view of an enemy, and even sometimes under his fire ; the resouroes available for their construction are also geverally very limited; consequently it is but seldom that any degree of perfection is attainuble with field worls, and all that can be usually attempted in defending a position by them, is to fulfil as much of the three conditions before-mentioned, as is possible in the time and with the means available.
119. In most cases any fortified position will consist partly of natural, partly of artificial works: the position being selected for defence from its natural advantages, which will be made the most of, as time and circumstances permit, by the addition of artificial works of defence.
120. Where no matural obstacles exist, troops are placed under cover of a bank of earth termed the Parapet, the earth for which is usually obtained from a Ditch excavated in front. (See Fig. 86.)

Fio. S6.


The Parapet fulfils the first two of the conditions before-mentioned, by covering the defenders from the vien and the fire of the enemy, and by enabling the defenders to make a proper use of their weapons, withont exposing themselves more than can be aroided.

The Ditch, the main object of which is to supply earth to form the parapet, partly fulfils the third condition, as it checks the advance of an assailant; but as it does so very imperfectly, other obstructions or obstacles are combined with it in Field Works, as will be hereafter expl tined.

The Parapet aud its Ditch (Fig. 86), as above described, form the main elements of all Field Fortifications.
121. On the Profime of Field Works. - The Command of a work is the height of its crest, or highest point, above the ground on which it is constructed.

One work is said to have a Command of Fire over another in its front, when it is made of sufficient height to fire over the latter and defend the ground in its front, without interfering with the fire of such adranced work. This great command oan be seldom required in Field Works.

One work is said to have a Command of Observation over another in its front, when it is only of sufficient height over the advanced work to prevent an enemy in possession of that work, being able to see into the interior of the higher work. nA additional command of 4 or 5 feet is usually sufficient for this purpose.

The Reure of a work is the height of its crest, or highest point, above the bottom of its ditch. Thus, the Relief is the sum of the command and the depth of ditch.
129. We will now proceed to consider the conditions that the profile of a line of intrenohment should fulfil, supposing the ground to be a level plane, and that therefore neither the defenders nor their opponents have any advantage of position.

The command of a work should be sufficient to give cover to the defenders standing on the ground inside. Infantry are assumed to be $6^{\prime}$ in height; and to protect men of that height, within a. reasonable distance of the parapet, from projectiles clearing the crest and teuding downwards in
the latter part of their trajectory, it is generally admitted that the command of a parapet on level ground should be at least 8 feet.

A greater command than 8 feet is necessary either when more than the usual cover is required, or when an enemy would be able, by occupying ground within effective range, to see into the work. Thus, in Fig. 87, a parapet to be constructed at P, to cover the ground in rear from the fire of an enemy on the rising ground H , would evidently require a greater command than 8 feet; but to be able to find out how much greater the reader is referred to the Chapter on Defilade.

Fig. 87.


Field Works are seldom given a command greater than 12 feet, on account of the great increase of labour required to construct them; the quantity of earth required for a parapet of increased command being in a much greater ratio to that required for the smaller work than the increased command of the former bears to the command of the latter.

If a parapet had to be constructed on the top of the height H in the preceding figure, facing the low ground in front, it would then be so advantageously situated that proper cover would be given to its interior with a command less than 8 feet. The necessary command would vary according to the height of the ground H , with reference to the ground in front within effective range ; where this superiority of site is very decided, parapets may be constructed with a command as low as $5^{\prime}$, or even $4 \frac{1}{2}$ feet, and yet give as good cover to the defenders as would be afforded by an 8 feet parapet on level ground.

This is one of the advantages attending a commanding position. There are others which will be pointed out further on.
123. Where time presses, parapets on a level site may be constructed with a command of 5 or 6 feet, cover being obtained from an excavation in rear (termed a Trench, to distinguish it from the excavation on the outside, which is always called the Ditch), the earth from which, as well as from the ditch, serves to form the parapet.


Fig. 88 exhibits a type of this method of construction. The defenders to be under proper cover from fire must be in the trench.

In cases where the chief consideration is to get cover quickly, the command of a parapet on
level ground may be as low as $4 \frac{1}{2}$ feet, the whole of the earth required being obtained from a trench in rear. Fig. 89 is an example.


Siege parallels, and frequently lines of intrenchment joining works of importance, are of this description.

In all eases where a trench is used, its bottom should be $6 \frac{1^{\prime}}{2}$ or $7^{r}$ below the crest of the work, to give cover. Its breadth at the bottom will vary with its requirements from 3 to 10 feet, and sometimes even more.
124. The advantages of the Trench formation are, that cover is very quickly obtained, since every foot of depth of the trench affords nearly two feet of cover; that the fire from it is grazing and effective; and also that it is not, if properly constructed, an impediment to the forward movement of the defenders, who can charge over it on a wide front. These advantages peculiarly fit it for certain positions.
125. The disadyantages are, that cover from view is afforded only to troops actually standing in the trench; that the diffeulty of draining the trench, frequently amounting to impossibility, unfits it generally for low and marshy ground; and that the defenders, if attacked by the bayonet, are unfavourably placed for contending with their assailants. As regards this last named defect, it is recommended that the defenders, if obliged to receive an attack in the work, should, at the moment of the enemy closing with them, step back to the ground in rear of the trench, which will then be an obstacle in the way of the attacking party. Or the defenders may, after having delivered a final volley at close quarters, themselves advance over the parapet and charge the assailants with the bayonet, with every prospect of success.
126. The Thickness of a parapet, which is measured horizontally at the top, as between D and E, in Fig. 91, depends upon the amount of fire and the calibre of the artillery likely to be brought against it. It should be sufficient to prevent the passage of projectiles, even after a considerable resistance, and it is usual to make the thickness in earth $1 \frac{1}{9}$ times the greatest penetrations of the opposing guns.
127. A Table of Penetrations of the principal pieces of ordnance and of the Enfield Rifle is here given.


The object fired at was a well-built parapet of clayey earth, having a thiekness at top of 95 feet.

Field Fortification.
fenetration of the enfield rifle bullet, regulation pattern, range 20 yards.

| Earlh, light and sandy, formed into a slight parapet |  |  |  |  |  |  | Penetration. |  |  | Thickness of Parapet. |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  |  |  |  | Mean, Greatest. |  |  |  |  |
|  |  |  |  | .. |  | 倍 | $15 \cdot 2^{\prime \prime}$ |  |  |  |  |
| Elm, solid | .. | .. | $\ldots$ | . | $\ldots$ | $\cdots$ | $6^{\prime \prime}$ |  |  |  |  |
| Oak, solid | . | .. | . | . | .. | . | $2 \frac{1}{\prime \prime}^{\prime \prime}$ | . |  |  | $\mathrm{B}^{\prime \prime}$ |
| Pint, solid | .. | $\ldots$ | . | $\cdots$ | . | . | $9 \cdot 88^{\text {k }}$ |  |  |  | $18^{\prime \prime}$ |
| Sandbags | . | . | . |  |  |  | $12^{\prime \prime}$ int | hea |  |  |  |
| Fascines | $\ldots$ |  |  |  |  |  | Strete | rs | asion | pa | thr |
| Galions | - | $\ldots$ | $\because$ |  |  |  | No bul | and |  | e |  |

128. To enable infantry to fire over a parapet is the object of the Tread of the Banquette (B C, Fig. 91), or as it is more usually termed, the "Banquette :" this is a raised pathway on which the defenders stand in order to fire over the parapet. It is always made $4 \frac{1}{2}$ feet under the crest, as that height is the greatest that infantry can fire over the ground on which they stand.

The banquette is made 8 feet wide, if the parapet is to be defended only by a single rank of men, and $4 \frac{1}{2}$ feet wide for a double rank of defenders. Its surface is given a slope of about 2 inches to the rear to drain off water, but for purposes of calculationit may be treated as horizontal.

The Slope of the Baxquetite is the term applied to the slope leading up to the banquette from the interior of the work. Its object is to allow the defenders to get on or off the banquette without inconvenience, and for this purpose it is given a base twice its height, or a slope of $\frac{1}{2}$.

In works where interior space is valuable, if the parapets have a command greater than usual, this slope of the banquette may be replaced by steps, as in the annexed sketch (Fig. 90), where the dotted line shows the ordinary position of the slope of the banquette, and illustrates the object of replacing it by steps to save interior space. These steps, however, have the disadvantage of requiring much extra material, such as planking, \&c., in their formation, and the communication by them to the
 banquette is not so convenient as with the earthen slope.
129. The Interior Slope of the parapet (C D, Fig. 91) is made as steep as possible. In Field Works its usual slope is $\frac{3}{\frac{1}{1}}$ or $\frac{4}{1}$. The object of this steep slope, when a banquette for musketry is used, is to enable the soldier to stand close to the crest, so that he may fire over the parapet with ease, using the crest as a rest for his musket. As the nature of ground is such that it will not stand by itself at so steep a slope, it must be kept up artificially by what is termed a Revetment, the mode of making which will be pointed out subsequently. See chapter on "Revetments."
130. The upper surface of the parapet, termed the Superion Stope (D E, Fig. 91), inclines to the front sufficiently to enable the musketry fire directed parallel to its slope to defend the top of the counterscarp or further side of the diteh. This will be effected whenever the superior slope produced passes within 3 feet of the ground at the counterscarp.

This slope is evidently an evil, though a necessary one, as it weakens the parapet at the crest, and the more so, the steeper it is; but it is a less evil than having the ground outside the ditch undefended by the fire from the parapet. An inclination of 1 in $6\left(\frac{1}{6}\right)$ is usually sufficient for the superior slope on a level site. A slope of $\frac{1}{4}$, or any intermediate one, may be employed, but steeper slopes than $\frac{1}{4}$ for superior slopes are not recommended, as the parapet at the crest would be too much weakened: if with a slope of $\frac{1}{4}$ the top of the counterscarp cannot be defended from the parapet, the ground in front of the ditch should be raised by means of a Glacis, as seen in Fig. 91, so as to keep an assailant exposed to the fire of the parapet as long as possible. This is of great importance; and as will be described in the next chapter, obstructions are placed in the way of an enemy to delay him under the fire of the work while he is close to it. |Experience has shown that nothing checks the ardour of troops more than being delayed under a close and accurate musketry fire, from ax opponent well posted behind a parupet. (/

The glacis should have a gentle slope to the front corresponding to the superior slope of the parapet, so as to be grazed by the musketry fire of the latter. The parapet should have a com-
annd over the gheis of at lenst 5 feet, in ocder that the attucking troops may not be able to fire inte the work.
181. The Ispmriob Crest, more nsually termed simply Tae Crest, of the parapet, is the line of intersection of its Superior and Interior Slopes. It is the Magistral Line in Field Fortification. This line is the one that is first laid down in drawing a plan of a work on paper, or in tracing it on the ground, as it is the principal line in the work, and it is frequently most important to fix its pusition properly; its length also determines the number of defenders required for a field work.
139. When a line of parapet is constructed so as to be able to fire down a sterp slope, the tep of the parapet may be made level for a breadth of about one foot, and the exterior sloped away in the direction of the slope of the hill. This level surface is termed a Crest Plane, and prevents the parapet from being weakened as much us it would be were the interior and superior slopes to meet in the usual manner. The defenders, while fining, lean forward over the crest plane. This mode of construction is only applicable to musketry parapets.
133. The Extertor Slope of a parapet, which is the slope most exposed to fire (E F, Fig. 91). should not be steeper than what is termed the natural slope of the earth, or the slope at which the garth used will stand without artificial support. With the generality of soils this slope is $\frac{1}{1}$.

In works which are expected to be exposed to a heavy fire of artillery (such as the batteries at a siege, \&c.) the exterior slope should have an increased base given to it.

Ia some cases, which are, however, exceptional, the exterior slopes of worls may be revetted steeply, so as to save space outsile the work so treated. This may be the case when one work is constructed inside another to prolong its defence. See Axt 224, "Reduits."
184. The intersection of the Superior and Extertor slopes is called the Exterion Crest, and, as before mentioned, the thickness of a parapet is the distance (measured horizontally) between the cresi and the exterior crest.
185. The Berm (F G, Fig. 91) is a space left between the parapet and the ditch; its object is to relieve the escarp from the pressure of the parapet by removing the weight a certain distance away. This pressure is very great, as the weight of earth when well rammed will usually be from 14 to 2 tons per cubic yard. The breadth of the berm depends upon the height of the parapet and the nature of the soil ; it may vary from 1 to 6 feet.

The berm facilitates the construction of and repairs to the parapet, as a line of workmen may be employed on it to throw the earth on to the parapet as required. It has, however, the great defect, in a parapet of ordinary height, of affording a footing to an assailant, safe from the direot fire of the work, at a critical moment of the attack. It is but seldom that a berm can be dispensed with altogether, but when indispensable it may be occupied with obstacles, and in many cases it may be cut away, after the work is constructed, without weakening the work, by producing the exterior slope till it meets the escarp slope.
136. We now come to the Drich, which supplies the earth required to form the parapet, and also acts asfan obstacle (though by itself it is not a very formidable one) to the advance of an enemy, who may have reached it. An inspection of the profiles given will show that the ditel in itself is no great obstacle; for an assailant baving reached its edge will not hesitate to junp into it, to be out of reach of the direct fire of the work, whatever may be the steepness of the counterscarp, aud once in it, if not exposed to flanking fire, as is generally the case in field works, may spread along it, and then rush into the work and close with the defenders in a body, to prevent which is a great desideratam in the defence.
137. The Escare (GH, Fig. 91), or side of the ditch nearest to the work, is made as steep as the nature of the soil will allow; as the steeper it is made, the greater the obstacle it will be. Its slope in ordinary groumd is $\frac{1}{\mathrm{i}}$, sometimes it can be made steeper; but in weak soils, aind when worke are required to last a considerable time, it will generally be impracticable to give the escarp a stecper slope than $\frac{1}{1}$, unless it is artificially supported.
188. The Boitose of the Drfer (HI, Fig, 91) is considered honzontal; but in executing a work it wonld generally be given a slight slope from sides to centre, to prevent water lodging at the foot of the slopes.
189. The Derth of thi Ditcir (P H, Fig. 01) should be at least six feet to be much of an obstacle, and it may vary from this to twelve feet, according to circumstances. A depth
of twelve feet is usually considered the maximum that should be given to the ditches of Field Works, on account of the difficulty of throwing up the earth from greater depths; but this rule, like most general rules, may be frequently departed from with advantage.
140. The Counterscarp (K I, Fig. 91) or outer slope of the ditch can be made steeper than the escarp, as it has not, like the latter, to resist the pressure of the parapet. It is usually formed at $\frac{3}{1}$ or $\frac{2}{1}$.
141. As the ditches of field works are generally without flank defence, it will be advantageous, whenever that is the case, to form the ditch triangular in section; i.e., with the escarp and the counterscarp meeting in a point at the bottom. This construction increases the depth, and prevents anything like a settled formation of troops in the ditch, and with the same object in view, the defenders should be plentifully supplied with hand-grenades. The ditches of the redoubts of the celebrated lines of Torres Vedras were generally of this shape.

The width of the ditch (G K, Fig. 91), always estimated at the top, ought not to be less than twelve or thirteen feet in works which may have to stand an assault; as, otherwise, planks sufficiently long could be brought up to bridge it.
142. The Glaers (K L M, Fig. 91) has already been alluded to, as being used in certain cases to keep the ground in front of the ditch under the fire of the parapet. It is also employed to screen obstacles of various kinds from the view, and protect them from the fire of an enemy. In the latter case, the glacis is formed with the earth from a trench made in its rear, as shown in Fig. $90 a$; care being taken that the slopes of both glacis and trench are such that they are exposed Fig. 90 a.

to the musketry of the work. A small glacis is also frequently made merely to get rid of superfluous earth, when the ditch is made larger than is required for the formation of the parapct.
143. Fig. 91 is the profile of a parapet, having a thickness of twelve feet and a command of eight feet, with the bases and heights figured, so as to show the ordinary dimensions of a work having a good field profile.

Fig. 91.-Scale $\frac{1}{14 .}$.


[^4]I44. In selecting the profile proper for a work, the nature of the ground, both in front and rear, and the degree of cover required, determine the command; the thickness of the parapet depends upon the projectiles it is to resist, aud on its chances of exposure to fire ; these main dimensions and the width to be given to the bauquette determine the section of the parapet. The dimensions of the ditch have then to be determined. In order to do this, either the width may be assumed, and then the depth calculated (the slopes of the sides having been previously settled) : or the depth may be assumed, and the requisite width then calculated. In most cases it is usual to assume the depth (as that to a great extent depends upon the mature of the soil, which may fix a limit to $i t$ ), and then to calculate the requisite width.

Two examples are given below to illustrate this method; they are given in full for the sake of elearness, and are apparently long, but with a little practice the necessary calculations may be performed in a very short time.
145. The French term Deblai is given to the mass of earth in the ditch before being excavated, and that of Remblai after it is built up in the work. The Remblai will be frequently greater than the Deblai, i.e., the earth on being excavated and built up will have increased in bulk, and this increase of bulk will vary according to the soil and the cure with which the work is constructed ; but experience has shown that this increase need not occur in ordinary soils, provided the workmen are properly superintended, so as to ensure the earth being well rammed. In the calculations that follow, it will not be taken into account, and also the ditch will be assumer to be equal in length to the parapet; therefore, the avea of the profile of the ditch will be equal to the area of the profile of the parapet.
146. Ex. 1. - A line of intrenchment has to be constructed on level ground, with a command of $7 \frac{1}{2}$ feet, a parapet of 12 feet thick and a banquette for double rank; the interior slope to be $\frac{3}{4}$, superior slope $\frac{1}{t}$, other slopes of the parapet as usual. The diteh to be 12 feet deep, the escarp to slope $\frac{3}{1}$, and the counterscarp $\frac{\pi}{1}$; required the width of the ditch.

Fig. 92.


In Fig. 92, which is a handsketch of the profile, D 0 will be $7 \frac{1}{2}$ and 0 N 12 ; as the superior slope is $\frac{7}{6}$, the point E will be $\frac{1}{6}^{\frac{1}{2}}$, or $\mathfrak{Z}^{\prime}$ under the point D , consequently $\mathrm{E} N$ will be $5 \frac{1}{2}$; N F will therefore be also $5^{\frac{1}{4}}$. The banquette BC being $4^{1}$ under the crest, $\mathrm{C}^{\mathbf{~}}$ 㝘 and BQ will each be $7_{\frac{1}{2}}-4 \frac{1}{2}=3^{\prime} ; \mathrm{PO}$, which is equal to CR , is equal to $\frac{R \mathrm{D}}{3}=\frac{4 \frac{1}{2}}{3}=1 \frac{1}{4} ;$ and $\mathrm{A} Q=2 \mathrm{BQ}=6$ feet. Thus the bases and the heights of the parapet are easily found.

In the ditch, the depth $M H$ or $L I$ is given as $12^{\circ} ; G M=\frac{M H}{2}=6^{\prime}$, and $L K=\frac{L I}{3}=4^{\prime}$. ML or HI, the width of the ditch at the bottom, is therefore the only unknown dimension in the profile.

To calculate the area of the parapet, the areas of the four figures ABRO, CRD, D ONE and ENF (two of which are trapezoids, and two are right-angled triangles) are found separately and added together, thus-

$$
\text { Area of the profile of the parapet .. .. }=123
$$

$=123 \frac{1}{2}$, say 123 sq. feet.
Then the area of the profile of the ditch will also be 123 ; and the mean breadth of the ditch will be $\frac{103}{10}=10 \frac{1}{+}$ (Geom. Art. 106). To this we must add half the sum of the bases of the escarp and counterscarp to get G K, the width at top ; or subtract the same to get H I, the width at bottom. Thus-

$$
\begin{aligned}
& \mathrm{GK}=10 \frac{1}{4}+\left(\frac{6+4}{2}\right)=15 \frac{1}{4}, \text { the width at top. } \\
& \mathrm{HI}=10 \frac{1}{4}-\left(\frac{6+4}{2}\right)=5 \frac{1}{4}, \text { the width at bottom. }
\end{aligned}
$$

Another method of calculating the width at bottom of the ditch, after obtaining the area of the profile of the ditch, is by calculating the areas of the two right-angled triangles formed by the escarp and counterscarp, with their bases and heights; and, subtracting their sum from that of the whole ditch, the area of the rectangle between them is obtained; the area of this rectangle divided by the depth of the ditch will give the width of the ditch at the bottom. Thus-

$$
\left.\begin{array}{l}
\text { Area of ditch GHIK }=123 \\
\text { GMH }=\frac{6 \times 12}{2}=36 \\
\text { ILK }=\frac{4 \times 12}{2}=24
\end{array}\right\}=60
$$

$$
\therefore \text { rectangle MHIL }=\overline{63}
$$

$$
\text { And } \frac{63}{12}=5 \frac{1}{4}=H \mathrm{I} \text {, the required width of ditch at bottom ; this, }
$$

as before remarked, being the only dimension of the profile at first unknown.
147. Ex. 2.-A line of intrenchment is to be constructed in haste, on level ground, the command to be only 5 feet, the parapet 6 feet thick, cover being obtained by means of a trench in rear 2 feet deep in front, $2 \frac{1^{\prime}}{\frac{1}{2}}$ depth in rear, and 5 feet broad at the bottom, the front slope of the trench being in contivuation of the slope of the banquette, and the reverse or rear slope being $\frac{1}{1}$; the banquette for double rank, superior slope $\frac{1}{6}$; no berm ; the ditch to be $5^{\prime}$ deep; base of both escarp and counterscarp to be 2 '; other slopes as usual. How broad must the ditch be made?

## Fig. 93.



[^5]\[

$$
\begin{aligned}
& \text { Area of } \mathrm{ABRO}=\frac{\mathrm{BR}+\mathrm{AO}}{2} \times \mathrm{RO}=\frac{6+12}{2} \times 3=27 \\
& " \mathrm{CRD}=\frac{\mathrm{CR} \times \mathrm{RD}}{2}=\frac{1 \frac{1}{2} \times 4 \frac{1}{2}}{2}=3 \frac{\frac{\pi}{8}}{2} \\
& \text { " } \mathrm{DONE}=\frac{\mathrm{OD}+\mathrm{NE}}{2} \times \mathrm{ON}=\frac{7 \frac{1}{3}+5 \frac{1}{2}}{2} \times 12=78 \\
& \text { " } \mathrm{ENF}=\frac{\mathrm{EN} \times \mathrm{NF}}{2}=\frac{5 \frac{1}{2} \times 5 \frac{1}{2}}{2}=15 \frac{1}{8}
\end{aligned}
$$
\]

In the secompanying handsketch (Fig. 93) $\mathrm{GQ}=5, \mathrm{QP}=6^{\prime}, \mathrm{HP}=\mathrm{GQ}-\frac{\mathrm{QP}}{6}=4^{\prime}$; $\mathrm{PJ}=\mathrm{HP}=4, \mathrm{FR}$ or $\mathrm{ES}=\mathrm{GQ}-\frac{4 y^{\prime}}{}=\frac{y^{\prime},}{} \mathrm{DS}=1^{\prime}, \mathrm{TD}=2 \mathrm{TC}=4, \mathrm{~V} \mathrm{~T}=5^{\prime}$,
$\mathrm{AV}=\mathrm{VB}=2 \prime^{\prime}, \mathrm{OK}=\mathrm{LN}=5^{\prime}, \mathrm{J}$ or $\mathrm{M}=2$ $\mathrm{A} V=\mathrm{V} \mathrm{B}=24.0 \mathrm{~K}=\mathrm{L}=5^{\prime}, \mathrm{J} \mathrm{O}$ or $\mathrm{NM}=2^{\prime}$.

To get the area of the ditch, subtract the area of the trench from that of the parapet.

Ares of profile of parapet .. .. .. $=41 \frac{5}{B}$ Area of $\mathrm{AVB}=\frac{\mathrm{AV} \times V B}{2}=\frac{2 \frac{1}{2} \times 2 \frac{1}{2}}{2}=3 \frac{1}{8}$

$$
\begin{aligned}
& \because \quad \mathrm{VBCT}=\frac{\mathrm{VB}+\mathrm{TC}}{2} \times \mathrm{VT}=\frac{2 \frac{1}{2}+2}{2} \times 5=11 \frac{1}{4} \\
& \Rightarrow \quad \mathrm{OTD}=\frac{\mathrm{CT} \times \mathrm{TD}}{2}=\frac{2 \times 4}{2}=4
\end{aligned}
$$

$$
\text { Area of profile of trench .. .. .. = } 18 \frac{3}{6} \text { square feet. }
$$

$\therefore$ Area of profile of ditch J K L M $=41 \frac{5}{8}-18 \frac{8}{8}=28 \frac{1}{4}$ square feet.
Mean width of ditch $=\frac{\text { area of ditah }}{\text { depth }}=\frac{23 \frac{1}{4}}{5}=4 \frac{s^{\prime}}{4}$ nearly.
Width of ditch at top $=4 \frac{3}{4}+\left(\frac{\mathrm{JO}+\mathrm{N} \mathrm{M}}{2}\right)=4 \frac{3}{4}+2=6 \frac{3}{4}$
Ditto ditto bottom $=4 \frac{3}{4}-\left(\frac{J O+N M}{2}\right)=4 \frac{3}{4}-2=2 \frac{s}{4}$
The above illustrations are sufficient to show how the size of the ditch for any required parapet may be quiekly calculated.
148. The area of the profile of a parapet may also be found by drawing the profile on a scale sufficiently large ( $8^{\prime}$ or $10^{\prime}$ to 1 inch), and afterwards reducing it to a triangle of equal area; the base and height of this triangle can then be measured, and the area found.

This method is usually applied when a parapet has to be constructed on sloping ground: but in that case it would be a quicker operation to calculate the parapet as for level ground, adding the triangle $\mathrm{D}^{\prime} \mathrm{G} F$ and subtracting H A $\mathrm{D}^{\prime}$, as shown in Fig. 94.

Fic. 94.


$$
\begin{aligned}
& \text { Area of } D E X Q=\frac{E X+D Q}{2} \times X Q=\frac{6+7}{2} \times \frac{1}{2}=3 \frac{1}{4} \\
& \text {, } \mathrm{FXG}=\frac{\mathrm{FX} \times X G}{2}=\frac{1 \frac{1}{2} \times 4 \frac{1}{2}}{2}=8 \frac{2}{3} \\
& \text { 7. } \mathrm{GQPH}=\frac{\mathrm{GQ} \mathrm{Q}+\mathrm{HP}}{2} \times \mathrm{QP}=\frac{5+4}{2} \times 6=27 \\
& \because \mathrm{HPJ}=\frac{\mathrm{HP} \times \mathrm{PJ}}{2}=\frac{4 \times 4}{2}=8
\end{aligned}
$$

The method of calculating areas by first drawing the figure to scale has the disadvantage of requiring drawing instruments to be at hand, and is not so rapid and cannot be so accurate as the method of calculation given above, which, in addition to rapidity and accuracy, has the further recommendation of requiring but a pencil and a piece of paper to effect it.
149. It must be remembered that these calculations are only approximate; for it has been assumed that there is no increase of bulk in the earth after it has been excavated, and also that the length of the diteh is the same as that of the parapet, neither of which may be the ease ; but they are sufficiently near the truth to enable a work to be marked out on the ground and commenced without loss of time.
150. The ditch, as determined by the above calculations, will usually be too great, when there is any error, and it will therefore generally be a good precaution to make a ditch a little narrower than its calculated approximate breadth, as it can be widened at any time in the progress of the work. This is preferable to running the risk of making it too large at first.
151. The parapet, as before described, protects men standing on the ground inside a work from direct fire, whether of artillery or musketry; but it does not (whatever may be its height) protect men standing on the banquette to a height greater than $4 \frac{1}{2}$ feet: therefore, when the banquette is manned for defence, the heads and shoulders of the defenders appear above the crest of the parapet. It is not practicable to protect men manning a parapet entirely from artillery fire, but it is important that they should be covered as much as possible from musketry, case shot, or splinters of shells. For this purpose Sandbag Loopholes are arranged on the top of a

## Fig. 95.



Fug. 96.

parapet wherever men are required to fire, as seen in Figs. 95 and 96 , which are respectively a front and a rear view of a sandbag loophole. In the former a musket is seen protruding through to be fired. Four bags are required for each loophole-one for each side and two for the roof. A single bag for the roof would not be musket-proof. The bag that crosses the wide part of the loophole should be supported underneath by short pieces of stick or plank to prevent its sinking.

For dimensions, de., of Sandbags, see Chap. III. Revetments.
Substitutes for these sandbag loopholes may be made in a variety of ways: trunks of trees or stont posts may be arranged, as shown in Figs. 97 and 98, resting on sods, de., two or three

$$
\text { Fig. } 97 . \quad \text { Fio. } 98 .
$$


inches above the crest of the parapet; short blocks of wood may be arranged transversely on the superior slope, with narrow intervals between them to fire through; and many other similar expedients may be resorted to, which will afford musketry cover to the defenders manning the parapet. Many of them have the disadvantage of splintering when struck by shot, and are objectionable when likely to be opposed to much artillery fire, and would therefore not be used in cases where there is a choice of materials ; that is, however, seldom the case on service, |lwhere the principal problem to be solved by an officer in charge of a defensive post is to make the most of the means at his disposal. |/
152. Parapets are sometimes formed of logs placed upright in the ground, and touching mach other, with loopholes (openings to fire through) ont in them. (Figs. 99, 100, and 101.)


This sort of rough timber parapet is termed a "Stockade" or "Stockade-work."
The logs or timbers should be $8^{\prime \prime}$, or more, in thickness; they should be sunk $3^{\prime}$ in the ground, and should stand $7^{\prime}$ or more out of the ground. The logs should be squared where in contact with each other; or, if this be not done, then smaller logs should be planted close before or behind the junctions, to resist the penetration of musketry at those parts. A stout beam, termed a "ribband," should be firmly secured to the logs near their tops, to add to the strength of the construction.
153. Provision should be made for preventing an enemy closing on the stockade. This may be done in a variety of ways. The simplest is that shown in the Figs. 100 and 102; viz., by

digging a small ditch outside, and heaping the excavated earth against the stockade as high as the loopholes.

When timbers $11^{\prime}$ or $12^{\prime}$ in length can be procured, the loopholes may be made $\mathbf{b}^{\prime}$ or more above the ground level; a banquette either of earth, as shown in Fig. 102, or of planks, \&e., being provided for the defenders.

Stockades have the advantage of combining the properties of a good musketry parapet and of an obstacle to the advance of an assailant; and unless breached by artillery fire, they require to be surmounted either by means of ladders, or by forming a breach in them, by means of a bag of powder exploded against them.
154. Walls and Hides frequently play an important part in defence, as, with very little labour bestowed upon them, they may be made to form very respectable substitutes for regular parapets.

They may be treated in various ways, according as they vary in dimensions and situation, and according to the time available for defensive purposes.

A wall 4 feet in height serves as a parapet without any preparation.
Fig. 103 represents a wall $6^{\prime}$ or $7^{\prime}$ in height; the ground inside is used as a banquette, loopholes being made 4' above the ground, for the defenders to fire through, and not less than $8^{\prime}$ apart. To prevent an enemy closing on the wall, and using the loopholes to fire through, a small ditch is excavated, and the earth from it piled against the wall.

If not practicable to form looplioles, from the absence of tools or other causes, rough openings may be broken down from the top, as shown in Fig. 104, to serve as loopholes.

Or a banquette may be formed on the inside, either of earth, as shown in Fig. 105, or by supporting planks on casks, stools, or other suitable and available means, to allow the defenders to fire over the top of the wall. The object of the small ditch shown in front, is to increase the difficulty of surmounting the wall on the part of an assailant.

This latter method of occupying a wall for defence has the adrantage of giving full play to the musketry fire of the defenders, which in the former instances is much limited by the loopholes ; but as a set off against that advantage (which, however, is a great one) the defenders are less protected, and the wall itself is wholly exposed to the fire of artillery.
155. Lofty walls, 10 or 12 feet in height, may be arranged for a double tier of defenders, by making a banquette of any available materials (b, Fig. 106), for one rank of men to fire over the top, as in Fig. 107, or through loopholes near the top, as in Fig. 108; and by making a row of loopholes close to the ground for the second rank, who stand on the bottom of a small trench dug for that purpose. No ditch should be dug in front, as it would afford cover to an enemy from the fire of the lower loopholes.


A wall so defended, if in a position protected from artillery fire, would prove a very formidable obstacle to an assailant; if liable to be cannonaded, it would be preferable to suppress the lower tier of fire, in order to strengthen the wall againstartillery, by forming an earthen banquette on the inside.
156. Hedges occupied for defence have the advantages of being obstacles to an assailant closing with the defenders, while at the same time the latter can generally manage to see and fire through them without being themselves seen.

A hedge growing by itself, without ditches on either side, may be treated in various ways, according to the time and means available.

Half an hour's work would suffice for a line of men to dig the small trench shown in Fig. 109 , and back up the excavated earth against the hedge; the bottom of the trench to serve as a banquette.


When more time is available the methods in Figs. 110 and 111 may be resorted to, the latter
being the best, as the ditch is an obstacle, but it requires the longest time to execute, as the earth from the ditch has to be thrown over the hedge before it can be formed into the parapet.
157. A hedge growing on one side of a ditch must be treated in different ways, according to which side has to be occupied by the defenders.

If the Ditch (D, Fig. 112 ) be on the outside, a parapet should be made, supported by the hedge, the earth being obtained by deepening and improving the ditch, and, if required, from a trench $T$ in rear.

Fis. 112


Fic. 113.


If the ditch be on the inside, occupy the line, as in Fig. 113, by deepening and improving the ditch, and forming a parapet on the inside, and use the hedge as an obstacle in advance of the ditch. The hedge may be partially cut down, allowing the parts so cut to drop to the front, care being taken not to sever them entirely from the stems.

Examples of this kind might be multiplied almost ad infinitum, but a sufficient number have ween given to show how obstacles, that may be slight in themselves, can be improved by the judicious expenditure of a little labour.

## ADDENDA TO CHAPTER I.

158. In the calculations that were given in the preceding chapter, no allowance was made for increase of bulk in earth on being excavated, the Remblai being taken as only the same as the Deblai. As this increase of bulk will frequently take place in constructing Field Works, from the earth not being properly rammed and, generally spealsing, from the haste with which they have to be thrown up, it will frequently be necessary in constructing intrenchments to make some allowance for this increase. The amount of increase will vary with every particular case, and practice ean alone determine it. An example is here given to show how the dimensions of a ditch are determined when this allowance is made.
159. Example 1.-Determine the dimensions of the diteh for the parapet shown in Fig. 92 (reproduced below), on the supposition that the increase of bulk in the earth on being excavated is $\frac{1}{7}$ th ; the depth of the ditch and the slopes of its sides being the same as given for Fig. 92.


In the handsketch here given (Fig. 114) the dimensions of the parapet and the known dimensions of the ditch ure figured. The increase of bulk being $\frac{1}{7}$ th, every 7 cubie yards of

Deblai become 8 cubic yards of Remblai, or, in other words, the area of the profile of the parapet is to the area of the profile of the ditch as $8: 7$.

$$
\begin{aligned}
& \text { Area of protile of parapet }
\end{aligned} \quad . \quad . \quad . \quad=123 \text { square feet. }
$$

160. Examples are also given below of the method of calculating the dimensions of a ditch, by first drawing the parapet to seale, and then measuring its area, and from that area obtaining
that of the ditch.

Exnmple 2.-A parapet of 12 feet in thickness and $8^{\prime}$ command, with a superior slope of $\frac{1}{3}$, has to be constructed on ground falling to the front 1 in 20 . The ditch to be 10 feet deep, slope of escarp to be $\frac{2}{3}$, of counterscarp $\frac{3}{1}$; other slopes as usual.

Increase of bulk of earth on being excavated $\frac{1}{2}$ th.


In Fig. 115 A B is a horizontal line: from any convenient point C draw C d any length (practically the longer it is the better), and de perpendicular to, and $\frac{1}{0}$ th of Cd . The line $\mathrm{C} e$ produced both ways will be the ground line. Draw the vertical line Cf , making it $8^{\prime}$ in height, the point $f$ will be the crest of the parapet; mark off $\mathrm{C} g=5 \mathrm{CF}$; join fg , which will thus have a slope of $\frac{1}{5}$, and will be the superior slope produced. Draw hi parallel to and 12 from c $f$; the point $i$ will be the exterior crest. To draw the exterior slope make $h k=h i$; join $i k$, producing it to meet the ground line in 1 .

Draw $m \pi$ and op parallel to $C f$, and at the distances from it respectively of $1 \frac{1^{\prime}}{\frac{\prime}{\prime}}$ and $b^{\prime}$ ( $4 \frac{1}{4}+1 \frac{1}{4}$ ) ; draw the banquette $\mathrm{n} p$ parallel to AB (i.e. horizontal), and $4 \frac{1}{2}$ under the crest; join nf for the interior slope; make $\circ \mathrm{q}=2 \circ \mathrm{p}$; joiu $\mathrm{p} q$, then pr will be the slope of the banquette: The parapet is now complete.

To draw the known parts of the ditch, draw the vertical line st'in any convenient position (for purposes of measurement only), mark the points $u^{\prime}$ and $v^{\prime}$, making $s v^{\prime}=2 \mathrm{~s} u^{\prime} ; u^{\prime} v^{\prime}$ will therefore slope $\frac{*}{\mathrm{~T}}$, and the escarp uv is made parallel to it. The bottom of the ditch is drawn parallel to the ground line and 10 feet under it: as the width of the ditch is unknown, the
counterscarp must be drawn in any convenient position for purposes of measurement; to draw it, mark the points $w^{\prime}$ and $t^{\prime}$, making $s t^{\prime}=3 \mathrm{~s} w^{\prime} ; w^{\prime} t^{\prime}$ will therefore slope $\frac{3}{1}$, and the counterscarp w $t$ is drawn parallel to it. Now, from the points $v$ and $t$ at the bottom of the ditch, draw lines v x and $t \mathrm{y}$ perpendicular to the slope of the ground AB ; the ditch is now divided into 3 figures, of which two are of fixed dimensions, and can therefore be measured by the scale; these are the right-angled triangles $u, x, v$ and $w, y, t$.

$$
\begin{aligned}
& \mathrm{ux}(\text { by measurement })=53^{\prime} \\
& \mathrm{y} \text { w }(\text { by do. })=39^{\prime}
\end{aligned}
$$

The area of the triangles $\mathrm{u}, \mathrm{x}, \mathrm{v}$ and $\mathrm{m}, \mathrm{y}, \mathrm{t}=\frac{5 \frac{3}{4}+3 \frac{3}{4}}{2} \times 10=47 \frac{1}{3}$ square feet.
Now, by reducing the profile of the parapet to a triangle of equal area, having the ground line sis a base, the base of this triangle is found (by measurement) to be $844^{\prime}$.

$$
\therefore \frac{34 \times 8}{9}=136 \text { square feet, the area of the profile of the parapet. }
$$

$\left.\begin{array}{l}\text { Dednct for in- } \\ \text { crease of bulk }\end{array}\right\} \frac{136}{10}=18 \frac{1}{5}$
$112 \frac{2}{2}$ is the area of the profile of the ditch.
Deduct $\quad 47 \frac{1}{2}$, being the area of the triangles $u, x, v$ and $w, y, t$.
$\therefore \quad 64 \frac{9}{10}$, say 65 , will be the area of the rectangle in the ditch.
Consequently $\frac{65}{10}=6 \cdot 5$, the required width of the ditch at the bottom, which can now be drawn to scale, and the counterscarp placed in its correct position.
N.B.-In the Fig. 115 referred to, the counterscarp is drawn at its proper slope, but it is not, and is not meant to be, in its correct position.
161. Exanple 3.-A parapet with a command of 8 feet and a thickness of 12 feet, has to be constructed on ground rising 1 in 20 to the front; the superior slope to be $\frac{1}{8}$, other slopes of the parapet as usual. The ditch to be 12 feet deep, escarp sloping 1 in 1 , counterscarp 2 in 1 . Allowance to be made for earth increasing $\frac{1}{\circ}$ in bulk, on being excavated.


The method of constructing the above Fig. 116 being exactly similar to the preceding case, the same letters of reference have been given to the two figures, so that the description for the one already given need not be repeated here. Only the actual calculation will be now stated.


## SHELTER TRENOHES, GUN-PITS, \&c.

161a. The long range, extreme aceurdey, and great rapidity of fire of the rifled arms of the present day render it more than ever necessary that cover should be provided for troops in action. When suitable cover does not exist naturally, it can be supplied by means of small trenches, called Shelter Trenches, which are now adopted into the service.

It is essential that there should be ready means of getting in and out of these trenches, both to the front and rear; it is also desirable that they should not offer any great impediment to a forward movement, and that troops should be able to march straight over them when necessary. At intervals of about 100 yards, to enable guns, cavalry, \&c., to pass, slight ramps should be formed, or intervals be left in the trenches, which may at those places be made to overlap.

161b. The most rapid way for infantry to obtain cover, is by the excavation of a trench 2 feet wide and $1 \frac{1}{1}$ feet deep: the earth is thrown to the front, so as to form a parapet about $1 \frac{1}{2}$ feet high, the interior slope being built up as steeply as possible with sods, \&c. Such a trench (Fig. 1, Pl. A) can be executed by men with their accoutrements on, distributed at from 4 to 6 feet intervals, in from 10 to 20 minutes. This is the smallest trench that is of any use, and will afford cover to two ranks, one kneeling in the trench, and one lying down in rear of it.

The above trench can be widened out to 4 feet in from 10 to 20 minutes more, and will then afford cover for a double rank kneeling (Fig. 2, PI. A). This may be considered an effective trench for occupation for a limited time, but as the troops in it would be in a constrained position, it would be desirable should still more time be available, to widen it out to a total breadth of 7 feet (Fig. 3), which would allow the men to lie down in it, and would require about 20 minutes more work.

Fig. 4 is the plan of a completed trench for a company of 30 files. The small trenches in rear, 2 feet broad and $1 \frac{1}{4}$ feet deep, are for the officers and non-commissioned officers of the company.

For temporary ocoupation of the ground on the field of battle, it is probable that shelter trenches would be thrown up in a continuous line, though the line need not be a straight one, that being determined by the features of the ground.

In all cases it is necessary that the parapet should not prevent any portion of the ground in front being seen by the defenders.

The height of the parapet given in the profiles, is that over which men can fire kneeling; the intermediate parts between the positions the men would occupy, may be made higher to afford better cover. Boughs of trees stuck in on top of the parapet would further conceal the defenders, without impeding their fire. Should there be no objection to placing impediments in the way of a forward movement, obstacles may be formed 100 yards or so in advance of the trench.

161c. Men skirmishing should be able to make cover for themselves. In most instances the men will only have to improve natural cover, but it may be necessary to dig small pits, which are called Shelter pits, in contradistinction to the larger pits used at sieges, \&c, which are called rifle pits. Each shelter pit should be for one man only.

A plan and section of a shelter pit, which can be made in about 5 minutes, are given in Figs. 8,9 , and 10 ; the depth need not be uniform, but should be about 10 inches, where the man's body will be, and about 6 inches in the other parts. After a little practice, each man will soon ascertain the exact form of pit that suits him.

161 d . It may be occasionally necessary to provide cover for the chargers of the monnted officers of a battalion posted in a shelter trench. This may be done by excavating Charger-pits parallel to, and 20 paces (from cutting line to cutting line) in rear of the line taken up (Figs. 5, 6, and 7). Each pit should be about 5 feet long, 3 feet wide at the top, and 2 feet at the bottom,
with ramps at a slope of $\frac{1}{3}$ at the ends. Such a pit can be executed by 4 men in half-an-hour. The turf should be used for the revetment of the parapet, which should be 8 feet high, and need not extend the whole length of the ramps, but only ubout 3 feet beyond the pit itself. The four men will not all be able to work in the pit at the same time; those who cannot will revet, and also increase the parapet from any place in front where earth can be readily obtained. Horses can be easily accustomed to go into such pits.

161e. Artillery may often be covered from the enemy's fire by natural banks, crests of hills, dc. In the absence of such cover, Gun-pits (Figs, 18 and 14) may be made.

This kind of pit can be excavated in about one hour, by men accustomed to the work. As the space is limited, the men must be carefully arranged, and should commence work where the pickaxes are shown. Should more time be available, the pit can be improved by lengthening the trenches for the gun detachments, and by thickening the parapet with earth from a ditch in front. As isolated gun-pits would form good marks for the enemy's fire, it would be advisable to connect them by shelter trenches, in which, however, places should be left to enable the guns to pass readily to the front.

Another type of gun-pit, suitable for muzzle-loading guns, is shown in Figs. 11 and 12.
161 f . Should no natural cover whatever be available for the limber, cover for it and a couple of horses might be provided in a pit, somewhat in the form of a charger-pit. The pit itself should be 12 feet long, $5 \frac{1}{2}$ feet wide at bottom, and 7 feet at top; it should be at least 3 feet deep, and have ramps at both ends of $\frac{1}{0}$ or $\frac{1}{3}$. Such a pit might be executed by 8 men in 2 hours. If recessary, cover could be provided for the other horses in a pit similar to the limber pit, but with a berm of 2 feet for the horses' heads.

Base of triangle of equal area to parapet $=35$ feet (by measurement).

Area of profile of parapet $=\frac{35 \times 8}{2}=140 \mathrm{sq}$. ft .
Deduct for increase of bulk $\frac{140}{7}=20$
$\therefore$ Area of profile of ditch $\quad . . \quad \overline{120}$
Deduct for triangles $u, x, v$ and $w, y, t=108$
$\therefore$ Area of rectangle in ditch $\quad . \quad=12$

Consequently $\frac{12}{12}=1$ foot, the required width of the ditch at the bottom.
N.B.-As in the preceding case, the counterscarp in the present case is drawn at the correct slope, but it is not, and is not meant to be, in its proper position.

In both the two preceding illustrations the bottom of the ditch is drawn parallel to the ground line, for facility of calculation.

In practice it might be made level, but no appreciable error as to the dimensions proper for the ditch would result.

## CHAPTER II.

OBSTACLES.
Why obstacles are recessary in Field Works ; conditions they should fulfil; Palisades ; Fraises ; Chevaux-de-prier; Abatuls; Trous-de-loup; Entanglements; Pointed Stakes; Ciow's Feet; Fougasses, common, shell, stone, and glass; Inundations, dams, waste weirs, sluice gates.
162. It was remarked, in the preceding chapter, that the ditches of Field Works formed, by themselves, a very imperfect obstacle to the advance of an assailant, who, when in them, was hidden from the view of the parapet in front, and might assemble in them in greater or less numbers,* and rush into the work in a mass. This is to be avoided, on the part of the defence, by all possible means, and is usually done by throwing obstructions or obstacles in the way of the advance of an assailant, in such a manerer that the closer he gets to a work, and the more accurate and deadly becomes the fire he is exposed to, the slower should be his progress and the more helpless he should become; so that, should he penetrate at all into the work, it shall only be in small numbers at a time, and not en masse.
163. On this subject, the following remarks by the late Major-General Sir John Jones, R.E., are given to show the opinion of one of the most experienced military engineers of the present age :-
"The great object of defence should be to contrive some expedient to check the assailants, and cause them to halt, if only for two or three minutes, under a close fire of musketry from the parapet. Such an adranced obstacle has ten times the effect of one of equal difficulty opposed to an ussailant, when he has closed with the defenders of a work. He knows that, in the latter case, he has but to overcome one difficulty to obtain complete success; whereas, in the former case, the troops exhaust their ardour and lose their formation on a mere preliminary effort, and every one must have felt how extremely difficult it is to revive confident boldness and restore order for a second effort after a check."
164. Obstacles used in conjunction with Field Works should generally be in advance of the ditch, as an enemy is thereby detained, and fully exposed to the close and accurate fire of the work ; but the ditch itself is a position peculiarly suited for certain obstacles, as will be shortly shown.
165. An efficient obstacle should fulfil the following conditions :-

It should be under the close fire of the work.
It should be covered from an enemy's fire.

- This remark refers to works having no flank defence, which is generally the case in works thrown up in the field.


## It should not afford any eover to an assailant.

It should be so strong as not to be cut down or removed withont great difficulty.
With a careful regard to these conditions, an officer when called upon to throw up an intrenchment will exercise his ingenuity in devising what obstades the resources of the country will provide ; he should by no means regard "obstacles" as merely restricted to a. few particular contrivanees which have been previously resorted to, and which will be presently deseribed, but should suggest any other forms which may appear to him more suitable to the circumstances against which he is called upon to provide.

The principal artificial obstacles which have hitherto been adopted will now be described separately, and their adrantages and defects stated. Although treated siugly, they are used in conjunction with one another, whenever time and circumstances permit.


Fig. 118.-Plañ.

166. Palisades (Figs. 117, 118, 119) are a stout description of fence or railing made in the following manner:-Beams of timber, 10 feet in length and triangular in section, each side of the triangle being in length about $8^{\prime \prime}$, are secured firmly to beams, termed ribbands, (Fig. 40) close to their ends, the intervals between the palisades being $3^{\prime \prime}$ or $4^{\prime \prime}$. A narrow trench is dug to a depth of 3 feet, in which the palisades are placed, and are secured in a position, either upright or slightly inclining. The upper ribband would be secured to the palisades after they are fixed in position, and should be on the side nearest to the escarp.

When large timber is not available, young trees $5^{\prime \prime}$ or $6^{\prime \prime}$ in diameter may be used whole for palisades; if the trees are $8^{\prime \prime}$ in diameter, they may be split down the middle.

Palisades, in order to be concealed from the vierv and protected from the fire of an enemy,
Fig. 120.

must be placed either in the ditch of a work, as in Fig. 120, or else in positions concealed by
works in front.
167. Fraises (Figs. 121, 122) are palisades planted in a horizontal, or nearly horizontal position. In forming them, a stout beam, or cushion (a a ), is laid horizontally, to which the fraises are spiked, and a ribband is secured to the top of the fraises near the inner end. Care should be taken in their construction to keep the flat sides of the fraises underneath, to increase the difficulty of standing on them, and with the same view they should be slightly inclined from a horizontal position.

They may be placed either on the escarp side of the ditch, as seen in Fig. 121, or on the counterscarp side, as in Fig. 122.


Fig. 122.-a. Cushion.


When on the escarp side of the ditch, they should slope downwards, so as not to interfere with shells or other missiles being rolled into the diteh from the parapet.

They are more exposed to fire on the escarp than on the other side of the ditch, and moreaver they afford a footing to an enemy who may have surmounted them. When placed on the counterscarp side, they are sloped upwards, to increase the difficulty of descending into the ditch; and on this side of the ditch they are very safe from direct fire, and have the great advantage of retaining an enemy outside the ditch, exposed to the fire from the work. The berm should, if possible, be cut away, to prevent planks being laid on it from the fraises; and the difficulty of the descent into the ditch will be much increased if the arrangement shown in the preceding figure can be effected. In this figure the ditch at the foot of the escarp is deepened and occupied by boughs of trees planted upright (see Art. 169, Abattis), which, combined with the fraises, evidently form a serious obstacle to an assault.
168. Chevaux-de-Frise (Figs. 123, 124) are made in lengths of from $6^{\prime}$ to $10^{\prime}$, any required number of lengths being chained together. Each length is composed of a barrel or stout beam,
from $6^{\prime \prime}$ to $8^{\prime \prime}$ square, with wooden spears $\theta^{\prime}$ long and $I^{\prime \prime \prime}$ or $9^{\prime \prime}$ square, passing alternately through either side, as shown.

## Fra. 123.



Fig. 124.


At each end of the barrel is a chain $6^{\prime \prime}$ long, with a hook attached.
In the iron chevaux-de-frise used in the service, the barrel is a cast-iron pipe, the spenvs are of wrought-iron, and can partly pack in the barrel for carriage. The dimensions are as follows :Length of barrel ${ }^{\prime}$

 Diameter of do. ${\frac{7^{\prime \prime}}{\frac{1}{2}}}^{\frac{1}{2}}$
Cheraux-de-ftise are generally employed as temporary barriers to close the entrance into a work, to bloek up a road or street, \&ce., as in these positions they can be quiekly moved aside When the communication is required to be used.

Their defeet is the amount of skilled labour required in their construction, which prevents their being used except in small quantities for the above limited objects.

They are occasionally recommended to be placed at the foot of the countersearp, and sometimes on the berm. In this latter position a glacis is required to cover them from the view and fire of an enemy; but usually an equally effective obstacle could be extemporised with less means.

When a single length of chevaux-de-frise is sufficient to close an opening (such as the entrance into a work), it may be arranged as shown in Tigs: 125 and 126, to turn on a post at one end as a

pirot, while the other end is supported by a wheel to facilitate its movement: this end is brought against a stout post, to which it may be chained.
169. An Abatris (Fig. 127) is a very formidable obstacle, formed from the branches of large Fro. 127.

trees, or the entire trunks of small ones, which are laid as close together as possible, the butt ends being secured firmly, and the branches turned towards the enemy. To be efficient the branches should stand at least as high as a man's breast, the smaller branches and twigs being removed, and the larger ones pointed, so as to present a number of small spears to an enemy.

The butts may be secured either by staking each one firmly, as shown in Fig. 127, or by beams laid across several and secured to them.

Abattis is usually placed in advance of the ditch, in a trench dug for the purpose, the earth from which is used to form a glacis in front, as seen in Fig. 127, where every part is under the musketry fire of the work.

It may also be placed in the ditch, as in Fig. 128, in an upright position against the
 counterscarp, where it forms a very serious obstacle to an assault, as it detains an assailant under fire, and it is very difficult to get at in order to destroy it, or to clear it by leaping over it.


The best woods from which to form abattis are hard and tough ones; the worst is pine, as not only is it bighly inflammable, even when freshly cut, but the boughs grow nearly perpendicular to the trunk, and cannot therefore be made to point towards an enemy.

The labour required to form ati abattis depends principally on the distunce that the trees have to be dragged after being felled. As the boughs are of course on them, if the distance be great, the labour heeomes extreme; if an abattis is formed close to where the trees are growing, it can be made very easily,
170. Trous-de-Loup or Mmprary Pirs (Figs. 129, 130, 181) are pits dug in the shape of an inverted cone or pyramid, each pit being provided with a stont stake fixed in the bottom and pointed sharply. They are of two descriptions, large and sinall. The larger ones are $6^{\prime}$ in diameter and ' $B$ ' in depth, and are usually conical; the small ones are only $9^{\prime}$ 'or $2 y^{\prime \prime}$ in depth, and are made in the form of a square pyramid inverted. These sizes are thus fixed because the former are so deep that an enemy cumnot fire out of them, and the latter are so shallow as not to afford any practical amount of cover. If trous-de-loup were made of depths intermediate to those named, they would serve as ready-made rifle pits to the skirmishers that usually precede the advaice of a column of attack:

Fre. 131.


If used with ordinary intrenchments, they should be in parallel rows, three (or more) in number' the central intervals of the pits in each row should be $10^{\prime}$ or $11^{\prime}$; and the rows should be arranged chequervise, i.e., the holes in each row should be opposite the intervals between those of the adjacent rows.

The use of the strke in each pit is not only to wound anybody who may fall into it, but also to increase the difficulty of firing from it.

Trous-de-loup are a good obstacle to oppose to cavalry. In ordinary soil one man can make one deep trous-de-loup or two shallow ones in a day.
171. An Entanglement is formed by outting the stems of small trees and bushes half through, and then by pulling the upper parts to the ground to which they are picketed.
172. Pornted Stanks, which can be made in great numbers, when any of the before-mentioned obstacles are being constructed, are very useful to occupy, as an obsticle, any ground in front of a work reqniring them. The berm, the bottom of a ditch, the ground in front of the counterscarp, and the intervals between trous-de-lonp, \&e., are good situations.

After being driven into the ground, they should be sharply pointed.
Fro, 132.-Plin. Fig. 133;-Elevation.

173. Crow's Feist (Figs. 132, 133) are formed each of four iron spikes $2 \frac{1}{3}$ or 3 inches long, joined together so as to make equal angles with each other. In whaterer way they may be thrown down, one point will always be directed upwards. They are principally used to obstruct the advance of cavalry, and have also been used to increase the difficuity of fording a stream, as was done by the French in 1814 at Bergen-op-Zoom, but with no good result, as the British were not delayed by them in fording the river Zoom, in which they were placed.
174. Common Fovgasser are small mines, of which the shafts or pits are from 3 to 10 feet deep. The charge of powder for any depth in ordinary soil is found by cubing the depth in feet, and by dividing the result by 10 to get the charge in pounds.

Thus the charge for a 0 feet fougass will be $\frac{6^{3}}{10}=\frac{216}{10}=21 \cdot 6 \mathrm{lbs}$., and for a 10 feet fougass it will be $\frac{10^{9}}{10}=\frac{1000}{10}=100 \mathrm{lbs}$., or nearly 5 times what is required for a 6 feet fougass; this charge is sufficient to make a hole in the ground the diameter of which is twice the depth of the charge (see chapter on Military Mining). In most cases it is preferable to have many small fougasses rather than a few large ones.

The powder is placed in a cubical box, which should be well tarred in order to be protected from damp, and is lodged in a recess called the chamber, on one side of the shaft at the bottom. It is fired from a secure spot by means of a powder hose or saucisson, enclosed in a wooden trough, which is carried up one angle of the shaft, and thence along a trench parallel to the surface. The trough should be 5 or 6 feet below the surface if there is any danger of shells falling upon it; if not, a depth of 2 feet will be enough. After the charge is placed and the powder hose laid, the shaft is filled up with earth, well rammed.

The position of the fougass should be concealed from the enemy's view. The powder hose is described in the chapter on Mining.

A second method of firing fougasses is to place a loaded musket with the muzzle in the charge or the priming, and to fasten a wire to the trigger; the wire can be led in the required direction, in the same manner as the hose, in a wooden trough; and being pulled at the proper moment, the explosion will take place.

This method has the advantage of being instantaneous, which for ordinary mines is a matter of great importance, as their effects are very limited, being confined to the ground which they move when fired; and it is therefore very desirable to be able to fire them at the moment when an advancing enemy is so situated as to receive their full effects.

The most perfect method of firing mines, and which would be resorted to whenever practicable, is by electricity, either by the Voltaic or the Magneto-electric battery. These methods are mentioned here to draw attention to them; but a description of them is beyond the limits of this work.

Fie. 134,-Plan.

shell fougass.
Fig. 135.-Section.

175. A Shell Fougass (Figs. 134, 135) is formed by dividing a box into two parts by a horizontal partition; the shells being loaded are placed in the upper part, with the fuzes pointing downwards through holes in the partition; in the lower part of the box is the charge of powder.

Shell fougasses are of two kinds: one of which has the charge of powder in the lower part of the box in sufficient quantity to form a crater in the ground, on being fired, at the same time blowing up the shells to the surface of the gronnd and lighting their fuzes,- these latter burst as their fuzes burn through; in the other kind the powder is mevely used to insure the fuzes of the shells being lighted, and when the shells burst, provided they have not been buried too deeply, they form their own craters.

The former of these methods is by far the most powerful, as they act first as a common fougass in blowing up the surface of the ground, and afterwards the full effects of the shells are obtained in addition; whereas in the latter method the only effect is to have the shells form small craters, the flight of the splinters being greatly retarded by the earth surrounding them.
176. A Stone Fougass (Figs. 136, 137) is intended to throw a shower of stones against an advancing enemy, and is thus formed:

An excavation, the axis of which is inclined at an angle of $45^{\circ}$ to the horizon, is made 6 feet, or thereabouts, in depth; at the bottom is placed a charge of powder of about $50 \mathrm{lbs.;}$ properly secured in a box; a wooden shield 6 inches thick is placed on top and perpendicular to the axis of the fougass; over this shield 3 or 4 cubie yards (about 4 or 5 tons) of stones, of not less than half
a pound each in weight, are placed; the enrth out of the excavation is built up over the charge to merease the resistance in an upward direction, and to ensure the effect taking place in the direction required. The side of the excavation over the charge will usually require to be revetted,

A Fougass, constructed as above described, can be made by twelve men in 3 or 4 hours, and when exploded will disperse the stones over a circle of 80 or 40 yards' radins, the centre being abont 60 yards from the month of the fougass. The usual und most effective pesition for fougasses is beyond the ditch, and on the approaches to the salients or other weak points of the work; they must be formed so far in advance of the ditch as not to injure the counterscarp by their explosion.

Fra. 136.-Stone Fongass fired at Chatham in 1853.


Fig. 137.
The illustrations (Figs. 186, 187) show a fougass of rather larger dimensions and charge than those stated above. It was successfully fired : the stones were thrown to a distance of 250 yards. The charge was 80 lbs ., and was placed $7 \frac{1}{2}$ feet under ground; the weight of stones was $5 \frac{2}{3}$ tons.

Fic. 188.

177. Fig. 138 is a section of a fougass, generally known as an "infernal machine."

It consists of a double deal box of a capacity to contain a sufficient charge of powder ( 80 or 40 lbs .) ; into the top of each box is inserted a vertical tin tube, connected with a horizontal tube (a), within which a glass tube filled with sulphuric acid, and coated with a composition of chlorate of potass, sugar, sulphur and gum water, which immediately takes fire on coming into contact with the acid. The space between the interior of the tin tube and the exterior of the glass tube,
as well as the vertioal tin tuhe, is filled with gunpowder.
These fougasses are buried in the ground where they are required to act, with the tin tube
just concealed by the earth. The weight of a man treading on the tin tube is sufficient to bend it so as to fracture the glass tube, and thus bring the acid into contact with the composition.
178. An Inundation is formed by constructiag one or more dams across the valley of a stream, so that the water colleets on the upper side.

To be unfordable an inundation should be 5 feet deep at its shallowest end; the means available for constructing the dams seldom allow a greater depth than 10 feet at the deepest end, -that is, at the end nearest to the dam.

The breadth of an inuudation, and consequently the length of a dam, depends (the depth being assumed) on the slope of the sides of the valley; its length will depend on the fall or slope of the bed of the valley: the most favourable positions for forming inundations are consequently where the bed of a stream has only a very slight fall, and the sides of the valley a regular and rather rapid rise. Where these conditions exist, long inundations may be formed with but few dams ; the dams themselves being short.

Where the means available do not allow of the shallow part of an inundation being deeper than 2 or 8 feet, it may be rendered impassable by digging pits and trenches irregularly over the surface, before the water is dammed up. Crow's feet and other obstructions may also be spread over the surface of the ground before the water is allowed to cover it.
179. A Dam (Figs. 189, 140) is constructed in the following manner, supposing its position, length, slopes, thickness, \&c., to have been carefully determined. The ends are first commenced, and the embankments forming the dam are completed, as shown in the accompanying sketoles, as far as can be done, without interfering with the stream. The waste weir (TV W) is also construeted.

Fig. 139.

D. Dam in progress.
W. Waste weir.
S. Stream not yet interfered with.

The soil of the dam should be impervious to water; or if not, a wall of clay or puddle should be constructed inside it. The materials for the dam should be taken from the lower side, to increase the depth of the adjacent inundation. Great care should be taken to properly ram the earth forming the dam. The chief difficulty in forming a dam is experienced when constructing the part over the bed of the stream; arrangements must be made to allow of this part being constructed with rapidity, as when once commenced and the stream dammed up, it must be built up at a more rapid rate than the inundation rises. For this purpose materials will be massed below the dam and on each side of the stream, and as many men employed as can work together. When everything is prepared, a bank of earth and sods is made across the opening between the two finished portions of the dam, to enable the workmen to commence the foundation of the dam on the bed of the stream; the work is then pushed on with all possible rapidity.

The thickness of a dam at top, as a general rule, may be made equal to the depth of water retained; the upside of the dam, or that nearest to the inundation, has usually a slope of $\frac{1}{3}$, and the lower side a slope of $\frac{1}{4}$.

When liable to be battered by artillery, the top of a dam should not be less than 10 feet thick.
180. The WASTE WEIR (Fig. 141), already mentioned, is an opening left in the upper part of the dam, so as to allow the water to flow over, on rising to its level. The surface of the weir should be two or three feet below the top of the dam, according to the liability to sudden floods,
and its brendth must be sufficient to allow the water of the stream to pass freely through it. The top nad sides of the weir, and also the slope of the dam over which the water runs, together with a part of the bed of the stream on the lower side, must be strongly revetted in order to withstand the action of the current. A double layer of fascines, securely picketed, forms a good revetment for this purpose.

Fig. 141.


Fig. 141 shows the profile of a dam taken through a waste weir, which latter is shown bridged over, in order to allow the dam to serve as a roadway.
181. Sluice Gates may also be constructed in dams, to allow the inundation being drained, whenever required.

A plan and elevation of a sluice gate are shown in Figs. 142, 143.
Fig. 142.-Elevation.


Inundations of the description and extent just mentioned are rarely within the compass of field operations; but frequently a ready means of increasing the obstacles to an enemy's approach will be found in blocking up the arches of a bridge, so as to cause the water to rise on the upper side.
182. An inundation will generally be in one of two positions, with reference to a line of intrenchment: either it will be in front of, and parallel, or nearly so, to the position; or it will run through the line and be perpendicular, or nearly so, to it. The latter is the most advantageous position.

Fig. 144.


When an inundation is parallel to a position occupied defensively (as in Fig. 144), it covers
that part of the position behind it from direct attack, and therefore fewer defenders will be required there ; but, on the other hand, as the dam is in front of the defensive works, it is exposed to the enemy's fire, its further end requires to be guarded to prevent access to it, and the dam may serve as a communication for the enemy. Moreover, the inundation, while it keeps the enemy ont of the position, prevents the defenders sallying out.

In Fig. 144, P P represents the position occupied for defence, I I the inundation, D the dam, W the work covering the head of the dam.

Fto. 145.


When an inundation is perpendicular to a line of intrenchment, as in Fig. 145 (where P is the position, D the dam, and I the inundation), the dam would be constructed inside the position, and would then be safe from fire, while it would serve as a communication to the defenders, and mask their movements behind it. The inuudation in this case is not a barrier to the advance of an enemy, but it forces him to attack under a great disadrantage; for if he attack only on one side of it, the defenders of both sides may be brought to oppose him; and if he (the enemy) attack both sides, he divides his forces, and renders himself liable to be opposed by superior forces on the one side, while he is held in check on the other, and thus to be beaten in detail.

## CHAPTER III.

## REVETMENTS AND REVETTING MATERLALS.

Object of a revetment; materials in general use. Sod revetiments; dimensions for sods; how to buitd thems, Gabions, brusthwood: method of making; tools, \&c., required. Sheet iron gabion; Iron band gabion; haw to build gabion revetments. Fasones: method of maloing; time, tools, fo., required; how to build a fascine revetment; use of anchoring pickets. Sandbags: details of their use for revebments. Casks; Plangs; Hurdles ; Stone revetments.
183. A Revetment is a support of any nature, constructed with the object of retaining earth at a slope steeper than it would stand by itself. The names of the materials in general use for revetting the slopes of Field Works are, Sods, Gabions, Fascines, and Sandluags; and when obtainable, Casks, Planks, Hurdles, \&c. \&c., are made use of.
184. Sods are cut usually $1^{\prime} 4^{\prime \prime}$ long, $8^{\prime \prime}$ broad, and $4^{\prime \prime}$ thick; and when built up in a revetment, each course or row averages $2 \frac{1}{2}$ " in height: these dimensions, however, may be varied to suit particular circumstances.

When spades only are available for cutting, a man can cut from 120 to 150 sods in a day of 8 hours ; but when any regular turf-cutting tools are to be had, a much greater number can be cut in the same time.

Sods are built in a revetment (Figs. 146, 147, 148), in courses or rows; they are laid, with the grass underneath, alternately as headers and stretchers (or with the ends or sides respectively exposed), and perpendionlar to the slope of the revetment. The joints of successive rows should be broken ; that is, the joint between any two sods in one row should not be over the joints of those in adjacent rows. The slope at which sods will retain earth at ordinary heights is $\frac{3}{T}$. The

grass should, as mentioned, be laid underneath in building: this allows the earth on the top of each course to be carefully smoothed for the reception of the next course, which can then be laid, and similarly treated; the last course is laid with the grass uppermost, for neatness of appearance. Thin deal pege are used to connect several courses. Five sods are usually required, when of the dimensions stated, for each square foot of revetment; and each square foot of meadow will produce, allowing for waste, 1 sod.

Sods form a very neat revetment, and are generally procurable on the spot, but they require greater labour, and more time to build, than any other lind of field revetment.
185. Gabions (Figs. 149, 150, and 151) are strong eylindrical baskets, having open ends ; their dimensions are $2^{\prime} y^{\prime \prime}$ bigh in the web, and $2^{\prime}$ in diameter. The gabion is made in the following manner:-A circle of 11 inches radius is traced on the ground; pickets from $\frac{5}{8}$ to $\frac{7}{6}$ inch thick, and 3 feet 6 inches long, are next driven into it at equal distances from each other ; the pickets are 12 in number, if ordinary brushwood be used, 8 or 10 if the brushwood be coarse, and a greater number if it be slender and weak. The waling or basket work is then commenced, with rods uevally stripped of leaves and twigs. Three rods are used at a time; they are first placed with the butts inwards and the tips outward (Figs. 149, 151), being separated from each

other by intervals of one picket. The first rod, which is to the left hand, is brought to the front by being passed outside two piekets, inside the next picket, and above the other two rods. The second rod, which is then to the left, is, in its turn, brought to the frout, by being passed outside two pickets, and inside one. The third rod is then treated in the same way, passing outside two pickets, inside one, and above the tivo preceding rods. Hence each rod comes in turn to the front; and a web is thas fromed roma the pickets. In making the gabion the web must be continually pressed down with the foot or hmd, or beaten with a mallet, and the greatest care
taken to preserve the proper diameter by constantly applying the gauge or measuring rod. The top and bottom of the gabion are finished with twisted withes, worked alternately in and out of the pickets. When the web is 2 feet 9 inches high, it must be bound from top to bottom with withes, previously well twisted, in four distinct places, so applied as to secure the ends rather than the middle of the external rods. The upper part of the gabion, being thus secured by withes, or sewing gads, is pulled out of the ground, turned upside down, and treated in the same manner, so that the two sets of withes may meet and cross each other about the centre of the gabion (as in Fig, 150). Before the gabion is pulled out of the ground, the tops of all the pickets must be cut off about an inch and a half above the web.
186. Three men will finish a gabion, with 8 or 10 pickets and large brushwood, in 2 hours; a common cabion of 14 pickets in 3 hours; and a very light gabion, with 16 to 20 pickets, formed of the smallest brushwood that can be used, in from 4 to -5 hours.

The tools required for each squad of three men are, 1 bill-hook, 2 gabion knives, 14 -feet measuring-rod, 3 ganges cut out of the brushwood, 1 chopping block, 1 mallet, and 1 grindstone (for several squads), or whetstones in lieu thereof.

The average weight of a brushwood gabion is 35 or 40 lbs ; but if thick wood be used, they will frequently weigh as much as 60 lbs . These gabions are required in great numbers during siege operations, where they are indispensable for revetting batteries, de.; bnt their disadrantages are numerous: they are heavy and clumsy to carry, require much labour to make, and are combustible and perishable.
187. These defects are so well known, and so important, that of late years two kinds of iron gabions have been introduced into the service.

The Shert Tron Gabion (invented by Captain Tyler, R.E.) is formed of a sheet of galvanized iron, 3 feet wide, and 6 feet 2 inches in length; at each end are three holes, having metal eyes. The sheet being bent round into a cylinder until the eyes at the opposite ends come together, is fastened, in that form, with three wire hooks, which are attached to the eyes of one side. The gabion, thus formed, stands 3 feet high, and 2 feet in diameter; it weighs 26 pounds, and is carried, like the common gabion, by means of a picket passed through it, for which purpose two holes are provided in the iron sheet.

This gabion is durable and ineombustible; it is very easily and rapidly put tngether, and the 'material (being in sheets) is very portable, and is applicable to many purposes, such as roofing huts, \&c. \&c. Being, however, without pickets, the sheet iron gabion has but little hold of the ground, and it is difficult to fasten intrenching tools in it; and, as it makes much noise in carriage ly working parties, it is unsuitable for secret operations, such as flying sap. It also splinters to a dangerous degree when struck by shot.
188. The Iron Band Gabion (Fig. 152), invented by Quartermaster J. Jones, R.E., is composed of 10 bands of sheet-iron, each $6^{\prime} 5^{\prime \prime}$ in length, and $3^{\frac{1}{4} / \prime \prime}$ in breadth; each band (Fig. 153) has two buttons at one end, fitting into two boles or slots at the other. Twelve wooden pickets are used with the bands to form the gabion.

Fig. 152.-Scale I.


Irou Band Gabion.
To put the gabion together, two men are required. One of the bands, with the ends joined together, is placed edgewise on the ground, thus forming a circle 2 feet in diameter; the pickets are then driven into the ground round the band, at equal distances from one another, and alternately on the outside and inside of the band, and touching it; the other bands are then placed in succession over the pickets, taking care that each band is outside those pickets that were inside the adjoining band, and vice versd, and are then pressed down on to the band last placed: no fastening is necessary

## Field Furtification.

to heep the bands on the pickets. The gabion has been put together in 5 minntes; and could be done with case in 10 minutes: it weighs about 29 lbs., of which the pickets weigh 5 lbs .

Compured with the brushwood gabion, the iron band gabion has the following udvantages, viz. : lightness, portability (us the bunds and pickets are sepurately packed together) durability. and incombustibility. Moreover, the uninjured bands of damaged gabious can be used to form ather gations.

The principal dofect attending them, besides splintering when struck by shot, is that in loose sandy soil the spaces between the pickets and bands allow the earth in them to run through.

Suspension bridges to carry field artillery have been made with these sheet iron bunds, buttoned together as a substitute for ropes or chains, and the inventor proposes to put theru to many other uses, such as roofing buts, forming camp bedsteads, military obstacles, de. \&c.
189. In building a gabion revetment from the ground level, the first row of gabions rests partly on the ground, and partly on a row of fascenes (see next Art.) sunk 8 inches into the ground, and firmly picketed thereto; the gations are then filled with earth, which is carefully pressed (not rammed), and the parapet is completed to the level of the top of the gabions, when nuother yow of fascines is laid on top of the gabions; the parapet is then completed to the top of these fascines, and a second row of gations can then be placed and filled.

Figs. 154 and 155 show, in internal elevation and in profile, a slope of $7 \frac{1^{\prime}}{2}$ in height, with a
gabion revetment.
gamon revicments-Scale $\frac{1}{\text { ron }}$
F10. 154.-Interior alevation.


Fig. 155.


Fig. 156.


Fig. 156 shows in profile the revetment of the interior slope of a parapet, provided with a banquette; it cousists of a row of gabions, with a lower and an upper row of fascines. A row of sods on top brings the crest to the proper height of $4 \frac{1}{2}$ feet above the banquette.

Gabions, in tiers, with a lower and intermediate course of fascines, form the strongest and most durable field-revetmeut, and can be used in any soil. They have also the great advantage of not requiring additional men to build them in a revetment, beyond the ordinary working party required to form the parapet: this renders them particularly serviceable for revetting works constructed at a siege.
190. Fascrases are strong fagots, usually made 18 feet in length and 9 inches in diameter; if shorter ones are required, they are sawn into 6 or 9 feet lengths.

Before fascines can be made, fascine trestles or horses have to be set up in the following manner :- Five pairs of stakes, each $6 \frac{1}{1}$ long and about $3^{\prime \prime}$ diameter, are driven obliquely into the ground, crossing one anoller like the letter X, at $2 \frac{1}{2}$ feet above the ground (Fig. 157), where they are secured by means of rope-yarn, \&c. Erch pair of stakes forms a trestle. The extreme trestles (Fig. 158) are first set up 16 feet apart ; the three others are then set up so as to divide

$$
\text { Fia. 157.-Scale } \frac{1}{7}+
$$


this interval equally, and are consequently 4 feet apart, care being taken that the intersections of the five trestles are in one straight line.

To make a fascine, brushwood is laid along the trestles, so as to project about 17 or 18 inches beyond their extremities, the thick and thin wood being equally distributed in the length of the fascine, and the thick wood kept as much as possible on the outside. When the proper quantity has been placed, the brushwood has to be fastened and secured by " withes" or "gads." Twelve gads are used to each fascine; they are placed 18 inches apart, the extreme ones being 9 inches
from the ends of the fascine.

In order to be able to fasten the gads, an instrument called a "choker" is used to compress the brushwood to the proper diameter.

The choker consists of a couple of wooden levers 4 feet long, joined with a chain 4 feet long, fixed at 18 inches from the ends. The chain has two small rings on it, 28 inches (the circumference of a 9 -inch circle) apart.

To use the choker, the chain is passed once round the brushwood, and the levers are pressed downwards until the rings of the chain meet. A gad can then be tied close to it. The choker is then-removed and applied successively to the positions where the other gads are to be fastened, which are tied in succession. The fascine is completed by trimming projecting twigs, and by sawing the ends square at the distance of 18 feet apart.

Spun-yarn is frequently used in place of withes or gads for the fastening both of fascines and gabious ; and if required to revet the cheeks of embrasures, annealed iron wire is made use of for the same purpose.

Five men are required to make a fascine; after setting up the trestles, they can make one fascine for each hour they work. The average weight of an 18 feet fascine is about 140 lbs .

The following tools are required for each squad of five men, viz,-5 pairs of stakes and lashings for the trestles, 1 choker, 1 maul, 1 handsaw, 3 billhooks, 2 gabion knives, 16 -feet rod, together with 1 grindstone (or several whetstones in lieu) for several squads.

Fascine Pickets, $3 \frac{1}{2}$ feet in length and $1 \frac{1^{\prime \prime}}{4}$ or $1 \frac{1^{\prime \prime}}{2}$ in diameter, are provided for securing the fascines, in the proportion of 6 or 7 to each fascine.
191. In building a fascine revetment from the level of the ground, a groove 8 inches in depth is first cut along the line representing the foot of the slope. In this groove the first row of fascines is laid, and fastened firmly to the ground by being picketed thereto; as soon as the earth of the parapet is brought up to the level of the top of the first row of fascines, a second row is laid, care being taken that the joints of successive rows are not over one another. Each fascine is fastened to the row beneath it by two pickets, and to the earth of the parapet by four or five pickets, driven as shown at $a$ in Fig. 159. The other rows are laid in a similar manner.

Fig. 159.-Scale $\frac{1}{74}$


In revetting with fascines in weak soils, the fascines should be anchored; that is, fastened by long withes or by rope to stout stakes driven into the interior of the parapet, while it is being constructed. This precaution greatly strengthens the revetment.

Fascines are built at a slope of $\frac{4}{1}$.
Revetments formed entirely of fascines are not so strong as gabion revetments, and are much
heavier, which is an inconvenience, particularly if the materials have to be brought from a distance. The average weight of a gabion revetment per square foot is from 6 to 7 lbs ; that of a fascine revetment being about 10 lbs . Extra men are also required to build up a fascine revetment. Fascines are requisite, as before shown, is intermediate courses between rows of gabions, where they add much to the strength of the revetment. Thoy are also most useful in revetting steps or similar small heights, where gabions would be too high, und they have the recommendation of being made of wood too coarse and large to use for constructing gabions.

Besides being used for purely revetting purposes, they may be used in place of planks for the superstructure of rough bridges, or for roofing Field Powder Magazines, Kaponiers, or for covering Blinded Galleries, \&c. \&c. They are also very serviceable in forming the rough drains that are required in Field Works.
192. Sandnacs are bags of coarse canvas, measuring, when empty and laid flat, $8^{\prime} 8^{\prime \prime}$ long, and $14^{\prime \prime}$ broad. They coutain when full a bushel of earth; but in building them in revetinents they are only three-quarters filled, in order that they may be easily flattened with a spade or shovel into the shape of a brick; and then weigh from 60 to 70 lbs , each. Tarred sandbags weigh when empty $1 \mathrm{lb}, 12 \mathrm{oz}$, each.

In building sandbags in a revetment, they are laid, as described for sods, in courses of alternate headers and stretchers, and with the joints of successive courses broken, like in brickwork. The choke or neek of the bags in the headers is laid inside, so as to prevent its unfastening.

The retaining slope of a sandbag revetment is 4 .
Sixteen bags are required on an average for 10 square feet of revetment; each course of bags will average $6^{\prime \prime}$ in height.

Sandbags have the great advantage of being very portable. When untarred, they are made up in bundles of 500, und two men can carry ome bundle on a handbarrow. On naval expeditions they are most serviceable, being so easily carried. Sir J. Jones has described them as the mainstay of British operations.

Gun batteries have frequently been built at sieges entirely of sandbags, which are filled at the nearest convenient site and brought to the place. This may be done either to save time, by employing a great number of men, or else in cases when the earth cannot be excavated on the spot, as in rocky or marshy soil.

In this manner whole batteries have been constructed and armed in a single night.
Fig. 160 shows a plen of one course of sandbags, Fig. 161, a profile, and Fig. 162, an internal eleration of a sundbag revetment in progress.
savobag hevitanant - Scale $\frac{1}{72}$.

Tro. 160.-Plan of a single course.


Fig. 162.-Interior elevation.


Fra. 161.-Profile.


The great defect of sandbags is that they are very perishable; if untarred, they will rot in a revetment in two months, or less if the weather be wet.

The formation with sandbags of loopholes on the top of parapets has been alveady described in Chapter I., and a similar use is made of them at sieges on the top of the parapets of the trenches.

They are also frequently useful in other ways, as, for instance, in sieges or bombardments, to cover over the roofs of magazines, and to repair damages generally.
193. Casks form a good substitute for gabions in revetments ; their ends being removed, they are filled with earth, like gabions. They should not be used in positious exposed to fire, on ascount of the splinters that would be detached from them.
194. Planks form a very good revetment for interior slopes, \&o, of Field Works. Stout
stakes are driven at intervals in the direction of the slope, and the planks are placed inside them, as shown in the accompanying Figs. 163, 164.
195. Hurdies for revetments should be made 6 feet long and 2 feet 9 inches high. On a circle of 8 feet radius, an arc of 6 feet long is measured, and 8 to 10 pickets are then driven in at equal distances. The web is made in a manner similar to that of a gabion, excepting that in the hurdle some of the rows of rods are twisted so as to cross each ather like a chain, as in Fig. 165 ;

whilst others are laid horizontally, passing alternately within and without each rod: the ends of the rods are secured by being passed upwards or downwards in a similar manner throngh the horizontal rods. A revetment of hurdles requires to be carefully attached to the parapet at the top by anchoring pickets; the pickets upon which the hurdle is made bsing driven well into the ground. Three men will make a hurdle in three hours; it will weigh 50 lbs .

A species of hurdle revetment may be formed for the interior slopes of Field Works, by driving in stakes in the direction of the slope, to answer to the pickets of the hurdle, and by working brushwood in and out of these pickets, throughout the length of the revetment.
196. Loose Stone Walls are frequently constructed for interior slopes; and when only exposed to musketry fire they may be used by themselves as breastworks, but they should not be used in positions where they would be liable to be struck by shot, on account of the danger from splinters.

## CHAPTER IV.

## DESCRIPTIONS OE FLELD WGRKS,

Deriniprons: Salient and re-entering angles, flank, line of defence, angle of defence, outline, face, garge, capital, open and closed works. Prinotples to bi observed in determining the outline of a Woris, with reference to the length of parapet, shape of work, flank defence, security from enfilade, sise of re-entering and of satient angles, length of lines of defence. Redans: their nature, defects, fic.; Double and Triple redans. Lunemters; theirnature, defects, der; modes of closing the gorges of open works. CLOsmD WORKs : redoubts or forls; defects inkerent to closed works; most uppareat in smail worls. Renoubrs: their shapes, sise, and garrisom; defects of redoubts, how remedied or modified; auxiliary flank defonce by kaponiers and counterscarp galleries; defects of kaponiers and galleries, their best situations; entrances into closed works, BLock advantages when of proper size; advantages of parapet flank defonce for field works. Stak Forts: their trace when regular and irregular; defects of star forts. DOUBLe STAR FORT: its advantages, Bastroned FORTS have complete parapet flank defence; construction of a front; Tengths of exterior sides, maximum and minimum; peculiar formation of the ditch of a bastioned front; to trace am irregular bastioned fiont. Denir-bastioned Fobts: their trace and defects; suitable positions. ReDurrs : their object; various methods of construction.
197. Definitions, \&c. A Salient Angle is one which points towards the exterior of a work. A Re-entering Angle is one which points towards the interior of a work.
A Flank (in Fortification) is a line of work designed for the special purpose of defending some other part by a flanking fire, and this latter is then said to be flanked by it. The term
flank hins other military meanings; when applied to a position held by troops, or to a line of works, it refers to the extremities of the line; and similarly to a line of troops.

A Line of Deforec expresses the distanee or line extending from a flank to the furthest part of the line flanked by it.
(This term is frequently confused with defensive lind or lines, when referriag to defensive woxks.)

An Angle of Defence is that formed by a Flank and a Line of Defence, whether they are joined together, us in Fig, 166, where ench side or face flanks the other; or, as in Fig. 167, where they are separated, and only one flanks the other.


F4G. 167.


The Outline of a Work is its general shape in plan. The term is also used to express the plan of only the Magistral Line of a work, which is then said to be drown in outline.

The Faces of a work are two of its sides which meet in an angle, whether Salient or Reentering. The term is also used to express any particular sides of a work.

The Gorge is a line joining the inner extremities of an open work, as $c, d$, Fig. 170.
The Capital of a work is an imaginary line bisecting its principal salient angle, as $a, b$, Fig. 170.
Open Warks are those whose parapets do not entirely enclose or surround the site occupied.
Closed Works are those whose parapets entirely surround the site occupied.
198. Principles to be oeserved in determining the outlines of Fifld Woris.
(1.) The outline of a field work should be proportioned in length to the number of men and guns intended for its defence, at the following rate, viz., 1 yard of parapet per man, if for single rank; or per file (or couple) of men, if for double rank, exclusive of the reserve.

If field guns are used in works, each gun will require 5 yards of parapet, if on a side; and if at an angle, and firing en barbette (over the parapet), each gon will require 10 yards of parapet, viz., 5 yards on each face of the angle; the remainder of the parapet only being manned by infantry, and therefore provided with a banquette.
N.B.-It is usually the custom, when stating the garrisons of Field Works, where guns are used, to mention the number of infantry, and the number of guns, but not gunners; for instance, if it be stated that a particular work ought to be garrisoned or defended by 800 men and 4 guns, it is to be understood that there are in the work 300 infantry, and, in addition to them, the artillerymen required to man the 4 guns.
(2.) The parapet of a field work should be so adapted to the shape of the ground on which it is constructed, that every spot within effective range of muslretry may be exposed to its fire. Ilustrations of this are afforded by the plans of works, as in Figs, 168 and 212, where the shape of the works was entirely regulated by that of the ground on which they were actually constructed.

In profile, this rule implies that, when works are on the top of moderately rising ground, the lines of pmapet should be retired away from the erest, a snfficient distance to allow the musketry fire from the parapets to graze the slope, as in Fig. 169. See Chapter XI., which explains the method of udapting works to irregular sites.
(3.) There should be a reciprocal defence between all the parts of any system of works, so that the grombl over which an enemy must adrance to the attack of any part of the works should be seen in flank from other parts.

A flanking fire is more effective, generally, than a direct one: 1stly, because one projectile may take effect upon a number of men, and it can be bronght to bear on the assaulting party
in positions where the other cannot, such as in the ditch, or on the capital of a work; 2ndly, because it affects the rear divisions of a column equally with the leading divisions, and is therefore more likely to throw the whole into disorder, and force them to retire.

Fie. 168.


Fic. 169.-Seale $\frac{1}{20 .}$


Taking these principles together,-viz., $1^{\circ}$. The proportionate length of the line of parapet to its defenders ; $2^{\circ}$. The adaptation of the parapet to the ground in its front; $3^{\circ}$. The reciprocal defence of the several portions of lines of works,-it will be evident that strength of plan or outline involves flanking defences, which, however, entail increased length of parapet; it is also clear that the adaptation of the work to irregular ground must, as a rule, require increased length of parapet : thus the second and third principles will be apt to clash with the first, and it may be added that the second, when the ground is very irregular, will generally clash with the third. In such cases skill and experience can alone assist in deciding how far one principle must yield to another, so as to obtain the strongest outline consistently with the efficient manning and arming of the work.
149. The foregoing are general principles; the following are principles of detail.
(4.) The faces or other long lines of parapet should be secure from enfilade fire, and should therefore be traced, so that their prolongations fall on ground which cannot be occupied by the enemy.

It is generally impossible to avoid some lines of parapet being enfiladed, and, as a choice of evils, it is preferable to have short lines so exposed, rather than long ones, both because the extent of the evil is so much less, and because short lines of parapet are more easily defiladed. (See Ohapter VI., Defilade.)
(5.) Re-entering angles, if intended to be flanking angles, ought to be never less than $90^{\circ}$ and seldom more than $100^{\circ}$; for if less than $90^{\circ}$, the men on the flanking parts would be liable to fire on the parts they should flank, and if more than $100^{\circ}$, the fire from the flanking parts would diverge too far from the salient to afford it efficient defence.

A flanking angle of $95^{\circ}$ appears the best size for Field Works, where the flanking defence is generally musketry five; for in a flanking angle of that size, the flanking fire will naturally tend a little away from the parapet flanked towards the counterscarp, thereby decreasing the danger of the men in the flank firing on to the parapet flanked.

Re-entering angles have frequently to be made greater than $100^{\circ}$, to suit the shape of ground,
or from other circumstances; but then, although the fire from the faces would cross on the ground in front, it would not be strictly a flanking fire, ns in Fig. 170.
(6.) The Salient Angles of works should be as obtuse as possible, and never less than $60^{\circ}$; otherwise the interior space would become too contracted, the angle would be so sharp as to be quickly worn away by the weather, and would be easily battered down; also the sectoral space in front of the salient angle undefended by direct fire (which is the supplement of the angle) would become very great (Fig, 171).

Fig. 170.


Etc. 171.


It is presumed that the soldier fires (as he generally does) at right angles to the parapet behind which he stands, or, as before stated, direetly to his own front. As the direction of the shots $o a, o b$, Fig. 1 rl (according to this presumption), make two right angles, $A a a, B o b$, with the parapets meeting at $o$, and as the four angles at o are equal to four right angles, it is clear that the sum of the remaining two, $A \circ B$, the angle of the work, and $a \circ b$, the sectoral angle undefended by direct fire, is also equal to two right angles.
(7.) The Lines of Defence (or distance from the flanking parts to those flanked) should not exceed 200 yards, so that the musketry fire from the flanks may bear on the assailants with effect, before they arrive at the ditch. It will rarely happen in a field work, that a longer line of defence than 200 yards will be required.

This length of 200 yards cannot be definitely fixed, but the following reasons are given for thus fixing it, so mueh below the extreme range of the present rifled muskets.

The effect of arms of precision is a maximum when the range is known, the object stationary, the marksman undisturbed, and time is afforded for correcting the aim. But none of these conditions are usually fulfilled when Field Works are attacked, for then the assailant (the object) advances rapidly, probably during twilight, and in heavy rain, and across the direction of the fire of a flunk; his advance is also covered by the distracting fire of numerous skirmishers, and probably by that of artillery, and by the noise and smoke on both sides. Under these circumstances, the maximum distance of effective musketry fire depends very little on the extreme range of the muskets employed, but prineipally on the steadiness of the defenders, and on the distinetness with which they can see the enemy.

In fortresses, which have a profile secure from assault, the long range and accuracy of fire of rifled weapons have allowed the lines of defence to be increased to 500 yards, and many advantages are the result, which, however, camnot be fully obtained in Field Works.
200. The works in general use in Field Fortification will now be described; their defects, together with the methods of remedying or modifying them, and also the positions suitable for each work, will be pointed out.

OPEN WORKS.
A Redan (Fig. 171) is a work consisting of two faces, or lines of parapet, meeting in a salient angle, the gorge being open. When the faces are not more than about 20 yards in length, it is sometimes called a féche.

The weak points of this work are, that it has the ground in front of the salient undefended, more or less as the angle is small or large, by direct fire ; its ditches are entirely undefended, being unseen, or dead; there is no flauk or reciprocal defence ; and its open gorge renders an attack there easy, particularly at night.

On account of having an open gorge, it is seldom advisable to construct a redan as an isolated work; it is best calculated for positions where there is some sort of protection or defence immediately in rear-viz., to cover a guard or advanced picket, as an outwork to look into hollows, or view slopes not seen from the principal works, or in front of a bridge (Fig. 176), dam, road, avenue, or defile.

The first defect-viz, that of having an open gorge-may be remedied in some degree by placing along the gorge abattis, chevaux-de-frise, or palisades, if time permits and materials abound; as to the second defect, a direct fire may be brought in front of the salient either by rounding the latter or by cutting off the angle so as to form a short face not less than 6 yards long, as $a b$, Fig. 172.*

Fio. 172a.


Fig. 172.

ab. Pan coupé.

A flanking fire may be procured for the ditch at the salient by constructing auxiliary flanks, which may be placed either at thie middle or at the extremities of the faces; these flanks also evidently bring a cross fire on the capital of the work. (See de, Fig. 170.)

The length of a flank depends on the length and importance of the line to be flanked, but no flank ought, as a rule, to be less than 12 yards long, as if made less the flank will not occupy the whole of the prolongation of the ditch it flanks, and the greater part of its length will be in the prolongation of the parapet of the line flanked. In Fig. 172A an auxiliary flank is shown having a length only slightly exceeding $a b$, which is the distance between the crest and the top of the counterscarp of the line flanked.

Fig. 173.-Scale troon.
Fig. 174.-Scale Tmin.


- A short face made in this way at the salient of a work, in order to obtain a direct fire on the capital, is termed as "pan coupé."

A Double Redan (Fig. 173) consista of two redans joined together, their extreme faces being longer than the two others, which should form a flanking angle. This work in its nature, defects, \&.., is similur to the Redan, except that it is stronger, owing to the cross fixe on the salients. Fig. 173 is evidently a stronger work than a redan of the same length of parapet.

A Triple Redan is one having three salients, as in Fig. 174.
201. A Lunette (Fig. 175) is a work with two of its faces forming a salient angle, and two other faces, called "flanks," parallel, or nearly
 so, to the capital: as a general rule, however, the flanks are traced perpendicularly to the direction in which they are required to fire. (See also Figs. 267, 272.)

Faces of 50 yards, and flanks of from 20 to 30 yards in length, are ordinary dimensions for Lunettes.

The defects, above quoted, as belonging to redans, apply equally to lunettes, as also the methods of remedying them, \&c., and the positions snitable for the work.
202. Open works generally are preferable to closed works in positions where there is a defence for their gorges, as in advanced works, for instance ; because, should the enemy gain possession of them, he would still be exposed to the fire of the works in rear, or to the attack of troops sent against them.

It is, however, generally desirable to close the gorges of open works with some line of obstacle, as a guard against surprise. This obstacle may be of any nature, provided that it keeps an enemy ont of the work, and gives him no protection from the fire of the works in rear after he has got in: this may be effected by disposing across the gorge a single or donble row of palisades, or a stockade-work. There should be a banquette to the stockade, that the defenders may have a command over the assailants, and a ditch to prevent the enemy from getting close, and cutting, burning, or blowing down the obstacle. This end may be best obtained by leaving a berm, about 6 feet wide, on the outside, and heaping upon it some of the earth excavated from the ditch against the palisading or stockade-work, as in Fig. 100 or 102.

Trous de-loup, abattis, dc., may be used to strengthen the gorge, as before mentionel.


A redan or lunette by itself has many defects, as has been pointed out; but when judioiously selected and supported, it may become a very formidable work. This will be evident from an inspection of Fig. 176, where the Redan (R) is intended to protect the head of the bridge (B) from attack.

In this position the gorge is naturally closed by the river; the works F F flank, from secure positions, the faees of the redan, and bring a cross fire on its capital. The ditches may also be filled with water, if the site allow, and are exposed to flanking fire from $F$; and should an enemy get possession of the work, the interior, as well as the passage over the bridge, is exposed to the fire of the work G. Fig, 176 illustrates also a principle in Fortification-viz., to arrange works so that an enemy, when attacking one work, must be exposed to the fire of as many other works as possible.

## CLOSED WORKS.

203. When a closed work has no flank defence for its ditches from its parapets, it is called a Redoubt ; and when it has a parapet flank defence for its ditches, and therefore re-entering (flanking) angles, it is called a Fort.
204. Closed works of every kind have the inconvenience of having some of their parapets exposed to be enfladed or taken in reverse, for, on whatever side an enemy opens fire, the projectiles that clear the parapets of the faces opposed to him take in reverse those of the further sides, or enfilade the lateral faces of the work; and from the fact that the work is a closed one, an attack from any side, or all sides at once, is possible, and therefore every part may be liable to be enfiladed, or to be taken in reverse.

It is not here implied that every part of a closed work is equally liable to these disadvantages ; for as one portion of a work will face the front of a position, the front faces will not generally be liable to be taken in reverse until after an enemy shall have penetrated to the rear.

Another defect inherent in closed works is, that the garrison when attacked are confined in a comparatively small space, and suffer, in proportion, from the effects of the enemy's fre, which may be concentrated on the work from various points, previonsly to its being assaulted. To illustrate this, compare the situation of the garrison of a square redoubt having 100 yards of parapet with the defenders of a straight line of parapet 100 yards in length, exposed only to fire from the front, and manned by the same number of men as the redoubt. The disadvantages under which the former labour will be evident; for with the straight line of work every projectile that clears the parapet passes to the rear without further damage, but with the redoubt the projectiles are arrested by the other parapets, and the effects of the enemy's fire, particularly that of shells, increased.

These disadvantages of closed works necessitate the construction of traverses (see Chapter V.) of various kinds, inside the work; these traverses, however, occupy much of the interior space, which, in consequence, becomes cramped, and the defence suffers in proportion.

These disadvantages are more fully felt in small works than in large ones, for in small works an enemy's fire becomes more concentrated, the defenders are confined in an area smaller in proportion to their unmbers, and there is less room to construct proper traverses than in large works.

In comparing the space inside a small work with that inside a larger one of similar shape (say two squares), it will be observed that, while the garrison of the two works will be in direct proportion to the length of the sides of works (or length of parapet), the interior space will be (nearly) in the proportion of the squares of the sides.

These defects are so well known, that it is almost a maxim in Fortification, that "Small works are bad works," whether a redoubt, a fort, or a fortress, is referred to; but Field Works must be used of a size suited to the garrisons that can be spared to defend them, and when small works are necessary they must be made the most of.*

* To give an idea of the garrisons ordinarily allotted to Field Works, it may be here mentioned, that of the works forming the celebrated Lines of Torres Vedras
$\left.\begin{array}{rccc}6 \text { had garrisons under } 100 & \text { men } \\ 49 & " & \text { of from } 100 \text { to } 200 \text { meu } \\ 47 & " & " & 200 \text { to } 300 \\ 33 & " & " & 300 \text { to } 400 \\ 3 & " \\ 3 & " & " & 400 \text { to } 500\end{array}\right\}$ " Exelusive of artillery,
And 10 works had a garrisou of or more than 500 men.


## Field Forlification.

205. It is, however, desimble to fix the minimum size that an enclosed work should have, and as a general rule it may be laid down that a redoubt onght not, under ordinary circunstances, to bave less than from 80 to 100 yards of parapet, according to whether the work is manned by a single or a double rank of defenders.
206. On the other hand, it is difficult to fix the maximim size that a redoubt should have; that is to say, when the unflanked trace of a redoubt should give way to the fliuked trace of a fort. It has been nsual to assume that a redoubt should not have move than 150 or 160 yards of parapet; the reason given being that, if a larger work is required, a flanked trace could be adopted without losing too much interior space. But the smallest fort recommended has always been much larger than the largest redonbt; and the rule laid down has not therefore been followed in practice.

There does not seem any good reason for assuming that a redoubt should not have more than 160 yards of parapet; and without fixing any arbitrary maximum, it may be stated that a redoubt, with 200 or even 300 yards of parapet, will in most sitnations be superion to a field fort having the same length of parapet, and requiring the same strength of garrison, notwithstanding its theoretical advnntages of reciprocal defence over the redoubt.
207. The size of a redoubt depends on the object for which it is constructed, the site it occupies, or the number of men and guns intended for its defence. Either of these may become the chief consideration in determining its size; for instance, in Fig. 168, the size of the work, and its shape also, were determined by the ground on which it was constructed; but more generally the garnisons of a work will be first fixed, and its size proportioned acoordingly,

The shape of a work will depend much on the nature of the site and the direction in which the fire of its principal faces is required to be directed; these faces being traced perpendicular to the direction in which they are required to fire, and the other faces directed 80 as to enclose sufficient space, or to be safe from enfilade, dc.

The garrison of a redoubt (its size and shape being determined) will depend on its position and liability to attack ; those sides most exposed to attack being given a double rank, the other side a single rank of defenders; and in addition to these men, who are required to man the parapets, there should be a reserve, varying usually from one-third to one-sixth of the entire garrison.

The duty of a reserve in a work is to attack the enemy when he first penetrates into the work, which will usually be in small numbers and in no regular formation, and drive him back before he can be sufficiently reinforced to outnumber the defenders.

The proportion that a reserve should bear to the garrison of a work will depend principally upon the time required to bring up supports to the relief of the work when attacked; for it must be remerobered that "Field Works, if left to themselves, will fall if vigorously assaulted," The reserve will therefore vary in the proportions named, as the work is in a more or less isolated position.

These methods of proportioning the gamisons of redoubts (and also any Field Work) are what wre quoted by Sir John Jones as being preferred to all others, in determining the garrisons of the redoubts in the Lines of Torres Vedras.

It has been customary, in calculating the garrisons of enclosed Field Works, to allow a certain number of square feet of interior space per man and per gun ( 10,15 , or 18 square feet per man, and 500 square feet per gun, according to different authors), on the supposition that the garrison will be confined within the parapets.
"In practice this rule oan seldom be necessary, for during daylight, until an attack is threatened, many men will be kept on watch outside, and others will be permitted to amuse themselves in rear; cooking, \&e., is performed outside the work, and during the might one-third at least are under arms,"

Redoubts are made of any shape, regular or irregular, most convenient to suit the particular circumstances of the case ; but the most usual form for a redoubt on a level site is a quadrilateral, because it is of simple construction, the ditches are more easily flanked, and there are fewer points of attack (the salients) than in a redoubt of a greater number of sides.
208. The defects of all redoubts, whether of a quadrilateral or of a polygonal form, are, 1 st, want of direct fire on the ground in front of the salients ; 2nd, no flank defence for any part; and 3 rd , the ditches are dead, being unseen from the work.

The want of fire in the direction of the capitals may be remedied, as in open works, by filling up an angle so as to form a short face or a curve, having room for a few files ( 6 or 7 ) to fire en capitale, at the same time obstructing the approach of the enemy in that direction by all a vailable obstacles.

Guns are also frequently placed en barbette (see Chapter V.) at the salients; but artillery in a Field Work are usually posted for offensive purposes, such as to bring a fire on ground over which an enemy must advance to an assault, or to enfilade a road or bridge, or to flank some other work; but for the close defence of a work, it is considered that the parapet required for a gun would be better occupied by infantry.

The defect of the ditches being unseen from the parapets is peculiar to most Field Works (except very large ones having their own flank defence), and, as has been before mentioned, one great object of defence is to prevent an enemy, as long as possible, from getting into the ditches, by detaining him under a close fire, by means of obstacles arranged for that purpose.

But when time and circumstances admit, a flank defence for the ditches of redoubts (and any other kind of work requiring it) may be obtained by forming in them kaponiers, either at the angles or in the middle of the faces, or by loopholed galleries, behind the counterscarp at the angles of the work.
209. A Kaponier (Figs. 177, 178, 179, 180) for the ditch of a Field Work is a covered building, the walls of which are made of stockade-work and are loopholed. It is roofed over with beams, planks, or fascines, with earth on the top, in order to secure the men within from the

effeets of shells, or a plunging fire from the countersearp. It ought to be flanked by musketry, and its salient should be bronght to a point, to prevent an enemy closing on it and getting under cover. A gallery of communication is constructed, leading to the interior of the work.

The kaponier should extend across the original width of the ditch, and the counterscarp should be enlarged round its salient, to prevent an enemy using it as a bridge. The floor-line of the kaponier may be sunk 3 or 4 feet below the bottom of the ditch, as the roof thereby becomes lowered a similar amount, and the work better covered from fire; but when this is the case, great precautions are necessary to keep the kaponier drained.

Frg. 178.-Section through C.D.-Seale T.
Fig. 150.-Scale tive


Fto. 179.-Section and elevation on A B.-Scale $\frac{1}{2}$. 0 .


The difficulty of draining the work, if its floor be sunk below the bottom of the ditch, may frequently render it imperative to keep its floor, as showa in Fig. 180, on the level of the bottom of the diteh.

In general the best position for a kaponier is at an angle, as in that position one work can flank two lines of ditch; it has, however, in that position the inconvenience of having its walls, when parallel to each other, oblique to the lines of fire, which correspond to the direction of the ditches: this is, of course, more felt with small salients than with large ones.

Fig. 181 shows a shape for a kaponier at a salient angle ; each side is made perpendicular to the ditch it flanks, and the head of the work forms a re-entering angle, thereby allowing it to be flanked.

Works formed with stockade-work can be destroyed from a distance if exposed to artillexy fire ; therefore, whenever a kaponier is used, it must be carefully protected from the effects of artillery.

This will be best effected, in general, by placing it at the angles nearest the enemy's position, as then the counterscarp and glacis in front cover it from fire, enfilading either of the ditches flanked by it.

The accompanying sketches (Figs. 182, 183) show how quadrilateral redoubts can be flanked by kaponiers, all of which are placed so as to be safe from artillery fire enfilading the ditches, from the front of the position, which is supposed in the figures to be the top of the page. Three kaponiers are required to flank four lines of ditches; if only two kaponiers were used, at opposite angles, one of them at least, and perhaps both, would be exposed to artillery fire.


Fig. 182.

210. A Counterscarp Gallery (Figs. 184, 185) is somewhat similar to a kaponier, as its front wall is constructed of stockade-work, and it is roofed similarly to a kaponier. It is constructed necessarily at an angle; and when used to flank two ditches, it has in itself reciprocal defence. A door of communication leads to the ditch, from which a gallery into the work is necessary.

The objection urged against counterscarp galleries is the isolation of the defenders, which prevents their being under the immediate supervision of the officer commanding in the work. They have, however, the great advantage of being able to be placed in positions of perfect security from artillery fire.

Fig. 183.


Fig. 184.


An inspection of the sketch shown in Fig. 184, where a redoubt is shown with its ditches flanked by counterscarp galleries under similar conditions to those given in Article 209, for kaponiers, will show that not only are the galleries in positions secure from artillery fire, but also that each gallery can be flanked by one of the others.

When a counterscarp gallery is necessarily placed at an obtuse angle, it may be given the Fro, 185.-Scale 1 ko.


Profile of counterscarp gallery. Section on A B, Fig. 184.

fire, a work of difficulty.
211. Circular redoubts, although they have no undefended sectoral spaces in front, and also enelose a greater space than any other work with an equal length of parapet, are seldom formed, on account of the difficulty of their construction, and because their ditches are not easily flanked by the contrivances already described. The equal distribution of fire from their parapets prevents the fire being concentrated on any part in front, and the circular tracing cannot usually be adapted to the ground, which rarely requires a uniform amount of fire in all directions. Moreover, in any case where a circular work would be a suitable work, a polygonal work of 6 or 8 faces would be equally efficient and more simple to construct.

These remarks apply not only to circular works, but in general to all works having a curved trace, in part or in whole.

It is a principle in Fortification, to concentrate as powerful a fire as possible upon certain points, even at a considerable sacrifice of strength in portions of the works. Such a sacrifice is then made up for, in other ways than by commanding fire.

## Fig. 187.



Fio. 188.


For instance, let S and C (Figs. 187, 188) represent parts of a square and of a circular redoubt, each having the same length of parapet, and therefore requiring the same number of
defenders. At first sight, the curved work may appear preferable, as no ground in its front is so deprived of fire as is the sectoral space in front of the angle of $S$; but it must be remembered that it is equally weak at every part, for at no one point in front can a heavier fire be directed than on any other point. Now, if we suppose time, dce, is allowed to occupy the sectoral space in front of S with obstacles, and a space equally large in front of C with similar obstacles, the advantage of the straight lined trace over the circular will become evident; for in attacking S , an enemy would have to choose whether he would advance over the obstacles, exposed to the small amount of fire from the pan coupé, or, in order to avoid the obstacles, to advance exposed to the whole fire of either one face or the other. But as regards the curved work, the obstacles may be said to be useless, for by avoiding them an enemy would be exposed to no more fire than if he attempted to advance through them.

Rectilinear works have the further advantages over curved works of being more easily defended by the cross fire from other works defending the same position, and also of having their ditches flanked more easily.
212. The garrison of a closed work communicate with the exterior by means of a passage from 6 to 9 feet wide, formed in the parapet on the side least exposed to fire. The passage should be closed by a musket-proof loopholed gate; and when artillery can be brought to bear on it, a traverse to cover the entrance should be thrown up, inside the work. Across the diteh a bridge, having the same elear breadth as the passage, is formed of planks resting on beams, which latter are termed baulks.

For details of the construction of the Passage, Gateway, Traverse, and Bridge, see Chapter V., Details.

Fig. 189.-Scale $\frac{1}{100}$

213. A Blockhouse (Fig. 189) is a covered loopholed building, usually rectangular in shape, the walls being formed of stockade-work, and the roof of beams and planks or fascines, with a covering of earth 3 or 4 feet thick. In mountainous and well-wooded countries these buildings are useful as isolated works, in positions where uncovered works would be exposed to the command of the neighbouring heights. Blockhouses also serve as barracks for the garrison, a row of bedsteads $6 \frac{1}{3}$ feet long forming a banquette to the loopholes, being formed along each side, with a passage 7 feet wide left down the centre. The interior width of the blockhouse, when thus used, will therefore require to be 20 feet or more. The interior height should be 8 or 9 feet; the logs forming the walls must be squared, so that the parts in contact may not be less than $6^{\prime \prime}$ in thickness: they should be sunk $8^{\prime}$ or $4^{\prime}$ in the ground, and must therefore be at least 12 feet long. A ditch should be excavated outside the building, and the earth thrown up against the walls.

When exposed to artillery fire, the walls are formed of a double row of logs, having a space between them from $8^{\prime}$ to $6^{\prime}$ wide, filled with earth, as in Fig. 190. Upright logs at intervals along the centre of the building act as pillars, and support the roof. Large and formidable blockhouses may be built in the shape of a cross, from which form flanking defence may be obtained. (See Figs. 191, 207.) A work of this description requires considerable care and time in its
construction. To blockhouses not exposed to the fire of artillery, an upper storey may be added,
Fis. 190. Scale reat

as sketched in plan in Fig. 192. The upper storey is placed diagonally across the lower one, so that its angles project beyond the sides of the lower storey. The floor is loop-

$$
\text { Fre, } 191 .
$$

Fig. 192.

holed; and thus both the interior of the lower storey, and the foot of the walls on the outside, are seen and defended. The additional storey affords to the garrison a better view and command over the surrounding ground than could otherwise be obtained, while its fire is directed on to ground which is least exposed to the fire of the lower storey.

Means of retreat to the upper storey should be provided, and every available precaution should be adopted to guard against fire. (See Defence of Houses.)

Blockhouses are well adapted to serve as Reduits of large works, provided proper precautions are taken to screen them from the artillery fire of an assailant. (See foot-note, page 92, Art. 224.)
214. Forts have been referred to as "enclosed works having flank defence from their awn parapets:" they are larger works than redoubts, $i . \varepsilon$., have a greater length of parapet, and require a greater garrison; because parapet flank defence necessitates re-entering angles, thus involving increased length of parapet, and re-entering angles cause a loss of interior space, which could not be spared in works of the magnitude of ordinary redoubts.

The disadvantages of small works, as compared to large ones, mentioned in Art. 204," apply equally to forts as to relloubts, though perhaps to a different degree. It will be remarked in the descriptions of the various forts in use, now to be given, that as the works get larger, and have more sides, the following advantages result, independent of the mere increase of garrison, viz., either the salient angles are lavger, or the re-entering angles beeome better flanking angles, and the reciprocal defence becomes more perfect.

The advantages of the fort trace do not become evident muless the salients are well flanked: this is illustrated in Fig. 193, where a rectangular redoubt is drawn. This redoubt would be a better work than the fort shown ly the dotted lines (if the salients are lialle to attack, which must be presumed); for, by adopting the trace of the fort, interior space is lost, the salient angles
rre diminished, and consequently the sectoral spaces in their front, undefended by direct fire, are increased, while the fire from the faces naturally concentrates in front of the re-entering angles, where it is least wanted.

But, in a work where each salient is flanked by some other part, as in Fig. 194, where the


Fic. 194

salient S is Hanked by the parapets F F, the advantages in trace of forts over redoubts become apparent, as the ground in front is everywhere subjected to the cross or flanking fire of at least two faces, while the ditches are more or less seen from the parapets.
215. This figure will also serve to illustrate the advantages for Field Works of parapet flank defence over auxiliary flank defence by kaponiers, \&c.; for in auxiliary flank defence, the length of the works for flanking purposes is limited by the small breadth of the ditches, and the fire from them only acts on an enemy while he is in the ditches; whereas, in the case of parapet flank defence, the flanking parts, as F F, are long lines of parapet (compared with the breadth of the ditch), and their fire, in addition to defending the ditch, crosses on the ground in front of the salients, where it is particularly required. And, it may be added, that these advantages in the fort trace are obtainable in the time required merely to build the parapets.

These remarks apply only to Field Works, and are not intended to apply to Permanent Works, whose ditches are usually insurmountable obstacles to an assault, and which are attacked under very different conditions to what is the case with Field Works.

The ordinary field forts will now be described; their names are Star Forts, Bastioned Forts, and Demi-bastioned Forts.
216. Star Forts are works composed of faces forming alternately salient and re-entering angles, and are so named from their form being like the usual representation of a star.

When regular in shape, they may be traced in a variety of manuers; the following seems as good as any other (Figs. 195, 196, 197).

Fig. 195.-Scale $\frac{1}{\text { sion. }}$.


Fro. 196. -Scale stion


Fig. 197.-Scale $\frac{1}{3 \text { cove }}$

Trace a regular polygon, of the same number of sides as the work is to have salients, each side of the polygon being of the length of the intended faces of the fort ; and on each side of this
polygon, erect an equilateral triangle to get the faces of the work. Thus, if an 8-pointed star: fort were required to be traced, so as to have 100 yards of parapet, an octagon would be first traced, each side being $\frac{400}{8 \times 2}=25$ yards in length, and on each of these sides of 25 yards an equilateral triangle would be raised to obtain the faces of the work.

The salients of star forts are usually made $60^{\circ}$, as by so doing the re-entering angles become better flanking angles.

To trace a star fort, when the nature of the ground, ©o., requires an irregular work, the following method is the most convenient. First select the salients $a, b, c, d, e$, Fig. 198, as their

Fic. 198.
 position is the most important, and is usually to a great degree fixed by the nature of the ground; bisect the angles formed by the exterior sides $a b, b c, c d, d e, e a$, which join these points, to get the capitals of the salient angles; and from each of the points $a, b, c$, $d$, $e$, draw lines making angles of $30^{\circ}$ with these capitals to get the faces, which are then produced until they meet.

This method, which is easy of execution on the ground, will give re-entering angles of a size as nearly approaching good flanking angles, as can be done without making the salients too small.

Star forts, consisting of re-entering as well as salient angles, were intended to obviate, in some degree, the main defect of redoubts; they, however, do not even partially obviate it unless (as in Fig. 197) constructed on polygons not inferior to an octagon ; as even on an octagon, the flanking angle being $105^{\circ}$, the fire from the faces, though it crosses the capitals, affords but little defence to the ditch: on polygons inferior to an octagon, they afford a fire which crosses at so great a distance from the salient as not in an effective manner to flank it.

A great portion of the ditches of star forts, whatever may be the number of salients, is dead at each re-entering angle. The actual amount of dead space will depend on the relief of the work and on the depression of the superior slope : thus, if Fig. 199 represents a section through

Fra. 199.-Scale $\frac{1}{\text { ग10. }}$

the face of a star fort and the ditch opposite to it, the relief being 18 , it will be seen that it will be $6 \times(18-3)=90$ feet before the fire from the parapet, with a depression of 1 in 6 , can defend the ditch, which it is usual to considex properly effected when fire can be directed within $3^{\prime}$ of the bottom.

With a superior slope of this distance will be $4 \times(18-3)=60$ feet. Thus, whatever may be the size of the re-entering angles, there will be a dead space in the ditoh, varying, as above shown, from 20 to 30 yards in a work having a relief of 18 feet. Hence, if it be considered necessary to have some portion of the ditch near the salients flanked, no side or face should be made of a less length than 25 to 35 yards, according to the depression of the superior slope.

A steeper slope than usual may be given to the superior slope of a star fort, at those parts of
the faces which occupy the prolongation of the ditehes, as by so doing the dead space in the ditches will be reduced, and the defect of weakening the parapets at the parts named will not be of much importance, as re-entering angles are less exposed to artillery fire than the other parts of works.

Star forts, as a class, have many defects, which may be summed up as follows, it being remembered that most of these defects are less felt in large than in small works.

Owing to the numerous angles, and the great thickness of the parapet and slopes at a salient of 60 (twice that on a perpendicular to the face), the construction of star forts is attended with trouble, particularly if the ground be uneven. The small salients are each a favourable point of attack, and are not well flanked in polygons inferior to an octagon; the ditehes are dead for many yards on each side of the re-entering angles; the length of parapet to be manned is great, when compared to the interior space, and is exposed to reverse and enfilade fire in all directions, and there is seldom room for sufficient traverses to lessen the effects of such fires. Most authorities consider small star forts as inferior works to redoubts with auxiliary flank defences.
217. Fig. 200 represents $a$ work termed a Double Star Fort, which has many advantages, which, however, are chiefly owing to its large size. In the example here given, the small redans, A A, afford a powerful flank defence to the main salients, without being themselves liable to attack, owing to their strong position, as they are situated in a re-entering position. The interior space is ample, and the work generally is not more exposed to enfilade fire, while the flanking parapets are much less exposed to reverse fire than is the case in bastioned forts, a description of which follows.

Fig. 201.

218. Bastioned Forts (Fig. 201) are sometimes considered the most perfect of elosed Field Works, as they possess the advantages of mutual defence between their several parts, their ditches are (when properly censtructed) seen throughout from the parapets, and every part of the exterior ground is exposed to the cross fire of at least two lines of parapet.

While possessing these advantages in their trace, bastioned forts can be rarely used on account of the large garrisons they require, the smallest bastioned fort having in round numbers
find yards of parapet; they are therefore used only in very important positions, and then all available means and labour should be expended on them, in order to make them us formidable as possible; and all the accessories of defence, such as abattis, trous-de-loup, palisades, fraises, Sc., nlready described, should be resorted to, in the positions most suitable for them.
219. The following is the method of tracing these works, when regular, a square being here taken (Fig, 201) as an example.

The points A B, \&c., at the angles of the square, are first fixed. The sides A B, B $y$, sce., of the square are termed Eaterior sides, and on each exterior side the following construction is performed.

Bisect A B in C ; through C draw the Perpondicular C D, perpendicular to, and $\frac{1}{7}$ th of, A B; join AD and BD , and proince them to obtain the Lines of defence, AH and B G : on these lines of defence set off A E and B F , each equal to sths (sometimes 1rd) of A B, to obtain the Facos of the buations: through the points E and F draw the Flants, E G and F H, at angles of $95^{\circ}$ with their respective lines of defence, BG and A H ; join the points G and H , to obtain the Curtain, GH, which completes the trace of the parapet of one side of the work, or, as it is termed, "a bastioned fromt of fortification," which consists of two faces, two flanks, and the intermediate curtain.

The names of the different parts, not mentioned above, are the following:- L K A EG is $a$ Bastion, similar in shape to a lunette; LG is the Gorge of the bastion; G N or L N the demigorges: A N the Capital; KAE the flanked angle: A E G or B F H the shoulder angles; E G B and FHA angles of defence or flanking angles; E G H and F H G the curtain angles or angles of the flank: and ABD and B A D the diminished angles.

It will be evident, on considering the preceding construction, that if the perpendicular C D were increased in length, it would have the effect of increasing the length of the flanks E G and FH, and at the same time it would decrease the size of the flanked angles KAE, \&ic.

The reason why the perpendicular is only made $\frac{1}{4}$ th of the exterior side, in a square fort, is that, if it were larger, the flanked angles would become less than $60^{\circ}$.

When a fort is constructed on a regular pentagon, where the angles of a polygon are $108^{\circ}$, the perpendicular is made $\frac{1}{7}$ th of the exterior side, as the flanked angle will then be larger than $60^{\circ}$, while the length of the flank is increased; and when a work is constructed on a hexagon, where the angles of the polygon are $120^{\circ}$, a perpendicular as large as $\frac{1}{1}$ th of the exterior side can be made use of, and a still larger flank thereby obtained, without having too small a flanked angle.

The perpendiculars are never made more than $\frac{1}{\mathrm{t}}$ th of their respective exterior sides, whatever may be the size of the angles of the polygon, as with that length a flank long enough is obtained.
220. The exterior sides of a bastioned fort may be any length most convenient between 120 yards as a minimum, and 240 yards as a maximum.

The minimum length is here fixed at 120 yards, because that length, with a perpendicular of th, gives a flank about 12 yards in length, which is the smallest size a flank should have to be at all formidable ; and if the exterior side were made less than 120 yards, the distance $G D$ or H D, in Fig. 201, would become too short to allow the point D to be defended from the flanks, with the ordinary relief of about 18 or 20 feet.

The maximum length of exterior sides is fixed at 240 Jards, in order to keep the flanks within 200 yards of the counterscarp of the flanked angle; with that length of 240 yards for A B in Fig. 201, G B and H A will be about 170 yards long.

The reasoning given in Article 199, par. 7 , to which reference is suggested, will show that this maximum of 240 yards cannot be arbitrarily fixed; but whether the reasons there given be good or bad, it will rery seldom happen that an exterior side larger than 840 yards can be required in a field fort.
221. The ditch of a bastioned front requires a peculiar construction, in order to derive the full benefit of the flanking defence obtained by the bastion trace.

If the counterscarp of the front were made parallel to the escarp, as is the method with ordnary works, the connterscap of each flank would prevent the fire from the opposite flank defending the ditch of the face nearly throughout its entive length ; the diteh of each flank would also be hidden from the fire of the opposite flank. Fig. 202 shows this, the ground shaded being dead.

By cutting ramps (a a, Fig. 203) in prolongation of the ditches of the faces, those ditches become exposed to the fire of a portion of the flanks, and a great improvement on Fig. 202 is effected with the expenditure of only a little labour; but still, merely that portion of the flank which oceupies the prolongation of this ramp is available for the defence of the ditch; in order, however, to allow the whole fire from the flank to defend any part of the ditch, the construction shown in Fig. 204 must be resorted to. Here the countersearp is directed on to the shoulder angle of the opposite bastion, and the whole of the ground between the original counterscarps of the two flanks is ramped, as shown in the section, Fig. 205; or it may be removed entirely, if considered necessary.


Fig. 205 is a section on the line A C of Fig. 204, in illustration of the above. If the ramp $B^{\prime} D$ had not been made, the fire from the flank $A$ would only begin to defend the diteh at the point C.

This mode of construction involves a considerable amount of labour, beyond that required to form the parapets.

In commencing a bastioned fort, the ditches at first would usually be made, as in Fig. 202, in order to obtain the earth for the parapets; and as time allowed, they might be improved gradually until formed, as seen successively in Figs. 203, 204.

## Field Fortification.

222. When the shape of a bastioned fort is necessarily irregular, on account of irregularity of the ground or other canses, the salients A, B, \&u. (Fig. 206), would be frst selected: these points

Fra. 206
 may be at any distances apart most convenient, between 120 and 240 yards (Axt. 219), provided that in no oase is the angle formed by two adjacent exterior sides less than $90^{\circ}$.

This will usually lead not only to having exterior sides of different lengths, but also to the angles of the polygon being of different sizes, and the construction of the fort becomes more intricate thau with regular polygons.

In Fig, 206 an irregular pentagonal bastioned fort is drawn in outline. The angle of the polygon at A is $108^{\circ}$; that at. $\mathrm{B}, 127^{\circ}$. In constructing the work, the two faces of the bastion whose salient is at A, would be determined by using perpendiculars $\frac{1}{5}$ th of their respective exterior sides, ${ }^{*}$ because, if longer perpendienlars were Yused, the flanked angle at A would become too small; but to trace the two faces of the bastion whose salient is ——" at B, perpendiculars $\frac{1}{6}$ th of their
 respective exterior sides can be used, and large flanks thereby obtained. Hence two perpendiculars are required to each front, whenerer the angles of the polygon at either end differ from one another, as much as do the angles of a regular square $\left(90^{\circ}\right)$, pentagon $\left(108^{\circ}\right)$, or hexagon $\left(120^{\circ}\right)$.

Fig. 206 shows the advantage of having large angles to polygons, and therefore (indireetly) of large works in general, for the flanked angle at B is larger than that at $A$; and in addition to this, the flanks which flank it are larger than those defending the faces of the angle at A.

Figs. 204 and 207 both show in detail a method of obtaining an increased length of flank without ultering the general trace of the work. The original flank, $c a_{\text {, }}$ in the upper front (Fig. 207), is carried inwarde,

[^6]so that the extra length $a b$ forms an angle of $95^{\circ}$ with the line $b c$, which is drawn from the point $c$ in advance of the counterscarp at the capital, just clear of the parapet at the shoulder angle. The brisure ( $b d$ ) of the curtain should be drawn at an angle of $95^{\circ}$ with $b e$, which is the general direction of the flank, as improved. The escarp and ditch are not altered by this arrangement, but merely the parapet: no dead angles are formed, which is frequently the case in forming brisures.

All the above mentioned points are shown in Fig. 207, which is the plan of a square bastioned fort, having exterior sides 120 yards in length, and provided with a blockhouse as a reduit.
223. Demi-bastioned Forts (Fig. 208) are traced similarly to those with bastions, but only one flank is used to each front, its line of defence being an unbroken line of parapet, as seen in Fig. 208.

This trace is defective, inasmuch as each angle of defence is dead, and the face of each demibastion receives only very oblique defence from the long face of the same front. Against these defects the slight increase of interior space gained, compared to the bastioned trace, is no advantage, as in these large works the interior space is ample for every requirement; therefore complete works on this trace are not usually recommended.

Fig. 208.

$$
x
$$

$$
0
$$



There are many positions, however, where the trace can be partially resorted to: for instance, suppose in Fig. 209 A B and B C are two exterior sides of a fort, and the angle at B was from any cause safe from attack; then the demi-bastioned trace would be suitable for these two fronts, but not necessarily for any other fronts of the fort. But if the angle at B were liable to attack, the demi-bastioned trace would not be suitable, as the angle at B would be unflanked. In the case of the work shown in Fig. 210, as covering the bridge D from attack, the demi-bastioned trace might be resorted to, in the manner shown; the flanks being traced so as to flank the angle $B$, and cross their fire on the ground in its front, where it is most required.
224. A Redurt is a work constructed within another, or it is some portion of a work separated from the rest, with the object of prolonging the defence, after the main work shall have been forced.

A room may be used as the reduit of a house; a redoubt, of a fort; and even in a redoubt a reduit may be made, in the shape of a small blockhouse. When a village is intrenched, some large building, sueh as a church or jail, is selected to act as a reduit.

The trace of a rednit constructed inside a work depends on that of the main work; it should be traced so as to be able to fire into those parts of the muin work where an enemy is most likely to penetrate. These are generally the salients, to each of which there should be one face of the reduit opposed, as in Fig. 206, which shows a fort of an ivregalar trace, provided with a reduit in the shape of a redonbt, each face of which fires towards a salient of the fort.

When a redoubt is used as a reduit, it should have a command of 5 feet over every part of the main work, in order that the enemy, when he has gained the parapet of the maia work, may not be able to fire into the reduit. This will lead to the absolute command of the reduit being very great, at least 19 or 14 ; and, in order to save interior space in the fort, the exterior slopes of the reduit may be reveted. Frequently the work may be constructed withont a ditch, the earth to form it being procured by sinking the terreplein of the main worle, or from its ditch. Obstacles should in this case be arranged along the face and foot of the exterior slope of the reduit.

Blockhouses, or other covered trorks, are suitable for reduits to works, as it is not necessary to give them the excessive command required for earthen works, when so used, mentioned in the lust paragraph; indeed, their floors may frequently be sunk sufficiently to hide them from external view, a great advantage considering the accuracy of fire of the artillery of the present day,* They occupy, comparatively, very little interior space, and they form barracks for a part of the garrison.

Existing buildings, as windmills, \&e., if of good masonry, may frequently be in positions suitable to act as reduits to works thrown up around them.

Fig. 211.


Portions of a work may in many cases be selected to act as a reduit. Fig. 211 represents a large work, that formed part of the Lines of Torres Vedras, having three separate portions isolated from the main work, by parapets and ditches, so as to allow of a protracted defence, in case the main work had been penetrated.

[^7]
## CHAPTER V.

## DETAILS OF VARIOUS KINDS.

Embrasures : different linds of; their construction, advantages, and defects, Barbeiters; their object and nature; construction for one or more guns, at an angle or on a face; advantages and defects. Bonnetres. Traveeses: splinter-proof; to cover the entrance into a work; to arrest enfilade fire, also reverse fire. Powder Magazines. Platforms. Barrier Gates. BRIDGES over the ditches of field works.
225. The works of defence hitherto treated of have been supposed to be constructed for musketry defence only, and therefore provided merely with a banquette for infantry.

Artillery, however, are frequently used in Field Works; but as has been mentioned, more usually for offensive purposes, than for the immediate defence of the work itself.

Artillery are fired from behind a parapet in two different ways,-viz., either through openings made in the parapet, termed Embrasures, or over the parapet by means of Barbettes.
226. The various kinds of embrasures are fully shown in the Figs. 212, 218, 214, 215 ; they are numbered 1, 2, 8, 4, and 5, in Fig. 218.

An embrasure is termed direct, when its centre line, or line of fire, is perpendicular to the line of parapet, as in Nos. 1, 2, and 3, Fig. 213; and it is termed
 oblique, when the line of fire is inclined to the line of parapet, as in Nos. 4 and 5.

Fig. 213.


Fig. 215.-Exterior elevation.


The following names are given to the various parts of embrasures :-
The Sole (No. 4, Fig. 213) is the bottom surface, and is that over which the gun fires.
The Cheeks are the sides.

The Sill is the line of intersection of the sole with the interior slope of the parapet.
The Genoullire is that portion of the interior slope of the parapet between the sill and the Lerreplein of the work, which Iatier in a Field Work is usually the ground level. The height of the genouillere depends on the nature of the gum-carriage used.

The Nock is the small inner opening of the embrasure.
The Mouth is the wide external opening.
The splay is the widening outwards, or the inclination of the sheeks to each other.
A Mertan is the partion of parapet above the level of the sole, which is between two adjacent embrasures.

The follaring details of construation are those in general use, when the lateral range requirer of the gun is limited.

The sill is made $3{ }^{5}$ above the terreplein (or surface of platform, if one be used), when the gun is momnted on a field carriage (see No. 1, Fig. 213). The sole slopes down to the front sufficiently merely to drain it, unless the gun is required to fire at a depression, when the slope of the sole should be parallel to the line of greatest depression. The sill is made $3^{*}$ wide; one foot being set off on eaeh side of the line of five to mack that width, which is increased to a width of $9^{\prime}$ at a distance of 's' in front of the sill, where bases of $1 \frac{1}{\frac{1}{3}}$ are set off on each side of the line of fire. The bounding lines of the sole are fixed by, and pass through, the points thus obtained; which in an actual construction are marked out, as soon as the parapet has been raised up to the level of the sole.

When howitzers are used, the widths of the sole at the parts just named are increased $6^{\prime \prime}$ on each side, or $1^{\prime}$ altogether; i.e. the sills of howitzer embrasures are $3^{\prime}$ wide, and at a distance of '5 from the sill, the width of the sole is made 4', as in No. 3. This increase to the width of howitzer embrasures is rendered necessary by the shortness of the piece, which prevents its muzzle entering the embrasure and renders the effect of its fire an the cheeks very violent.

The cheeks of an embrasure are built at a varying slope; at the neek they are made very steep, about $\frac{48}{\tau}$, in order to give as much cover as possible to the gun detachment. The base of the slope of the cheek increases regularly towards the exterior crest of the parapet, at which point the slope of the cheek is made $\frac{4}{\top}$ for field guns, and + for heavy guns.

This alteration of the slope of the cheeks from the steep one at the neck to the more gentle one in front, is necessary to afford veat to the explosion of the charge in the gun, which would otherwise blow down the cheeks. In No. 2, the revetments of the cheeks are shown; it will be observed that the gabions successively in advance of the neck are laid with greater bases, or incline more and more out of the perpendienlar.

In order to protect the revetments of the cheeks from the flame of the explosion of the gan, the materials to be protected are covered with raw hides firmly secured to them. When brushwood gabions are used, it is a good precaution to wrap each separate gabion in a raw hide before building it in the revetment.
227. Direct embrasures should be used in preference to oblique ones, as the latter not only weaken the parapet more than the others, but they prevent the muzzle of the gun, when run up for firing, from entering the neck, as only one wheel of the gun-carriage would touch the interior slope. This is so great a defect that it is desirable, whenever oblique embrasures are necessary, to indent the interior slope of the parapet of each gum portion, as in Fig. 213, No. 5, making it perpendicalar to the line of fire.

Field guns require 5 yards of parapet each, in order to allow room for their proper working ; consequently, when guns are placed as close together as possible in a work, their embrasures shonld have central intervals of 15 feet.

When guns are used singly, they will require a width of terreplein of $7 \frac{1}{8}$ feet on each side of their lines of fire. The banquetie for the infantry should be terminated (as shown on the left of No. 1, Fig. 218, and also in Fig. 220) in directions parallel to the opposite cheeks of the embrasures, in order to allow proper room for working the gun, if the latter be fired in a line parallel to the cheeks, which in extreme cases may be necessary. The terminating slope of the banquette shonld be reveted to prevent loss of banquette. It is drawn at a slope of + in Fig. 218,

Whenever guns are used behind parapets, it is usual to fasten a beam of wood, or a fascine,
so as to catch the wheels, when running up the gun for fring, just before they touch the interion slope. This beam is called a Hurter.
228. Guns on field carriages, and also on siege or travelling carriages, fire over a height of $3 \frac{1}{v}$ feet above the ground on which they rest; while those mounted on garrison carriages fire over a height of only $2 \frac{1}{4}$ feet. When embrasures are constructed for these latter, the sill is not made 21 feet above the level of the ground, but is usually fixed at the same height above the ground, as for a gun on a travelling carriage, viz. $3 \frac{1}{z}$ feet, and the terreplein in rear of the embrasure is then raised up to within $2 \frac{1}{4}$ feet of the sole.

This is necessary to avoid having a cheek to the embrasure higher than $4^{\prime}$ or $4 \frac{1^{\prime}}{2}$. If this height be exceeded, it becomes extremely difficult to give sufficient support to the eheek. For this reason it will become necessary, when embrasures are made in parapets having a greater command than $8^{\prime}$, to fix the sill $4^{\prime}$ or $4 \frac{1^{\prime}}{2}$ under the crest, and to raise the terreplein behind to within $2 \frac{1}{4}$ or $3 \frac{1^{\prime}}{2}$ of the sill, according to the nature of the gun-carriage used.
229. The embrasures just described, the soles of which slope down to the front, whether direct or oblique, are termed Sloping embrasures; but when guns are required to fire always with an elevation, as in ricochet firing, the sole slopes up to the front, and the parapet thereby is less weakened and the interior of the work less exposed. An embrasure of this construction (No. 3, Fig. 213) is termed Countersloping.

A countersloping embrasure evidently has the defect of preventing the ground in front of the work being exposed to the fire of the gun. The embrasures shown in Fig. 213 would be thus designated-

> Nos. 1 and 2. Direct sloping embrasures for guns.
> No. 3. Direct countersloping embrasure for a howitzer.

Nos. 4,5 . Oblique sloping embrasures for guns.
230. Embrasures in general have the defects of weakening the parapet, and of limiting the lateral range of the guns; they also act as funnels for the passage of projectiles, and expose the interior of the work to a certain extent; but they give better cover to the gunners than barbettes.

They are applicable in cases where the guns are required for a specific object, such as enfilading a road, pass, bridge, \&c., or for flanking ditches, where only a limited lateral range is required, and where protection to the gunners is a more important consideration than a wide range.

When musketry fire is much to be feared, the necks of embrasures are closed by means of Mantlets, a species of shutter made musket proof, which hang to, and swing on, a bar of wood or iron rod laid across the top of the embrasure.
231. A Barbette is a raised platform of earth, sufficiently high to allow a gun being worked on its upper surface or terreplein, and fired over the erest of the parapet. The gun is then said to be fired "en barbette."

Barbettes may be made for any number of guns, and may be constructed either behind the face of a work, or at the salients. The salients are the most usual position for barbettes, as from them a wide lateral range is secured, and a better view of the surrounding country is obtained than from the re-entering parts, more especially when works occupy rising ground.

The terreplein of a barbette for a single gun should be 15 broad and 20 feet long, when ordinary field guns are used. These dimensions may be increased, if guns of position are used, to 18 feet broad and 24 feet long. In all cases the terreplein of a barbette should be level; for, if given a slope to check the recoil of the gun, the gunners would be too much exposed. As a field gun fires over a height of $8 \frac{1}{2}$, the terreplein of a barbette for field artillery should be $3 \frac{1}{2}$ feet below the crest of the parapet.
282. Figs. 216, 217, show a profile and a plan of a barbette for one gun, behind a straight line of parapet; the slopes of its sides and end being drawn at $45^{\circ}$ or $\frac{1}{1}$ : the parapet is $7 \frac{1}{2}$ feet in height, with its interior slope at $\frac{4}{1}$. In drawing the barbette, the front line of the terreplein $a b$ is made parallel to the crest, and distant from it $\frac{3 \frac{1}{3}}{3}=1^{\prime} \mathbb{Q}^{\prime \prime}$, and is 15 feet in length. $c d$ is drawn parallel to $a b$, and 20 feet distant; $a c$ and $b d$ being drawn perpendicular to $a b$, complete the rectangle forming the upper surface, or terreplein of the barbette. To draw the plan of the slopes, $e f$ and $m n$ are made parallel to the sides and one foot from them, as the terreplein of the
barbette is $4 \frac{1}{2}-3 \frac{1}{2}=1$ foot above the banquette; for a similar reason, as the terreplein of the barbette is in this case 4 feet above the ground, $g h, h k$, and $k l$, are each drawn parallel to the lines $a c, c d$, and $d b$, and 4 feet from them.
833. A Ramp, or inclined road, is necessary with a barbette to take the gun up or down. Its breadth for a field gun should not be less than $8^{\prime}$; its slope may vary from $\frac{1}{4}$ to $\frac{1}{4}$; but when great heights are to be ascended, and heary guns to be moved up-as is the case in fortresses-ramps require a gentler slope than the above, and are given a slope of $\frac{1}{10}$ or $\frac{1}{12}$.

Fia. 217.-Scale $\frac{1}{2 \pi}$


The ramp shown in Fig. 217 is 8 feet broad ; it slopes 1 in 6, and its sides are drawn at $45^{\circ}$. To draw it the lines $o q$ and $p r$ are drawn 8 feet apart ; its length $o q$ will be $4^{\prime} \times 6=24^{\prime}$ : therefore $q r$ is 24 feet distant from op. The plan of the sides is obtained thus : set off $o s=4^{\prime}$ (the height of point $o$ above the ground); join $q s$ to obtain $q v$, which fixes the point $v$; then join $v o$. Repeat this operation on the other side to obtain the lines $r w$ and $w p$.
234. When a barbette is constructed on a face which is exposed to enfilade fire, it should be protected on its exposed side by a traverse of the proper thickness and height above the terreplein, and the ramp may then with advantage be placed on the side of the barbette for security from the enfilade fire. Fig. 218 shows in plan a barbette and traverse thus constructed: the slope of the side of the traverse that is exposed to fire is drawn at $\frac{1}{1}$; the other slopes of the traverse at $\frac{s}{1}$, in order to save interior space. The slopes of the sides of the barbette and of the ramp are all made $\frac{1}{+}$ in the illustration.
235. A barbette for one gun at a salient (Fig. 220) may be thus drawn, it being assumed that the gun is required to fire both on the capital and over either face. The salient is made with a pan coupe, the foot of the interior slope of which, $a b$, is made 9 ft . long; parallel to $a b$ and 20 feet distant, draw $c d$, also 9 ft , long; from the points $c$ and $d$, draw $c e$ and $d f$ perpendicular to the faces (if the barbette be situated in an obtuse angle, but if the angle be acute, draw ce and
$d f$ parallel to the opposite faces) to complete the terreplein of the barbette. The slopes of the sides and ends are then drawn as before described.

The ramp is here shown on the capital, but, if required, it might be placed at a side, for greater security from fire.
236. When more than one gun is placed en barbette, each gun should have on the terreplein a separate space $15^{\prime}$ broad and 20 feet long, for purposes of manceuvring; and in addition to this space, a breadth of 4 feet in rear and at the sides should be provided for communication. The triangular spaces between these rectangles are useful to pile shot in. Two ramps should be provided to such a barbette battery.

Fig. 221 is an example; it shows a barbette battery for 3 guns at a salient, constructed in accordance with the above data. The dotted rectangles do not represent gun platforms, but merely the space required for working each gun. 237. Barbettes have the advantage of affording a wide lateral range, while they do not weaken a parapet, as is the case with embrasures ; but they expose the gun detachments very much. They are therefore employed in cases when a wide range is required, and the objects to be fired at are at some considerable distance; such, for instance, as to keep reconnoitring parties of the enemy at a distance, to cross fire on the salients of collateral works, \&c.; but they are not suitable for positions where a close musketry fire has to be sustained, as they would then, in all probability, be quickly silenced. It is not to be understood, however, that they should never be used in such positions, as owing to the facility with which guns can be worked on a barbette, compared with embrasures, a few rounds of case shot conld be quickly delivered, and, in many


Fig. 219.-Section and elevation on A B.


0
instances, a rapid fire of case shot at elose quarters would be a desideratum overbalancing apy considerations of danger or exposure to the gun detachments,

Fro. 221,-Scale air.

238. Cover for musketry fire may be provided with barbettes, by building on the crest of the parapet a thin wall of sandbags, or a line of gabions filled with earth. The joints of the sand bags must not be broken. These can be easily removed when required to allow the muzzle of the gun to pass through; and in case of the work being attacked in the absence of the guns, these sandbags would cover infantry manning the barbette.

Bonnettes may also be used between the guns for the same purpose. A bonnette is merely an increase of height given to the parapet, by prolonging its interior and exterior slopes upwards for 3 or 4 feet: it is, in fact, a sort of traverse built on top of a parapet.
239. Traverses are monnds of earth built in certain positions, as a protection from different kinds of fire. When made only of sufficient thickness to arrest splinters of shells, they are termed Splinter-proof Traverses; and when made as a protection from reverse fire, they are termed Parados.
240. A splinter proof traverse should be 4 feet thick at top, its height not less than 6 feet, and its sides should be revetted in order to save space.

Fig. 222 is a section of one revetted with gabions, and is used between guns in siege batteries. There should be a passage round both ends of these traverses, to enable men to retreat behind them quickly to cover themaselves from shells bursting on either side.

When traverses are exposed to fire, their exposed slopes should not be revetted, and they must be made of the proper thickness at the top, according to the fire to which they may be exposed. They oan frequently be made to serve defensive purposes; whenever such is the case they should be provided with a banquette.
241. A traverse to cover the entrance into a work, mentioned in Art, 212, should be long enough to intercept shot passing in any direction through the entrance. To do this, it is necessary to make it long enough to stop shot entering in the most oblique direction possible, which is when the opposite sides of the entrance are both grazed by the same shot.

The method of drawing the plan of an entrance into a work, and of its covering traverse, will now be described (see Figs. 223, 224). A B on the right is the profile of the parapet, and of the traverse behind it: as each is exposed to the same projectile, the profile is the same, although in this case the banquette for the work is for a donble rank, that for the traverse for a single rank only. The line $a d$, drawn through the profile up to the exterior slope of the traverse, $4 \frac{1}{2}$ feet above and parallel to the ground, represents a line of fire directed through the opening and intercepted by the traverse. The opening $G$ is made 7 feet wide in the clear, in order to admit of the passage of a gun, and the banquette is cut off at an angle $45^{\circ}$ in plan, to enable a
 according to the revetting material available for supporting the sides: in the drawing they are represented as $\frac{3}{4}$, and $e, f_{,} g$, and $h$ in the plan are projections of points corresponding to onethird of the heights of the exterior and interior crests, and banquette respectively from the foot $k, l$ of the slope. The intersections $b, c, d$, of the line of fire $a, b, c, d$, with the exterior and interior slopes of the parapet, and the exterior slope of the traverse, are projected on the plan

Fig. 223.-Scale $\frac{1}{7 \times 0}$.

by the lines $m n, o p, q r$; and it is evident that if the lines of fire $n o, m p$, be drawn, they will represent the most oblique lines which can be directed through the opening; and if they be produced to meet the line $q r$ in $q$ and $r$, and the traverse be made to extend 4 feet at each end beyond $q$ and $r$, every shot that enters the opening will be intercepted by the traverse. The plan represents an opening 7 feet wide in a parapet 12 feet thick; it requires a traverse 50 feet long to cover the opening completely. Every alteration in the thickness of the parapet will affect the length of the traverse $r$; if it be made less than 12 feet, the lines of fire $n o, m p$, will intersect at a greater angle, and the traverse must be made longer; if the thickness be increased, the angle of intersection will be less, and the length of the traverse be diminished. The width of the opening will depend on the object to be attained. If musketry defence only is wanted, a less width of opening will be required for the passage of the troops, and less space between the opening and the traverse.
242. At C, C (Fig. 222), a mode of doing this is shown, the parapet being formed in an angle, and carried in at its full height to the inner edge of the banquette. The same width of opening in a parapet having the same profile as in the preceding case is, in this instance, covered

## Field Fortification.

by a traverse of only 35 feet in length. In the drawing of this opening the points $m^{\prime}, a^{\prime}, n^{\prime}, p^{\prime}$, are obtrined by drawing lines $m^{\prime} \partial^{\prime}, n^{\prime} p^{\prime}$, parallel to the foot of the slopes $k^{\prime} l^{\prime}$, $\delta^{\prime} \ell^{\prime}$, at a distance of $1 \frac{1}{2}$ feet; that being the position where a shot fired $4 \frac{1}{2}$ feet from the ground would just graze the side (at $\frac{2}{3}$ ) of the passage throughout its entire length.

F19, 225.-Scale ${ }^{2}$.

wther slopes at $\frac{1}{\mathrm{~T}}$, in order to save space.
24. Parados, or traverses for protection from reverse fire, when required to cover infantry on the rear or flank banquettes of a work, are necessarily high masses of earth, and involve great labour in their construction, as they must be of sufficient beight to cause shot that may pass over them to clear the heads of men occupying the banquette of the parapets protected. Passages should be made through them for facility of communication, and they afford a secure position for raggazines ou actount of their great thickess at base. They will be more fully mentioned in the chapter on Defilude.
246. Powder Magaznes in Field Works are not often required to be of large dimensions, and when many guns are mounted in a work it is always preferable to have many small magazines mather than one large one, not only on account of the danger caused by the storing, issuing, de., of a large quantity of powder in one place, which, if exploded, would cause great damage, but also because small magazines can be coustructed conveniently near the guns they are to supply.

Magazines in field works therefore come under the designation of Expense Magazines, a term used when the quantity of powder contained is only sufficient for the expenditure that can bo required for one day, a sufficient quautity being in reserve in some secure position to replenish the expense maguzines when required.

The positions for magazines should be such as to be as secure as possible from fire, to be easily drained, and conveniently near to the guns served. There should be an entrance passage leading to the magazine, the body of which should be clear of the prolongation of the passage.


Section and elevation on A B.
Magazines may be formed in a variety of ways, but in general they are of two sorts, either triangular or rectangular in profile.
247. The Triangular, or Lean-to, magazine may be formed by laying stout beams about $6^{\prime \prime} \times 10^{\prime \prime}$ at an angle of $50^{\circ}$, or thereabouts, against the revetted side of a traverse. These beams should be covered with two feet of earth and a tarpaulin laid over all to keep off wet. A floor of planks may be provided if necessary. One end of the magazine should be closed by a sandbag wall, and the other provided with a rough door.

Fig. 228 is a section of such a magazine, which is presumed to be in a position safe from fire.
The facility of construction of this magazine is its great recommendation. Its shrpe in profile is evidently inconvenient for stowage.

Fig. 228.

248. Rectangular Magazines (Figs. 229, 230) are preferable to others on account of their convenient shapes for stowage. Their sides may be lined with planks or with gabions, as seen in Figs. 229, 230, crowned with fascines. The roof should be formed of stout beams 10 " thick, with 5 or 6 feet of earth on the top.

This shape of magazine is that in use in the British service for the batteries constructed at sieges, and is made so as to be able to be transported and put together without any fastenings by

## Field Fortification.

nails, de. Drawings and descriptions of this magazine are given in the chapter on the Attack of Fortresses.

When very small quantities of powder ouly are required, powder boxes or barrels may be buried in the parapets or in any convenient situations, and used as small magarines.
249. Piatrosms may be required for field guns, when they are fired frequently from the same spet, as is the case when they fure through embrasures.

A regular gun platform ennsists of a floor of stout planks resting on beams, termed slecpers, underneath. Such a platform is fully described in the chapter on the Attack of Fortresses ; it is indispensable for the proper working of heary gurs, but would seldom be required for a field gun.

A platform sufficient for most purposes for a field gun may be made, as shown in No. 2, Fig. 213 , with 8 stout planks, one of which is laid for each wheel to recoil along, and the third for the trail. These planks should be laid with a rise to the rear of about half an inch to every foot, to check the recoil of the gun on boing fired, and to facilitate its being run up after being loaded.
250. Barrier Gates are required to elose openings of various kinds in words. If guns or carts ure required to pass, the gates should have a clear width of opening of at least 7 feet. Figs. 931, 232, represent the elevation and plan of such a gate, which is formed of tiro leaves, and is made
 of planks which are musketproof and loopholed. It swings on strong hinges'; and whilst the hook which supports the lower hinge points upwards, that to which the upper is attached points downwards, so as to prevent an enemy from lifting the gate off its linges by crowbars, de. A strong bar of iron secures the gate when closed, and it is further fastened by a strong bolt at the bottom.

Such a gate when closing an entrance into a work, if not exposed to artillery, would supersede the necessity of an eartheu traverse inside, and would therefore save interion space.

These gates should open

 of the same length as the clear width of the opening, secured at each end by chains to posts; so that it can be moved away when required. It may also be made to swing open on one end as a centre, the other running on a small wheel, as shown in Chapter II,, Figs. 125, 120.
252. When a gate is required for the passage of infantry only, its width may be reduced to 4 feet. Fig, 283 is an example of such a gate made through a line of palisudes; it is composed of a single leaf formed of 5 palisades, and turning on a central pivot; it might also be rade to open on hinges at either side.
253. Brimges over the ditches of Field Works are requived whenever an entrance opening is provided; they are usually
made of sufficient width and strength to allow of the passage of field artillery into, or out of, the work.


Fig. 236.


Such a bridge (Figs. 234, 235, 236) has its roadway of planks, $a, 2^{\prime \prime}$ in thickness, resting on strong beams, $b$, termed baulhs, which themselves rest on the escarp and counterscarp of the ditch. The baulks are $5^{\prime \prime}$ or $6^{\prime \prime}$ broad and $8^{\prime \prime}$ or $10^{\prime \prime}$ deep. A small beam of wood termed a ribland, $c c$, $4^{\prime \prime}$ square, is laid along each side of the bridge, and is secured firmly to the baulks underneath, thereby keeping the planks fixed firmly. The ribband in a bridge has the twofold object of securing the planks of the roadway, and also of preventing the wheels of gun carriages or carts slipping over the side of the bridge. The width of roadway inside the ribbands should be 7 feet, if guns are required to cross.

The ribbands should be secured to the baulks by racklashings, at intervals of about 6 feet.
A rackstick and lashing consists of a wooden pointed stick $11^{\prime \prime}$ or $2^{\prime}$ long, to which is secured about $7^{\prime}$ of rope. To use it, the end of the rope is passed through an opening in the planks (made for the purpose) brought round the baulk and ribband, and then formed loosely into a loop, as shown in Fig. 237. The point of the stiek is then inserted into the loop, which is then twisted round
by means of the stick used as a lever, as tightly as possible, after which the point of the stick is jammed betiveen the rope and the ribband. By menns of this simple and ingenious method, great rigidity is obtained. The fastenings can be quickly made and unfastened, without damaging the timber, as would be the case were nails or sorews used.

In ditches wider than $19^{\prime}$ the baulks of bridges should be supported midway, by a trestle resting on the bottom of the ditch, as shown in Fig. 234, which represents a bridge made over a ditch 16 feet in breadth.

## CHAPTER VI.

## DEFLIADE.

Object of defiladi; to deformine commond of a line of parupot; to defilade an open work fiom one or more Mills; use of pavados in open vorls ; to defitade ac elosed work, completely or partially; construction of parados; defilade of lines.
254. Defmading (Defilade) has for its object the determination of the heights to which the different covering masses of works must be raised, in order to give proper cover to the defenders behind them.

A command of $8^{\prime}$ has been bitherto assumed as the least required for a work on a level site, for the reasons stated in Art. 122, where the reader was referred to the present chapter for a description of the method by which the commands of works may be practically determined.

The most simple case of defilade will be first treated of, before passing to the more complicated ones.
255. Suppose a line of parapet has to be constructed at P, Fig. 238, commanded in front by


Fir. 239.-Scale $\frac{1}{304}$

the height $H$, and that cover in rear is required as far as R . If the parapet be constructed with its crest C in an imaginary plane passing $8^{\prime}$ above the ground at R , and $4 \frac{1}{2}$ feet above the most commanding* point of H, as shown in Fig. 238, then cover in rear will be afforded to the same extent that a command of $8^{\prime}$ would afford on a level site, but only for the distance in rear P R : in fact, the parapet would be said to defilade the ground in rear to a height of $8^{\prime}$ as far as $R$.

On a level site a parapet 8 feet in height not only protects the ground immediately in rear from fire passing over it, but it has the further advantage of screening the whole of the ground in rear from the view of an enemy, thereby concealing from him any movements of troops in rear of the work. This latter advantage is more fully obtained when works occupy commanding positions, but it cannot be obtained completely when works are thrown up on unfavourable sites, unless an excessive command is given to them.

The imaginary plane before mentioned, passing through C, which is termed the Plane of Defilade, passes $4 \frac{1}{2}$ feet above the commanding ground, because that is the greatest height from

[^8]which an enemy can fire (whether artillery or infantry*) without constructing parapets, to fire over.

The Plane of Site is an imaginary plane, passing $8^{\prime}$ under, and parallel to, the Plane of Defilade.
256. To determine practically the command P C, an imaginary plane (Fig. 239) is assumed, tangent to the height and parallel to the plane of defilade, and therefore $4 \frac{1}{2}$ feet under it ; this plaue is distinguished as the Tangent Plune, and would evidently pass $4 \frac{1}{9}$ feet under the crest of the parapet, and $3 \frac{1}{2}$ feet above the ground at R : therefore, to find the command practically, the following rule is given.

Look from a point $3 \frac{1}{\frac{1}{2}}$ feet above the ground at $R$, in a line to the most commanding point that can be occupied by an enemy; observe the intersection $a$ of this line with a vertical pole planted at P ; measure $a \mathrm{P}$, and make the command equal to $a \mathrm{P}+4 \frac{1}{2}$ feet.

The tangent plane is used in practically observing on the ground, merely because it is convenient, for it passes $3 \frac{1}{2}$ feet above the ground to be protected, which is a convenient height for observing from, and it is tangent to the commanding ground, which is easily seen. For purposes of calculation, the plane of defilade would be more convenient to work with.

The command requisite for a parapet will necessarily depend on the height of the hill, its distance from the work, and the distance in rear PR to which cover is required,
257. The same amount of cover as is shown in the preceding figures may be obtained by making the parapet of any determined height, and then by excavating the ground in rear, so as to make it $8^{\prime}$ under the Plane of Defilade passing through the crest of the work (Fig. 240).

Fra. 240.-Scale $\frac{1}{300 .}$.


This method of lowering the terreplein may be frequently resorted to in closed works, with great advantage.

An inspection of the last figure will show that, if a site can be selected for a work, the plane of which, when produced, either touches, or passes over, the most commanding ground in front, then no increase of command is required for the parapets, which would be as favourably sitnated as if the whole ground were level. This is illustrated in Fig. 241, where the ground line PR passes, when produced, above the top of the height $H$ : evidently a command of $8^{1}$ at $\mathbf{P}$ would cover from fire, and hide from view, the ground in rear, as well as it would do on a level site, When works are necessarily constructed facing high ground, a site such as is shown in Fig. 241, having a fall to the rear, should be carefully sought after.

$$
\text { Fic. 241,-Seale } \frac{1}{300}
$$


258. The planes of defilade need not necessarily pass 8 ' above the ground to be protected from fire; but that height is usually taken as affording sufficient cover for ordinary cases, in the same way that a parapet with a command of $8^{\prime}$ does on a level site.

If necessary, in order to afford more cover, the planes of defilade may be made to pass 9 feet, 10 feet, or even at a greater height, above the ground in rear, just as on a level site works may be, and frequently have been, constructed with a greater command than usual.

* The fire of cavalry need not be taken into consideration, although they fire from a height of about $7 y^{\prime}$ above ground.

The least height at which the planes of defllade should pass above the ground, when the terreplein is not sunk, is $6 \frac{1}{2}$ feet, as that is sufficient only to screen the defenders from view.
259. An open work, such as a redan or lunette, should be defiladed as far as the gorge line, where practicable. If a redan is commanded by one hill in front of its salient, its interior would be defiladed by making the crests of its faces in a plane of defilade passing $8^{\prime}$ above its gorge, and 4 ' above the commanding ground; in other words, each face must have a command of $8^{\prime}$ at its end nearest to the gorge, and it must increase in command towards the salient, where it would be highest.

Fig. 288 will serve to illustrate this: if P be supposed to be the salient of the redan, and R a point in the line of the gorge, then each face would have at the salient the command $\mathrm{P} C$, and at the other end a command of $8^{\prime}$. The command at only one point would thus have to be found; viz., at the salient.
260. A lonette would be similarly defiladed by constructing the erests of the faces and flanks in a plane of defilade, passing $8^{\prime}$ nbove the gorge, and $4 \frac{1^{\prime}}{}{ }^{\prime}$ above the height in front; but in this case, the command would have to be determined at three points, viz. at the salient, and the two shoulder angles.

To determine this on the gromed, plant poles, P P , at the angles of the work, and stretch a cord (Fig. 242) $3 \frac{1}{2}$ above the ground at the gorge, and therefore in the tangent plane; then hold a straight edge, $s$, steadied against one or two pickets in rear, and move it about until its edge is in the tangent plane, which will be when it is in the plane passing through the top of the hill and the cord.

By this means two lines will be found, both of which are in the tangent plane: these are the cord and the straight edge; then by observing the intersections of this plane with the poles at the salient and the shoulders, points will be determined $4 \frac{1^{\prime}}{}{ }^{\prime}$ under the crest of the work at those angles.

This is illustrated in Fig. 242, where the lunette is supposed to be defiladed from the single bill, H.

261. When an open work has to be defiladed from two hills (or from a range of hills), the tangent plane being tangent to the tops of two hills cannot contain a horizontal line at the gorge, but only a point, which should be near that end of the gorge on the side of the lower of the tivo hills. In Fig. 244 the lunette is to be defiladed from the two hills $H$ and $\mathrm{H}^{\prime}$, the latter being supposed the lower of the two. A stake is fastened in the line of the gorge, $8 \frac{1}{9}$ ' in height: the top of this stake is a point in the tangent plane. The tangent plane is obtained practically by having a straight edge, $8 s$, moved about, until its edge appears tangent to both hills, when viewed from the top of the stake; and to the heights obtained by it, on the poles at the angles of the works, $4 \frac{1}{2}$ feet must be added, as before, to obtain the command at those angles.

The position of the straight edge, with reference to the stake in the gorge line, should be selected so that, when looking from the latter, the observer can see both the hills and also the poles at the angles of the work over the straight edge.
262. This method of defilading by means of a single plane of defilade will frequently necessitate too great a command, in which case the left part of the work should be defiladed from the left hill, and the right part from the right hill, by which means a lower command will suffice. But by so doing the parapets become exposed to reverse fire from the heights; i.e, the left face and flank become exposed to fire from the right hill, passing over the right face, and vice versáa; and it beeomes necessary to protect them from such fire, by means of a parados (Art. 215), which would be usually constructed as shown in Fig. 245, on the capital of the work. The length of the parados should at least be what is shown at $a$ in Fig. 245, as there it is only long enough to protect the flanks from reverse fire, but it is not long enough to cover the whole of the interior of the work from reverse fire from the heights.

$$
\text { Fig. } 245 .
$$



The method of determining the command of a parados is explained in Art. 265.
In Fig. 245, both flanks, and in Fig. 244 the right flank only, are exposed to enfilade from the hills, and should be protected by traverses at the shoulders from such fire, as is shown in both figures. In Fig. 245, the flanks would not require an increased command, but only the faces, in order to defilade the interiwr of the work from the hills; the faces would, in that case, serve as traverses to protect the flanks from enfilade, and especially so if bonnettes (Art. 238) were constructed at the shoulders.

The foregoing descriptions are sufficient to illustrate how open works can be defiladed from commanding heights, and they may serve to show the great defect of constructing works in positions commanded by hills within effective range, as not only do the parapets require a greatly increased command, but the parados that may be necessary to construct are enormous masses of earth.
263. The great increase of labour required for the construction of high parapets, compared with those having the ordinary commands, will be evident, when it is considered that a parapet 12 feet in thickness at the top, and having a command of 8 feet, with the usual slopes, has an area
in profile of 137 square feet; whereas, if the command be increased to 12 feet, the thickness and slopes being retained, the area in profile is incrensed to 288 square feet, or more than doubled.

26s. A closed work commanded by one or more heights can be completely defiladed only by means of a parados constructed across its terreplem, the parados being high enough to cover the defenders of the parapets from reverse fire.

No fixed position can be assigned for a parados, but it would usually be most convenient to construct it in the middle of the work; its divection should be, as nearly us possible, perpendicular to the line of fire from the commanding ground.

Having selected the position of a parados, the command of each of the different faces must then be determined, 80 as to give cover to the interior of the work, between themselues and the parados, from direct fire. As soon as these commands are determined, but not before, the height of the parados can be found.

In Fig. 246 is shown a rectangular redoubt, commanded by the hill H, opposite a face A B. The parados E F here would run parallel to the

Fioc: 24t.
 faces of the work A B and CD.

The faces AC and BD would be made shorter than the others, in order to lessen the distance to which cover is to be afforded from the hill. These faces may also be traced, as shown by the dotted lines AX and B Y , to prevent their being enfiladed from the hill.*

The parapet A B must have a command sufficient to defilade the ground inside, between itself and the parados from the hill H: this will be done by making its plane of defilade pass $8^{\circ}$ above the ground at the site of the parados, as shown in the section (Fig. 247). In the present case, where only one isolated hill is considered, the remaining faces would be given the ordinary command for level ground ( $8^{\prime}$ ) throughout. But if instead of one isolated hill, a range of hills rau facing the redoubt, it would be necessary to construct the crests of the faces AE and BE in the plane of defilade of the front parapet ; i.e., they would have a command of $8^{\prime}$ at E and F , and at their other ends $A$ and $B$ they would have the same command as the face AB.
265. Having thus determined the commands of the different lines of parapet, that of the parados can be found. The parados has two perfectly distinct functions to fulfil. In Fig. 246 it has to be sufficiently high to protect infantry maming the parapet CD from reverse fire from the hill, and at the same time it must be high enough to protect the defenders manning AB from reverse fire from the ground opposite the

$$
\text { Fic. } 247 \text {, - Scale } \frac{1}{\text { fint }}
$$



[^9]hill. The height sufficient for each of these separate conditions being found, the greater height of the two would of course fulfil both.
$$
\text { Fig. 248.-Scale } \frac{1}{480^{*}}
$$


This is illustrated in Fig. 248, in section, where the front and rear parapets are shown with the command assumed to be already fixed. The planes of defilade of the parados pass $8^{\prime}$ above the respective banquettes, thereby covering the defenders on those banquettes from reverse fire.

The height of the parados being thus fixed, its thickness at the top, and the slopes to be given to its sides, would give its breadth on the ground. An idea of the great labour required for the eonstruction of such works will be formed when it is considered that a parados 15 feet in height, and 10 feet thick at top, with its sides revetted at a slope of $\frac{s}{1}$, has an area in profile of 225 square feet. Material to revet such a height would seldom be obtainable; if not, the sides of the parados would be built with a slope of $\frac{1}{1}$, thereby diminishing the interior space in the work, and increasing the labour, as the parados would have an area in profile of 375 square feet.

A parados is not made entirely across a work, but passages are left between its ends and the parapets, as in Figs. 243, 246, 249: the communication round these passages is covered by short traverses, which are connected with the parapets. Covered passages would also be made through the parados, for purposes of communication from one part of the work to another. Magazines may also be placed underneath the parados, which in certain eases may afford cover to "blindages" for the protection of part of the garrison.
266. A redoubt traced as shown in Fig. 249, with a salient pointing to the hill, should have the parados A B on the diagonal of the work. The faces A G and G B should have the same command as if they formed a redan whose gorge was at AB. The other faces AL and L B would have a command of $8^{\prime}$ throughout.

The parados in this case would be higher at the midale than at the ends, for in the middle $\mathbb{K}$ its height must be sufficient to defilade to the distance K L from
 reverse fire from the hill; and also to protect men on the banquette at $G$, the highest part of the work, from reverse fire from the plain ; while at its ends, the parapets to be protected by it from reverse fire are much closer to it, and its height may be lessened accordingly torvards the ends.
267. In the preceding descriptions, it has been assumed, in defilading closed works, that it is necessary to provide cover from fire (direct or reverse) equally in every direction. Such, however, would seldom or never be actually the case, for Field Works of every description are usually supported on either side by other works, and in the rear by works or troops; consequently, it is fire from the front which in most cases has to be guarded against in determining the commands of the different parts.

Athough protection from reverse fire in every direction oannot be attained without resorting to the construction of a parados, yet, if the main consideration in fixing the command of a worls is to afford protection to its interior from five (whether of artillery or musketry) from the front, most pratical requirements oan be fulfilled withont resorting to the construction of $a$ parados. For instance, if in Fig. 250, R shows the position of the vear parapet of a redoubt, F that of its front pirapet, and H a commanding hill in front, which can be occupied by an enemy, then most of the requirements of the work will be met by making the front parapet F high enough to conceal the rear parapet R from view from the hill; and that may be done by making the plane of defilade of F pass either throngh the crest of R ( n s shown in the figure), of one or two feet above it: the command of R should be made as small as possible. In Fig. 250, $R$ is constructed with the command of only s feet, and cover is obtained by means of a trench in rear, and by lowering the terreplein of the work pavallel to and 8 feet under the plane of defilade of the front parapet, as shown by the dotted lines; consequently, every part of the interior would be properly protected from fire from the hill II in front.

Fto. 250.-Scule in.


This instance is given as illustrating a confessedly imperfect case of defilade, but still one which would fulfil most requirements of cover without necessitating a great expenditure of labour.

In constructing Field Works, the chief conoideration is not always to determine what is most desirable, but generally what is most practicable under the circumstances; and however desirable efticient parados may be, in many cases they would be dispensed with as involving too much labour in their constraction.
268. Deplade of Lines. - In defilading lines of intrenchment, the same rules before given will apply, but will require modification according to circumstances. The object sought for, that of providing cover in rear of the works, will be attained by increased commands to the parapets, by traverses or bonnettes, by siuking the terrepleins of worles, where such cover is not provided by the shape of the ground, In some cases cover from view will be the main requirement, to enable troops to manceuvre for defensive purposes, unseen by an enemy; in others, protection from fire will be required for troops posted in reserve, and for this latter purpose trenches similar to siege parallels are perhaps the most suitable form of work, as infantry in them can move at once direct to the front, and cavalry and artillery by means of ramps and openings made for the purpose, while they require comparatively little labour for their formation.
269. It may be here remarked that the amount of cover required in the rear of any work depends very much on the object for which the work is constructed. When the work is required to be held against assault, preceded in all probability by a violent cannonade, then too much cover inside can hardly be provided. Such is the case in redoubts and forts, and in most separate works; but when the chief object of the cover provided is to afford merely a screened communication for troops, then to be hidden from the view of the enemy is the main consideration, and cover may be provided only to a height of $6 \frac{1}{3}$ or $7^{\prime}$. Experience has shown that almost perfect security is attained with such communication, even when the covering parapets are not shot-proof, provided that the line of work has not to be kept constantly manned for defence at every part. This is the case with parallels used in sieges, which are never made shot-proof; and although large bodies of troops have to be lept in them, very ferv casualties are experienced, arising from the thinness of their parapets.

A remarkable instance of the security afforded to a communication which is concealed from hostile view, without any other protection, is afforded by an ineident which occurred at the defence of Badajoz by the French in 1812. The garrisou kept up a communication during daylight with an outwork (Junette St. Roqué), by stretching a line of sheets supported on posts along the exposed portions of the road, The device was perfectly successful, as the British marksmen were
unable to know when anybody was passing in rear of the screen, which served its intended purpose of protecting the communication.

It is also well known to be a nightly occurrence at sieges for troops to be posted with comparative safety close to an enemy, and unprovided with any cover whatever from fire, being merely concealed from view by the darkness.

## CHAPTER VII.

## EXECUTION OF EIELD WORKS,

Determination of the oulline and profile; tracing of the work on the grownd; use of profiles, direct and oblique; distribution of a working party; mode of excavating the ditch; employment of one or two rows of diggers; calcutation of the time required for a work; importance of proper drainage; usual method followed.
270. In the actual construction of Field Works the following operations have to be per-formed:-

1st. The outline of the work has to be determined, with reference to its intended object, the available garrison, and the shape of the ground on which it is to be built; each of these conditions affect either the shape of a work, or its size.

2nd. The shape of the work being decided, the necessary command and thickness of parapet for its faces must then be determined, with reference to the amount of cover required, and the exposure of each face to fire. The front faces of a work, i.e. those facing to the front of the position, will require the thickest parapets, on acconnt of their exposure to cannonade from the front, and, at the same time, their parapets will usually be the lighest ones of the work, in order to cover the interior of the work from fire.

The lateral and rear faces may generally be constructed with less command, and also with thinner parapets than the front faces.

3rd. The shape of the work and its profile throughout being determined, the work can then be traced on the ground.

4 th. The workmen are then told off, and the work executed.
271. In tracing a work on the ground, the angles of the magistral line are marked by driving in stout pickets at the angular points; the lines which join these points give the magistrals of the faces.

Profiles are then erected on the faces to show the workmen the shape of the work they have to construct.

To set up a profile, first trace on the ground a perpendicular to the line of the parapet at the position of the intended profile, and in that perpendicular set up a slip of wood, as at A (Fig. 252), to mark the interior crest, making it of the proper height; at B set up another slip of indefinite length for the exterior crest, nail a slip CD at the crest C, and with a "field level" give it the inclination of the superior slope, and nail it at D ; then place another slip DE at the slope of + for the exterior slope, and nail it to a stout picket driven into the ground at $E$; the other slopes of the parapet are treated in a similar manner, and a correct skeleton of the parapet is thus obtained.

Sometimes the angular points only of the profile are indicated, as shown in Fig. 253, where uprights are erected at the intervals formed by the bases of the slopes of the parapet, and crosspieces are nailed to these uprights to mark the actual angles. This method has the advantage of not impeding the movements of the workmen on the parapet during its construction.

Two profiles at least should be constructed to each line of parapet, and in long faces three, or even a greater number of profiles may be requisite.

In addition to these regular profiles aloug the faces of a work, the intersections of the parapets at the various angles are shown by what are called "oblique profiles," as shown in the plan, Fig. 251.

To set up an oblique profile at an angle of a work, it is first necessary to erect two profiles to each face forming the angle; theu the upright slips may be erected at the angle, at the intersections of the lines joining the corresponding uprights of the profiles. The actual height of the different parts of the oblique profile are, of course, the same as for the corresponding parts of
the regular profiles. In fact, an "oblique profile" shows the section of the parapet on a line bisecting the angle.

The work having been profiled, the ground occupied by the parapet and ditch should be shown by marking the inner and outer lines of the parapet with a pickaxe, and also the top of both escarp and counterscarp, as shown in Fig. 251, which is the trace of three lines of parapets forming a salient and a re-entering angle. Everything is then ready for the execution of the work.
272. For the execution of a work of ordinary profile, three sets of workmen are required, in addition to any men who may be required for purposes of revetting, \&e.; they are, (1) Diggers to excavate the ditoh; (2) Shovellers to pass on the earth supplied by the diggers, and spread it over the whole surface of the parapet; and (3) Rammers, who ram the earth into a firm mass as the work proceeds.

With regard to the diggers, experience shows that (except in one particular case, which will be further alluded to) a single row of diggers in the ditch is all that can be employed with advantage; and that they should not be less than 6 feet apart, as, if placed closer, they incommode each other.

Fio. 251.-Seale $\frac{1}{40}$
DISTPIRITIOS OF A WORKING PAETT.

Fio. 252.-Scale do.

Diggers are, however, sometimes placed as close together as 4 feet, but, in that case, the same amount of work cannot be obtained from each of them, as when they are 6 feet apart, and the risk of accidents is increased. Each digger is provided with a pickaxe and a shovel.

The shovellers should be just in sufficient numbers to be able to pass on the earth as fast as the diggers can supply it. Their actual number will greatly depend on the nature of the soil, as the diggers will supply more earth in favourable than in unfavourable soil. As a general rule 2 shovellers to every 3 diggers is a good proportion. Each shoveller is provided with a shovel only.

One rammer to every 3 diggers is usually sufficient.
This detail of workmen has the advantage of simplicity, as it gives an average of one man to every yard limeal of the work; for 6 men ( 3 diggers, 2 shovellers, and 1 rammer) are required for every 6 yards of work ; and it also allows the diggers, who have the hardest work, to change places
with the shovellers and rammers, who have the lightest work, these latter being together equal to the diggers.

In posting the workmen, the diggers (D D, Fig. 251) are placed along the line of the escarp, 6 feet apart, and facing the work; in exeavating the ditch, they should be made to throw the earth to a distance of at least 12 feet, horizontally, at the commencement of the work. The shovellers (SS, Fig. 251) are placed 12 feet from the diggers, and facing them; the rammers (R R, Fig. 251) should be kept moving over the whole surface of the parapet, as they will thereby consolidate the parapet by treading on it, as well as by regularly ramming it.
278. In digging ditches and trenches having sloping sides, it is a rule to commence them by excavations having vertical sides, the slopes being finished last. By this means the mass of the excavation is done without loss of time. The ditch is usually dug in successive depths of 3 feet, or thereabouts, the sides being left in steps, the base of which depends on the intended slopes of the ditch. Fig. 254 is a sketch showing in profile a work in progress : two depths of 3 feet have been excavated in the ditch, and the third depth is about to be commenced.


Fig. 255.-Scale $\frac{1}{2}$ 识.


After the ditch has been carried down to the full depth, the slopes may be formed by first carefully cutting at intervals small sections, according to the proper form of the finished profile, and then the intermediate earth would be cut away between these small sections, which answer the same purpose of ensuring regularity in an excavation, that wooden profiles erected at intervals do, in the formation of the parapet.

A double row of diggers in a ditch may be used at the beginning of the work when the soil is very difficult, and the width of the ditch at top is not less than 20 feet (Fig. 255). The first row of diggers (marked I in the figure) next the escarp should excavate to a width of 5 . The second or outer row of diggers (marked II in the figure) are placed 12 from the inner row, to excavate a second trench; they pile the earth on the tongue of ground between themselves and the first row of diggers, but special care must be taken to prevent the earth being thrown over the tongue among the first row of men. The depth sunk at first, in this case, should be 5 feet.

This method of employing two lines of diggers in a ditch is the only one employed in the service, and is evidently only applicable in the cases of wide ditches, and then only at the beginning of work; in no case is it recommended to employ a double row of diggers in the same excavation, both rows throwing their earth at the same time on to the parapet, as experience shows that by so doing the first or inner row of diggers are so interfered with by the second or outer row, that their exertions are paralysed, and they become mere shovellers to the outer row, and do no other work.

When parapets are formed, partly from a ditch in front and partly from a trench in rear, as is shown in Fig. 88, a double set of diggers could be used with advantage (one in the ditch and the other in the trench), as neither would interfere with the other, and the work would be executed in a comparatively short time by the combined labour of many men.
274. The time required to throw up a work, with a given distribution of workmen, depends on the dimensions of the profile, and on the nature of the soil. The trace of the work does not materially influence the time required for its construction, provided it be commenced throughout at the same time.

If the workmen are properly proportioned, it will be only requisite to estimate the time required to dig the ditch, as the parapet ought to be built as fast as the ditch is excavated.

In "easy soil," which term implies soil that hardly requires the use of the pickaxe, each
digger pught to excavate 1 cnbic yard of earth for each hour of a day's work, not exceeding 8 hours' daration.

In "diffioult soil," which may be hard gravel or wet clay, one half of that quantity will be a fair task.

On the above supposition, the number of notual working hours required to throw up a field work of hnown profile will be thus found:-Estimate in cubic yards the contents of the length of the ditch oceupied by each digger ( 6 feet usually). In easy soil the number of cubie yards will give the time in hours ; in difficult soil double the time will be wanted.

Estimates of this kind are, of course, approximate, as the soil may vary very much at different depths, und cannot always be determined accurately beforehand: neither can it be expected that the whole of the workmen will prove equally expert.
275. In throwing up works there is always a superabundance of earth at the salient angles, and a deficieney at the re-entering angles, as will be seen from Fig. 256, where the shaded part of the ditch at each angle supplies earth for the shaded part of the parapet. This is an inconvenience which may be partially remedied by making the workmen throw the earth obliquely towards the re-entering angles; and, if necessary, the ditch at the re-entering angles may be enlarged. With every precaution, however, there will be a superfluity of earth at the salients, and, to get rid of it, the surplas is usually spread out to form a small glacis in front.


The importance of draining a work is very great; and great care should be taken to effect this before beginning the work.*

Should the ground fall to the rear of an open work, the only operations necessary would be to form gutters or small trenches to lead the water off in the required direction to the rear; but should the ground rise to the rear, the water must be led to the front, under the parapet, into the ditoh. To effect this drains should be cut under the ground to be covered by the parapet, and filled up with stones and fascines, as in Fig. 258, before the parapet is constructed, so as to let water soak through them. All enclosed works should be thus drained. If bricks, stones, \&e., are available, regular covered draias may be constracted. Where the water is led into the ditch, precautions should be taken to prevent its injuring the slope of the escarp, by prolonging the drain beyond the escarp, and by revetting the latter, and a portion of the bottom of the ditoh, with stones, \&e., as shown in Fig. 257.

[^10]
## CHAPTER VIII.

## LINES OF INTRENCHMENT.

Continuous and Broken Lines: general employment and advantages of Lines; should be supported by manceurring troops. Vauban's Redan Lines. Tenaille Lines. Indented or Crbmatllerep Lines. Bastioned Lines, Lines with Inteevals, when used, advantages; arrangement of a double line of works, either open or closed; single line of works for defence of a position.
276. When several works are combined for the defence of an extended position, they are called Lines, and, as regards their nature, are divided into two groups ; viz, Continuous Lines, so named when they consist of a continuous line of defensive works, and Lines with intervals, or Broken. Lines, when they consist of separate and distinct works, which usually mutually defend one another, but not necessarily so.

When the object of lines is to enclose a space between themselves and a fortified place, such an enclosed space is usually designated an Intrenched Camp; when they are thrown up by an army besieging a fortress, with the view to resist the sorties of the garrison, they are called Lines of Contravallation; when intended to resist the attacks of an army attempting to raise the siege of a place, they are termed Lines of Circumvallation; and when intended simply to allow an inferior army to give battle to an enemy, but without reference to siege operations, they form Intrenched Positions.
277. Lines of intrenchment are useful in defensive operations, provided their extent and requisite garrisons are not disproportionate to the numbers of the defensive army ; in general terms, not more than one-third of a defensive force should be required to garrison works, leaving the remainder free for mancuvring. It must never be lost sight of that Field Works are always, on account of their weak profile, liable to asscult at any point, and that they therefore require the assistance and support of troops encamped in their rear, and favourably posted for the support of the lines in the event of an attack. The advantage of the lines will be to a great extent measured by the freedom of movement they allow to the defensive manceurring force.

In all intrenched positions the works of defence are accessories or aids to the manourres of the defenders, and should never be treated as the principals of any defensive system. Their object is to help the efforts of the defensive force, and, if skilfully arranged and constructed, they will give such assistance, to the following extent.

1st. They will allow fewer troops to defend a position than would be required without defensive works.

2nd. They will allow the defenders to remain on the defensive, thereby forcing an enemy to attack on a field of battle well prepared for his reception.

3rd. They will allow the manceuvring defensive army to assume the offensive, whenever a favourable opportunity occurs; such as an assailant being thrown into disorder in attacking the position.
"Continuous lines were much used in the wars at the end of the 17 th and beginning of the 18 th centuries, and were frequently thrown up for an extent of many miles; but such long systematic lines of defensive works, besides the great labour, expense, and publicity attending their formation, have the serious defect of being of no strength unless equally well guarded throughout ; and further, when attacked, the defenders have, in consequence of their flanked trace, to man an alignment of nearly double the length of front to be defended, and are utterly incapacitated from making any instantaneous or powerful forward movement: they therefore necessitate the worst possible disposition of troops for attack or defence, and must be regarded as inadmissible under the present system of tactics. Indeen, such long defensive lines, even when most in repute, were invariably forced as often as attacked; and it is difficult to conceive on what foundation their popularity so long sustained itself." *

Although long continuous lines have the before-mentioned defects, continuous lines of the short extent of a mile or two may be advantageous in positions where the flanks can be naturally

[^11]or artificially secured, as when resting on a river or a fortress, or to close the intervals between two strong works, or to bar au enemy's advance aloug a peninsula, as at Gallipoli by the allied French aud British arwies in 1854, or for some other limited and specific object, when the defensive force is greatly inferior to that of the enemy.

## VARIOLS OUTLINES FOR CONTINUOUS LINES.

278. Vauban's Redan Lines are continuous lines of redans, joined by curtains; the dimensions generally assigned to them being those shown in Fig. 259. The salients of the redans are 240 yards apart, each redun having a gorge 60 yards broad and a capital 44 yards long. The defect of such a trace is that the flank defence is imperfect, the angle between the curtain and the faces of the redans being large (about $130^{\circ}$ ); the ground in front of each redan is, however, defended by the cross fire from the faces of the collateral redans, which, with the rifles of the present day, would be effective.

To improve the flank defence of the simple redan line, the arrangement shown in Fig. 260 is sometimes recommended. This, however, is very defective, as, while the flanking angles are better Luan in the trace shown in Fig.259, this advantage is obtained by doubling the number of salients, whieh having equal prominence are equally open to attack; also the faces BC and CD of the brokeu curtain become liable to be enfiladed, because their prolongations can be taken up by an enemy, while the re-entering angles at B and D become dead.


A better modification of the redan trace is shown in Fig. 261, where the curtain is broken
 outwards into two faces, the prolongations of which are directed on to the salients of the collateral redans, and may therefore be considered as secure from enfilade fire. The salient angle formed in the middle of the curtain, being in a re-entering position between the adjacent redans, is not equally open to attack as those works.
279. The Tenambe Line is shown in Fig. 268, it is formed by a series of redans with obtuse salients joined to one another. It is difficult to imagine a position where such a trace would be a desirable one to adopt, as all the faces (which are long) are exposed to enfilade fire. This is so serious a defect, especially with the artillery of the present day, as to condemn this trace for all positions, which would permit an enemy to ocoupy the prolongations of the faces.
280. Tue Inmented or Cremamuibre Line (Fig. 263) is formed of faces bc (called branches) and flanks $a b$ (called crotchets), making angles of $95^{\circ}$, or thereabouts, with one another. The dimensions shown in the figure are ordinary ones, but may be varied if required; the flanking angles, however, should not be less than $95^{\circ}$.

This trace, which is useful in many positions, has the advantage of having the branches (long faces) safe from enfilade or nearly so, as their prolongations fall on ground so near other works, or so close to the general front A B, that generally it would be impossible for an eneray to occupy them with his artillery. The flanks from their direction are liable to enfilade; but owing to their being short lines of parapet, they are comparatively easily protected, by means of bonnettes, traverses, \&c., from such a fire.

$$
\text { Fic. 262.-Scale } \frac{1}{3)^{20}} \text {. }
$$





The indented line is well suited to close the interval between two strong works, as shown in Fig. 264. If these works A and B are sufficiently close to afford each other a powerful cross fire of artillery, the indented line should be traced so as to flank the main works, as is shown in the figure, where the branches are evidently safe from enfilade ; and if the works A and B are suffciently powerful, from their profile, garrison, and armament, to prevent an enemy attempting to pass between them without attacking them, then the indented line might be formed of a simple trench, with the earth thrown up to the front, as in Fig. 265, similar in nature to siege parallels, and it would then have the great advantage of affording cover from a cannonade to troops deployed in line in favourable positions for flanking the main works A and B when attacked, while it (the indented line) would of itself be no obstacle to the forward movement of the troops occupying it. But to obtain the full advantage of the freedom of mancuvring on the part of the troops either occupying the intervals between A and B , or posted in reserve in rear, it is necessary that those works should be strong, both from their profile, size, and armament.

Fig. 264.-Scale $\frac{1}{5200^{\circ}}$


Fia. 265.-Scale $\frac{1}{260^{-}}$


When an indented line is carried across a valley, it should not be traced on a straight line, hut in a re-entering enrve, as in the dotted trace (Fig. 264), which should be made more or less coneave as the sides of the valley are more or less steep. This variation in the general direction of the line is necessary to defilude the gronnd inside the lines from the opposite side of the valley.
281. Bastionid Links are formed by a series of bastioned fronts joined to one another (Fig. 265) ; they are not generally recommended, as their construction is intricate (as already pointed out in Art. 221, Bastioned Forts), and they are not easily adapted to irregular ground.
289. It is desirable to mention, that as oontinuous lines may under certain circumstances be advantageously resorted to,-as, for instance, when their front is short, their flanks secure, and, generally speaking, when the defenders are so inferior to their adversaries that offensive movements ave hardly possible,-in such eases their profile cannot be too strong, and they should be strengthened by every possible means ; but if the defenders are not so inferior to their adversaries, then the works of defence should be planned and executed so as to give to the defenders as much cover as possible, without preventing their assuming the offensive at any desirable moment.
283. Lines with Intervais (broken lines), already defined, have the advantage of consisting of a small extent of works, as compared with the front occupied. The works are arranged either in a single or else in a double row, in such a manner that the inner works may flank those of the outer row. The works should oceupy the most favourable positions on the ground ; and if solidly constructed, they form so many strong points behind which the manceutring force may be massed ready to move to the front whenever a favonrable opportunity may oceur.

Compared with continnous lines, covering an equal front, lines with intervals lave the following advantages.
(1.) Less extent of parapet, consequently less labour in construction, and smaller garrisons to man them.
(2.) Freedom of movement to the defensive force, allowing them to move to the support of the part attaeked at any moment.
(3.) At assailant must attack and overporver several works, in order to force the position; whereas a purely continuous line, if forced in any part, is usually lost to the defenders.
( $\pm$. The works, if of a strong profile, may be garrisoned by untrained troops, who would be useless in the open field.
284. For an open site the following arrangement of a double line of works is a suitable one.

 The advanced line is composed of lunettes ( $a$ a, Fig. 267), traced so as to afford each other reciprocal defence, the fire from their flanks crossing in front of the salients of the collateral works. The profiles of these works should be strong, and their gorges closed by a good obstacle, which should, however, be no impediment to guns in rear sweeping the interior of the lunettes.
The rear line is composed of works favourably situated for flanking the advanced works and defending their gorges. These works would generally be closed ones, and are so shown in Fig. 267. It is difficult to fix dimensions for such an arrangement of works as the above: the distance apart of the lunettes wonld vary greatly; if their flanks were armed with artillery, the distance from salient to salient might be as much as 600 yards. The position of the works in the rear line would depend on the direction of the faces of those of the advanced line. Epaulements (c) may be added for guns to sweep the interior of the lunettes by their fire.

The works of either line may be connected by trenches, having a profile similar to that shown in Fig. 365, wherever it may be necessary to post troops under oover. These trenches may have a trace affording a flazk defence, as shown by $t$, Fig. 267.

In this manner the defensive powers of a position may be increased to a considerable extent,
without preventing the defenders from making a porverful forward movement, whenever they may require to do so.

In positions where the outer line of works is disposed along a convex curve, the inner line may be replaced by a strong central redoubt or fort. This work would be the key of the position, and no labour should be spared to render it in every respect as formidable as possible.
285. Artillery posted to assist in the defence of broken lines, similar to those just described, would be thus distributed:-One or more guns would be placed en barbette in the salient of each of the advanced works, in order to thoroughly sweep the ground in front; the flanks of these works should be armed with at least 3 guns each, to afford a powerful cross fire over the intervals, and in front of the collateral works. The heaviest guns would be placed in the rear line, as being most secure, and affording a position where their long range would allow them to take an active part at every period of the attack.


It is almost unnecessary to add, that these guns should be protected as much as possible by means of traverses (Art. 239), bonnettes (Art. 238), de. Fig. 268 is given here as exhibiting a type of work such as would be required for one of the advanced works indicated in Fig. 267. A barbette for three guns is shown at its salient; at each of its flanks is a barbette for one gun and embrasures for others. The gorge of the work is closed by a stockade having a flanked trace. If time permit, a blockhouse reduit (B H.) should be added; its floor should be sunk, in order to keep its roof low for protection from distant artillery fire, and with the same view the blockhouse should be placed near the salient of the lunette.

In determining the armament of Field Works of every kind, it should be remembered that guns are most beneficially employed for offensive purposes, such as for sweeping the ground in front of the position, enfilading the most probable line of advance of an assailant, crossing their fire in front of the salients of collateral works, \&c., but they are not usually (except in very large works) posted for the close defence of the work they occupy; in fact, while a field work is a protection to any guns inside it, those guns are not to be considered as a protection to the works, although when attacked they are used as such. It is generally allowed that, for the close defence merely of a field parapet, the space required by a gun in a work would be better occupied by infantry.
286. When a position is defended by a double line of closed works, the rear faces of the advanced line should have slight parapets ( $4^{\prime}$ or $5^{\prime}$ thick only), in order to allow of their being destroyed by the artillery in rear, should an assailant gain possession of them. For the same reason, the rear parapets should have as small a command as possible.
287. A position mny be sometimes defended by a single line of works, placed on the most favourable points. In such a case the works should be large enongh to contain strong garrisons; they should be near enougla to one another to submit the intervals to a powerful fire of artillery, and to afford each other mutual support; they should be closed at the gorge, and should have a profile capable of resisting a violent assuult, At the same time they should be supported by troops in rear, in readiness to move to their assistance when attacked; for it cannot be too strongly impressed that Field Works will fall, when properly attacked, if left to their own unaided efforts.

## OHAPTER IX,

BRIDGE HEADS, NTO.

Bemae Hreas; their objot, nahuv; extent dependent on importance of the commmication; liest position in a river jor defonce; condikions lo be fulfilled; achion of curvent in a winding river; formation of shools; probnble positions of fords; derths for forids.
288. A Bridge Head (Tête-de-pont) is a work, or series of works, thrown up to cover the communication across a river. When works are required to protect only one end of a bridge, they are termed Single bridge heads; when both ends have to be protected, the intrenchments thrown up for that purpose form a Double bridge head.

Fortresses which occupy both sides of a river form double bridge heads, and give to the army possessing them the great advantage of being able to operate on either bank of the river, or on both banks at the same time.

The best position, as regards facility of difence, for a single bridge head is a re-entering bend,* i.e. one concave towards the enemy's side, because in that position the near bank, being salient on each side of the bridge head, envelopes it to a considerable extent, so that batteries and other works on that bank can flank the tete-de-pont with great effect, provided the river be not very broad. The bridge head in this position also covers the bridge from view, and the ground in front can be submitted to the fire of the bridge head.

These considerations peculiarly fit a re-entering bend as a good position for forcing the passage of a river.

The number of works required for a bridge head will depend principally on the importance of the communication, and on the number of troops likely to retreat by it.

In some instances a single redan or lunette covering the immediate head of the bridge might suffice, as in Figs. 969, 270, or 271 ; but on an important line of communication more than one

bridge would be constructed. Each bridge would be protected by a small work, such as a redan or tambour, at its head, and the whole would be enclosed within a line of works thrown up for the purpose. An advanced position might be occupied by a chain of detached works.

The great range of rifled artillery will make it impossible for the future to prevent an euemy occupying a position within range of a bridge, by any moderate development of works in a bridge

[^12]hend; it will therefore be of greater importance than formerly to conceal the bridges from an enemy's view.
289. The points to be principally attended to in arranging the works of a bridge head are-

1st. To cover the bridge from the view and the fire of an enemy to as great an extent as possible.

2nd. To flank the works of the bridge head, where possible, from the other side of the river, or from islands in the river. In the case of very wide streams, the bridge head must be given its own flank defence, as in Fig. 210.

3 rd. To provide easy communications for the retreat of the defenders across the bridges, so that after the main force may have effected its retreat the garrisons of the works may be withdrawn in succession, commencing with those of the most advanced works.


4th. To construct works bearing on the bridges so as to be able to destroy them, should an enemy attempt to make use of them for forcing the passage.

These various requirements are fulfilled in the arrangement of works forming the Bridge Head shown in Fig. 272.
290. While re-entering bends of rivers form the best defensive position for a bridge, for the reasons above stated, the action of the water in a winding river frequently unfits such positions for the establishment of a military bridge.

A eurrent rumning in the direction of the arrow in Fig. 273, will continue in its straight course until it impinges on the curved bank at A , which will cause it to deflect to the right: it will then take an oblique direction across the river (as shown by the dotted line), and at the next eurve of the river it will impinge on the bank at $A^{\prime}$, and be again deflected obliquely across to the other bank. This change of direction from side to side will continue as long as the course of the stream is winding. This is shown in Fig. 273, where the dotted line represents the general direction of the current: thus the stream is always running in the winding parts of a river obliquely to its banks; and this oblique direction causes the stream to take effect on the sides of the boats, or other floating bodies forming the piers of a military bridge, instead of on their bows. When the current is very rapid, from floods or other causes, this oblique action of the stream may exert such a strain on the piers as to carry away the bridge.

Another reason why the enrved parts of rivers may be bad positions for establishing bridges is, that at those parts the depth of water, and also the uature of the bottom, is very variable.

In Fig. 278, the stream rubs against the banks at the concave parts A and $\mathrm{A}^{\prime}$; and, as a result, the velocity of the stream at those parts is increased, the bauks are being continually worm away, and the soil carried down stream to form shoals elsewhere. The banks of the stream at $A$ and $A^{\prime}$ will be therefore very steep, and the depth of water at the same points will be probably the greatest. On the other hand, the converse effeet happens at B and $\mathrm{B}^{\prime}$, for there the velocity of the stream is very slight, perhaps uil; sometimes, as in a very sudden bend, there may be even a backwater at $B$ and $B^{\prime}$ : this slackening of the current at these points leads to the deposit there of the matter brought down by the stream, and shoals are thes formed, while the opposite banks ure being worn away.

With reference to the formation of shoals at those parts where a rapid current is slackened from any cuuse, the following table gives the greatest velocity which each of the various substances named can resist, without being moved:-


Fig. 27 t


This mequal action of the current is illustrated by the section (Fig. 274), which shows deep water mith steep banks at one side (A), and shallow water with shelving banks at the opposite side (B):

A sudden fall of the stream at such a position might be very injurious to a floating bridge, for one part might be left aground, while the other, dropping with the fall of the water, would be torn away from it.

When a bridge is established across a river, special precautions must be taken to prevent its being injured by floating bodies carried down by the current. Boats stationed on the up stream side of the bridge should watch for such bodies, and should either tow them on shore before reaching the bridge, or, in the event of their being unable to effect this, should guide them to any opening that may be made in the bridge to allow them to pass through.
291. From the foregoing observations it will be apparent that in a winding river fords may frequently be found rumning obliquely across it from one convex part to another,* as shown in Fig. 273 ly the line +++++ ; but, in general, fords are to be looked for at enlargements of a river, where its course is straight.

A Ford to be passable should not be more than 4 feet deep for cavalry, 3 feet for infantry,
?
4" for artillery;. and $2^{\prime} 4^{\prime \prime}$ for artillery.

[^13]In rivers the bottom of which is moving sand or fine gravel, the fords are dangerous and deceitful; because, if large bodies of troops have to pass and the current is strong, the sand stirred up by the operation will be carried away, and the ford will probably become impassable for the rear of the line of march.

The best precaution for passing a ford is to drive two rows of pickets at small distances apart, to show between them the line of the ford ; strong ropes should be passed along each row, taking a turn round each picket.

A good method of reconnoitring a ford is to descend the river in a boat with a sounding line, hung over the stern, adjusted to the requisite ordinary depth of 3 feet. Conducting the boat in the direction in which, from the principles already laid down, fords are most likely to be found, the somding line will indicate when it touches the battom; and the direction of the ford, its width, the nature of bottom, \&c., can be ascertained and laid down.

## CHAPTER X.

## DEFENCE AND ATTACK OF POSTS, ETG,

Defence of Intrenchaments, general arrangements for; Defence of a Field Wore, against a surprise and against an open assault; Derenoe of a Hovse, conditions to be fulfilled; operations to be performed; tambours and machicoulis galleries. Defence of a Vthage; oulline of operations; formation of bamicades. Attack on Field Works-usually by assaull sometimes preceded by partial siege operations. ATTACK BY SURPRIsE described. ATTACK BY OPEN FORCB: formation of the assauilants into shirmishers, storning party, and reserve; their several duties; employment of artillery in the attlack on Field Works ; mode of aduance of the assaulting parties. Attack on A Hovse described. Usual metlods of destroying. or passing, the obstacles encountered when assaulting Field Works.
292. Defence of Tntrenchments. - The defence of small works, or simple intrenchments, is confined principally to infantry; but in large works, such as redoubts, or forts, forming in combination an intrenched position, artillery will become an essential element in defence.

In the defence of a position artillery should be posted so as to obtain a cross fire on all the approaches to it, and the heaviest guns should be placed in the most commanding and inaccessible positions, under the protection of those Field Works which are capable of offering the most prolonged resistance to an enemy's attack, and in such a manner as to be able to keep up a fire on the assaulting columns without incommoding their own troops. The lightest pieces should be stationed at the most advanced posts, so that they may retire from them with facility, if obliged to do so. One of the many advantages of the present riffed field artillery is their comparative lightness, which will allow them to be moved rapidly from one site to another, while they have the advantage of long range, which light smooth-bored artillery do not possess; for if long range is required with smooth-bored guns, it is necessary to use large calibres, and it is therefore impossible to combine long range and lightness in the same gun.

The reserve troops should be stationed in convenient positions in rear, covered if possible from an enemy's riew, either by taking advantage of the inequalities of the ground, or by means of trenches, \&c., in readiness to be moved to the support of the works attacked, as soon as the intentions of the enemy shall have become apparent. To give the greatest possible freedom of movement to these manceuvring troops, roads of communication are generally formed in rear of the works, ditches are filled, hedges levelled, and streams bridged where required; and, in fact, every effort will be made to allow the defenders to assume the offensive when required.

It is beyond the province of the present work to enlarge on these main operations, which would be usually settled in all their detail by the General in command, or his staff. Such operations as may fall to the lot of an individual officer to carry out with the men under his command, will now be referred to in greater detail.
293. Defence of a Field Work,-In occupying a Field Work for defence, the first duty of an officer is to take the necessary precautions agaiust an attack by surprise; with this view his detachment should be told off to the positions they are to occupy, so that at the first moment of alarm every man may repair, without coufusion or delay, to his proper post. By day there is slight danger of surprise, provided the commonest precautions are taken; but at night too great
vigilanoe cannot be exercised, particularly in bad weather, which is most favonrable for such au enterprise. A sentry should, as a geueral rule, be stationed in every salient of the work; piquets and ridettes should be posted in advance, and, if necessary, on the flanks, to watch every road or path by which an enemy could advance, taling care that they are not so far apart as to allow an enemy to pass between them. ${ }^{*}$ Provided this is the case, the line of sentries cannot be too far advanced from the work, in order to give ample time for the defenders to get under arms and repair to their posts. Frequent patrols to the front and flanks should be made at uncertain intervals, both to assist in preventing surprise, and to keep the advanced posts properly on the alert. Heaps of dry brushwood, straw, \&c., to be lighted when the piquets are compelled to withdraw, may be prepared at intervals; in a wet stormy night, however, these cannot be depended upon, and the alarm will usually be given by the piquets firing on the enemy.
29. In posting the defenders of a work to resist an assault, a double rank should be allotted to the lines of parapet most exposed, and, in order to get the most effective fire from them, one rank should occupy the banquette, and should fire ; the second rank behind them, under cover, should lond and supply the front rank with londed rifles. The best shots should be selected for firing. By this division of labour, as rapid a fire would be kept up as if both ranks were on the banquette firing independently, while only oue-half the men would be exposed to direct fire ; and until the struggle became hand to hand, this arrangement appears most suitable. In most instances of actual assaults, the defenders have mounted on the superior slopes,, when the assailants have arrived close to the works, in order to preserve the advantages of freedom of movement, and a clear view, together with a favourable position for preventing the enemy scaling the parapets : at such a critical moment the mere cover afforded by the parapets is altogether a secondary consideration.

A reserve, varying from one-half to one-sisth of the garrison, according to the situation of the work, its liability to assault, \&ec., should be provided, in addition to the men required to man the parapets. The reserve should be held in readiness to attack the enemy on his first penetrating into the work, which usually will be in small numbers, and in no regular formation. $\ddagger$ A sapply of hasd-greandes to throw into the ditehes should be provided, together with live shells, which latter should be slid down the superior slopes on wooden tronghs, made into a $V$ shape from a couple of planks, supported on sods, \&ec, in the proper position. One objection to the use of Iarge shells in defending Field Works, is that by their explosion they may destroy, or blow gaps in the defensive obstacles, such as palisades, \&e., which would not be the case with hand-grenades. Trunks of trees arranged on the crest of a parapet, and a few inches above it, will answer all the purposes of loopholes of sandbags; and when no longer required for that purpose, may be rolled down the superior slope into the ditch, with great effect. The approach to the work should be rendered as difficult as possible, by improving existing obstacles, wherever practionble, -such as, for instance, by deepening or obstructing fords, felling trees on the ground they stand, forming entanglements of hedges, do. ; and where natural obstacles are not existing, artificial ones would be constructed, in the manner described in Chapter II.

A position or work occupied for defence should be strengthened by every resource available, while an enemy delays his attack. If, when an officer takes charge of a work, he find it weak, there is every inducement on his part to make it strong; but should he find it already strong, his best endeavours should be directed to making it stronger.

Finally, as regards the arrangements to be made for the proper defence of a work, an important consideration will be its communication with the rear; not necessarily for a retreat, which may tale place if the orders under which the post is held admit of it, when every defensive

[^14]effort has been made ; but also for receiving reinforcements and fresh supplies of ammunition, on the fulfilment of which the proper defence of a work or post has often hinged.*
295. Defence of a House. - In occupying a house for defence, there are the following advantages on the part of the defenders :-
(1.) Most of the defensive obstacles, such as the walls, acting as parapets, \&c., are already existing, and require improvement merely.
(2.) Materials are more or less at hand for strengthening the post.
(3.) The defenders are well covered from musketry.
(4.) The walls are great obstacles to an assault.

As a set off to these advantages there are the following inconveniences, which will become more apparent according to the ability of the assailant to bring artillery to the aid of his attaek.
(1.) The walls are not proof against artillery, and cannot usually be made so.
(2.) The buildings are liable to be set on fire by incendiary projectiles.
(8.) They are also liable to be breached by artillery.

The art of converting buildings, with the outhouses and walls that usually surround them, into defensible posts, consists in selecting from the mass of objects at hand such as will answer the purpose in view, and in destroying everything which interferes with it, making use of the materials to strengthen the part which is to be fortified.
296. When there is a choice, the building should possess some or all of the following requisites :-

1st. It should command all that surrounds it.
2ndly. It should be substantial, not thatched, and it should be of a nature to furnish materials useful for placing it in a state of defeuce.

3rdly. It should be of an extent not too great for the nnmber of the defenders, and should only require, for the completion of the proposed object, the time and means which can be spared.

4 thly. It should have projections flanking the walls and angles.
5 thly. It should be difficult of access on the side exposed to attack, and yet have a safe retreat for the defenders.

As a rough guide to judge of the requirements under the third head, one man ought to be allotted to every 4 feet of wall round the interior of the lower story; one man to 6 feet for the second story; one man to 8 feet of an attic, with a reserve of about one-sixth of the whole.

The following comprise most of the operations requisite to place the house in a state of defence: they must be undertaken in the order of their relative importance according to circumstances; and after the immediate object for which they are designed has been secured, measures may be adopted for their improvement:-If time permit (see Figs. 277), barricade the doors and windows on the ground-floor; make loopholes in them; loophole the walls generally, with one, two, or three tiers of holes, according to the nature of the rooms, attending first to the most exposed parts; break communications through the party walls and partitions, making arrangements to defend, on either side, one room after another; sink ditches opposite the doors and windows on the outside; loophole the floors of the upper rooms, so that a fire from above may be directed on the enemy should he force an entrance into the lower rooms; cut away the staircases, substituting ladders; barricade the upper windows, and loophole them and the walls; level anything outside that would give cover to the enemy; arrange a flanking defence, where requisite, by constructing a tambour in front of a window, door, or angle of the house; remove thatched or wooden roofs, and all combustible materials near the house; place vessels of water in the rooms to extinguish fire ; loophole, and otherwise place in a state of defence, garden-walls and fences; cut up the roads and paths, and arrange obstacles around the house, beginning with the most assailable points ; and, finally, arrange means of communication with the rear.
297. In loopholing the walls of houses, the holes should not be closer to one another than

[^15]3 feet, and the only rule that can be followed is to make them as small as possible, as at the best they will be very rough opemings. Loopholes at the angles of $a$ house, if practicable, will be found extremely useful. For directions as to loopholing and preparing for defence walls and hedges of different sizes, the reader is referred to Chapter I.

A flank defence for buildings may be obtained by constructing either Tambours or Machicoulis Galleries.

A Tambour (Fig. 275) is formed of stockade work, and is usually made in the shape of a redan or lunette, enclosing a space in front of a wall;

Fig. 975.
Loopholed wall.
 communication is kept up with the interior, either by taking advantage of an existing doorway, or by breaking a rough one through the wall. The tambour should be flanked by loopholes cut obliquely in the walls behind it. A roof may be added if required. If the tambour serves also to cover a communication with the exterior, then it must have either one or two openings left between it and the walls, such as a, Fig. 275, which can be easily barricaded.

An existing porch would serve as a tambour by loopholing it, and barricading its doorway or strengthening its door, so as to make it musket-proof.

Doors may be made musket-proof by nailing planks on to them diagonally, so as to increase their thickness to at least 6 inches.

A Machicoulis gallery is a kind of balcony built outside windows; it should have musketproof walls not less than 4 feet in height, which may be loopholed; openings are left in the floor through which a fire of musketry can be directed downwards, so as to defend the entrance into the building. A loophole made in each end wall will also serve to flank the walls of the main building.

A Machicoulis gallery is shown in profile in Fig. 276, and may be thus made.

$$
\text { Fig. 276.- } \mathrm{Sc} \text { cale } \frac{1}{\frac{1}{2}}
$$



Fig. 277.


Break two holes through the wall, 10 or 12 feet apart, on the level of the floor; through these holes pass from the outside stout beams, B , which are part of strong brackets, the upright part of which (C) must rest against the wall, W. The beams (B) may be secured to the floor of the room by passing ropes throngh holes made in the planks round the joists, J ; or they may be secured to a transverse beam, D : the secmity of the work depends on the proper fastening of these beams. A couple of sleepers, F F, nailed to the beams, B, will support a floor of planks, P;
openings being left between the planks to serve as loopholes. Musket-proof walls must then be sdded to the front and sides.

If a window serves as a communication, it should be cut down to the levelof the floor.
An exposed doorway may be protected from artillery fire by laying a row of splinter-proof timbers outside, in an inclined position, touching one another, and afterwards covering them with 5 or 6 feet of earth, built up in sandbags.

The sleepers and joists of the house that bear on the walls should be shored up, so that, if the walls are partly breached with artillery, their partial fall need not be necessarily followed by that of the floors above.*

Fig. 277 is a plau of a house, with outbuildings and garden-wall, forming a good defensible post. T T are stockade tambours. The projecting porch of the house is used as a tambour. According to the time and means available, all the contrivances of defence which have been referred to, would be carried into effect.
298. Defence of a Velage.-When a village (Fig. 278) is to be placed in a state of defence,

Fig. 278.

either as an advanced post of an army or as an independent post, it will generally be important to select some strong masonry building, $F$, such as a church, jail, or court-house, to allot for its garrison a due proportion of troops, and to fortify it as the citadel, keep, or reduit of the position. If there be a choice, that building is preferable which is centrally situated, and on high

- Owing to the precautions taken by the French, although the walls were frequently breached, and the houses set on fire by the English artillery, yet the former were prevented from falling, and the latter were speedily extinguished-De/chec of the Fortified Buillings at Salamqnea, in 1812.


## Field Fortification,

gronad, commanding a view of the village and adjacent country, flanking the principal streets, and having nu open space suound it. Such substantial houses (E E) and walls should then be chosen as will become substitates for intrenchments, outworks, Sc. Some of these may be made to bring a cross fire on the streets lealing to the citadel, and flamk it if assaulted. The buildings which interfere with this arrangement, or which cannot be occupied, must be either entirely levelled or opened to the fire of the others by pulling down the intervening walls, and where no walls exist, the vacaney should be supplied by stoekade work, S. Ensy, direet, and well-assnured communications should be then established between the outworks and the citadel, carefully barricading, B E, the lanes or streets by which the enemy might intercept the retreat or concentration of the defenders. The outskirts of the village may be made to assume the character of an advanced covered way, by occupying the intervals with trous-de-loup, abattis (A A), palisades, and stookade work, using for the purpose garden paling, and forming banks, hedges, and walls into breastworks, with ditches or trenches. Buildings such as H H , conveniently situated for the purpose, should be loopholed, either to flapk the appronches, or to serve as reduits or intrenchments to the advunced line. The roads by which an enemy might be expected to advance should be cut up and obstructed with felled trees, harrows, hurdles, or paling firmly planted in several rows, and slanting forvards. All obstacles should be so placed as to be exposed to a flanking fire. Bridges should be broken, and the passage disputed under cover of some simple Field Work placed favourably to command the road. The paths for the retreat of the advanced parties should be in direct lines, converging towards the keep, and should pass, as much as possible, straight throngh buildings by openings made in them for that purpose ; a fire being kept up on the advancing enemy from loopholes cut in the upper portion of the building. Streams should be dammed up in order to deepen them; or, if time and means suffice, to form inundations.

If the village be of too great an extent for the force thrown into it, a portion only should be strengthened, and the remainder separated or destroyed : or the defence might be confined to one or two separate buildings.

The order in which the above-mentioned operations should be executed, and the extent to which they can be carried out, must be left to the intelligence of the commander, who will be necessarily intluenced by various contingencies, such as the strength and composition of the defensive force, the proximity of the eaemy, the nature of the country, and the character of the village, the purpose and time for which the position is to be maintained, \&c. The resolute defence of villages situated on the front of an army has often decided the fate of a battle."
299. Streets are barricaded by forming across thern an obstacle which should serve also as a parapet. Wherever a barricade is construoted, the houses on either side should be occupied and loopholed, so as to flauk it. A barricade should extend quite across a street, communications being kept up by breaking openings through the adjacent houses. If time permit, a ditch shonld be sunk across the street, forming the earth into a parapet ; paving stones, de., being used as revetments. But if time presses, a ditch would not be dug, the parapet being formed from the most available materials, such as casks filled with earth ; boxes, bags, de., being also made use of. Planks supperted on casks, stools, or chairs, would be used as banquettes. Furniture, carts, barrews, ic., would form an obstacle in front.

In all cases preenutions must be taken to prevent barricades being turned by an enemy penetrating to their rear throngh other streets, which should be equally defended.
300. Atrick on Fifid Works.-It is usually by assault that earthen intrenchments are taken, as it is genexally practicable, by a superior fire of artillery, to ruin many of the accessory defences, and to dismoint guns which would retard the advance of the assailants. Field Works, however, may frequently be so formidable, from their profile, armanent and extent, as to be secure from immediate attack; in which case the assailants must resort to partial siege operations, before they would be justified in giving the assault. +

The attick on Field Works, which are open to assault, may be executed by Surprise, or by Open farce.
201. As attack ey somerse can only take place when the advance of the assailants is

[^16]concealed by fog or darkness, or by irregularity in the form of the ground, as in momtainons countries, and when proper precautions have not been taken by the garrison.

In order to succeed in this method of attack, the enemy shonld be deceived, so as to lead him to imagine that some totally different enterprise was contemplated.

Night is the most favourable time for a surprise, as the preliminary movements and arrangements are concealed by the darkness. The actual attack generally takes place shortly before das light, us, if successful, the assailants are assisted by the daylight in making the necessary arrangements to retain possession of the works.

If the object of the attack be merely to hold the works for a sufficient time to destroy the defences, spike the guns, explode the magazines, \&c. \&c., the attack may be executed early in the night, and the works be abandoned before daylight.
302. In the attack of Field Works by open force, it is advisable to advance against several points at the same time, in order to distract the attention of the garrison: of these attacks some may be false, but should, however, be converted into real attacks, if the enemy appear weak or hesitating on the points threatened; one attack ought generally to be directed on the rear of the work, if open at the gorge, as such an attempt will lessen the confidence of the defenders.

As many assaulting columns should be formed as there are points to be attacked. Each column is ustally divided into three bodies, - viz., Skirmishers, Storming Party, and Reserve.

The skirmishers precede the storming party, and endeavour to keep down the fire of the works attacked; they advance up to the edge of the ditch, profiting by any natural cover they can find.

The storming party are usually accompanied by a party of sappers or pioneers carrying axes, crowbars, bags of powder, \&c., to surmount the obstacles that may be expected to be encountered, and also by a small party of artillerymen to spike any captured guus, or, if necessary, to turn them on the defenders. The storming party should not be allowed to fire, but should be moved to the assault as rapidly as can be done, without putting them out of breath. A rapid assault raises the spirits of the assailants, and also lessens the duration of their exposure to fire.

The reserve follows the storming party a short distance in rear ( 100 to 200 yards), to act as circumstances may require; it may repel attempts to aid the defenders, reinforce the storming party if they succeed in entering the work, or it may afford them a rallying point, and cover their retreat if they fail.

The troops destined for the assault are drawn up in the cover nearest to the works.
Artillery used in the attack of Field Works should be placed when possible in the prolongations of the faces of the works, in order to enfilade them, and to destroy their accessory defences, such as traverses, abattis, palisades, \&c.; for this latter purpose howitzers are best adapted. They should continue their fire on the works until the advance of the storming columns has rendered it necessary to cease, when it may be directed to the rear of the position against any troops that may be supporting the works.

The signal for the assault being given, which is done immediately the artillery have produced the requisite effect, the attacking columns march to the assault in the direction of the capitals in the before-mentioned order of skirmishers, storming party, and reserve. The advance being made on the capitals, allows the artillery to continue their fire until the infantry have arrived close to the works, and also exposes the latter to less fire than they would experience elsewhere.

If the salient attacked be not flanked, the assailants may descend into the ditch at the salient, and give the assault at once on both faces; but if there are flanking defences, it is desirable that the assailants, when they arrive close to the salient, should edge off to the right or to the left, so as to be exposed to the fire of only one flank; they should then make for the re-entering portion of the ditch, and give the assault on both faces forming the re-entering angle.

Should the ditches have a great depth, it will be necessary to lessen it by means of bags, filled with hay, \&c., or with fascines carried by a party of men in advance of the stormers.

In assaulting a work whose escarps and counterscarps are revetted, scaling ladders must be employed. The first division of each column of assault carries the longest ladiders, they descend into the ditch by their means, and then carry them across the ditch and rear them against the escarp. The next division curries other ladders, which they place and leave against the counter-

## Field Fortification.

stary, so that the remainder of the column can pass down the countersearp ladders and up those of the escarp without delay.
1803. Arrack on a House.- The attack on a house is conducted on the same principles as that on a Field Work. If guns and rockets are available, they should be employed, before the assmil, in smoothing the path for the infantry, by destroying obstacles, breaching the buildings, or setting them on fire: howitzer shells and rockets are especially suitable for the latter purpose. When the nssailauts are umprovided with these powerfnl projectiles, at least two attacks should be directed on different sides of the house, and an attempt made with ladders to get in by the roof. A strong body of skirmishers should, as in the attack of a Field Work, precede the storming parties, and advuce as close to the house as the requisite cover will permit, always recollecting that they will be less exposed to the fire from the loopholes of unflauked buildings when close to, than when at $\Omega$ moderate distance from them. The skirmishers fire into the loopholes, unbarricaded windows, and other vulnerable parts : under the distracting effeet of their fire, and of the smoke balls which they throw into the rooms, the storming parties will advance rapidly until close to the walls, when efforts will be made to blow in the doors or lower windows with bags of powder, or to force them either with crowbars or a heavy piece of timber used as a battering-ram. An effort may be made to undermine the walls whilst the escalading party is trying the roof or upper windows; any thatched or wooden outhouses adjoining the main building shoald be set on fire, or a fire of straw, de., lit under the walls of the house on the windward side, so as to fill the rooms with smoke, as either will diminish the confidence of the defenders. I reserre will be held in readiness to follow up success or to cover a retreat.
gil. Destroying or passing Mmitary obstacles.
Before assaulting worlss artillery is used, as before-mentioned, in clearing the way for the infantry. As regarls the destruction of defensive obstacles ricochet fire may be used to enfilade lines of abattis, or the ditches of works, to form gaps in palisades, fraises, de.; but the effect of sach fire is uncertain, on account of the objects fired at being usually concealed from riew, and it is necessary to make provision for the further destruction or removal of the obstacles that may be encountered. For this purpose a special party of men are usually told off; they carry axes, crowbars, sledge-hammerg, and bags of powder, for the purpose of cutting down and breaking gaps through obstacles, or for blowing gaps in them; their efforts being directed prinoipally to improve the effects already produced by the fire of the artillery.

Ponder in bags may be employed for breaching, or blowing an opening through barricades, doors, gateways, stockade work, palisades, walls, or almost any other obstacle that checks the advance of a storming party. From 30 to 50 lbs , of powder should be used to blow down an ordinury stockade or palisade, while from 60 to 100 lbs . will be sufficient to breach a stockade or gateway, however strong it may be.

In breaching with bags of powder great care is requisite to avoid accidents, by properly preparing the bags; by using a proper fuze, and by fixing it firmly into the bag; and by arranging the bags against the wall or other obstacle, in a systematic manner. The placing of the bags, and indeed the whole of the operations, should be rehearsed several times. The wen to carry the bags should be selected for their activity and coolness.

If the quantity of powder does not exceed 50 lbs., and the ground to be passed over is not very difficult, and the distance not great, it is better to carry it in one bag, otherwise it is advisable to apity the powder in bags containing 25 lbs . or 30 lbs . each. When the object to be opened is a barrier gate, and it is to be effected by surprise with a single bag of powder, a gimlet may be screwed into, or a forked stick inclined against the gate, and the bag suspended on it; but when more than one bag is employed, it is generally preferable to place the bags on the ground close to each other, against the obstacle to be breached, and, in order to increase the effect, to back and cover them with half-bushel bags of earth. This rough kind of tamping has been found to greatly inerease the effect.

The fuze, which is fastened into the bag and by which the charge is to be fired, should be sufficieutly long to allow it to be easily lighted without risk of accident, and yet not so long as to delay the explosion too mich. A piece of Bickford's mining fuze is about the best, as it burns regulaily at the rate of about 18 inches in 80 seconds. A common mortar fuze is also very good for the purpose, 16 it burus out in sto seconds, and it is 6 inches in length.

## CHAPTER XI.

## ADAPTATION OF WORKS OF DEFENCE TO IRREGULAR SITES.

Difficult nature of the subject; usual mode of proceeding in arranging a scheme of defence; limited nature of the subject treated in the presint Chapter.
Manner in which the object of a work may influence its shape. Ground favourable for defence or the reverse. Hrw to occupy the swnmit of a gentle slope with a work. Defect of slope which is convex in section. How to occupy the summit of a very stepp, but not precipitous slope ; also a slope which is precipitous.
Examples.-1. A salient bend of a hill occupicd by a satient angle. 2, A low spur of a hill occupied by a salient angle. S. A redoubt occupying the summit of a hill. 4. A fort ocoupying the summit of a hill. 5. Two works occupying the summit of a hill, which is too extended to occupy with a single work.
305. The formation of the ground selected for the site of intrenchments influences, to a considerable extent, both the trace and the profile of the works to be constructed. The trace of a work is frequently determined from the shape of the ground it occupies, and the command is greatly dependent on the slope of the ground, both in front and also inside, or in rear of the work.

The art of apportioning works for the defence of a given position, in such a manner that the objects of defence are attained with the smallest possible expenditure of time and labour, is the most difficult branch of the science of the Field Engineer. It requires for its fulfilment a practical acquaintance with the modes in which troops of all arms are manceuvred, in order that the works selected shall aid to the utmost the efforts of the defensive troops, and it also requires a good eve for ground, in order to be able to select such sites for the works as will give the greatest defensive advantages with the least labour.

The general scheme of defence for a position is arranged by the General in command of an army, or by superior Engineer or Staff Officers deputed by lim, who would determine the number and sites of the proposed works, their general dimensions and armament, the positions of troops to support the works, \&e.; in fact, the mode of occupation of the position as a whole. The details of execution of any one work, the determination of its exact shape, and of the profiles of its various parts, \&ce,, are important duties that may fall to the lot of an individual officer. The olject of this chapter is to facilitate the comprehension of this practical and highly useful brauch of Field Fortification.
306. A work of defence may sometimes be constructed rather for offensise than for defensive pureoses, -that is to say, its object may be more to bring a strong fire on a particular ground which would favour an enemy's attack, than to resist an assault. In the former case the work assumes the nature of a battery, being especially intended to afford protection to the guns that may be placed in it, and its outline cannot be too simple; but when the object of the work is purely defensive, as when it is intended to prevent an enemy occupsing the ground that it stands on, the work should be planned so as to be capable of resisting a powerful assault, and every attempt should be made to increase its defensive powers by giving it a strong profile, by providing a good flank defence, and by making use of all the accessories of defence, in the shape of obstacles, \&c., that have been already described. In many cases a work may be required to fulfil both conditions, for it may be in a position favourable for the action of artillery for offensive purposes, while it may also be an important point to hold in respect to the general defence.
307. The most favourable ground to occupy for defence, whether with or without works, is the top of rising ground which has a gentle slope before it, like a glacis, that can be grazed by the fire of the defenders; at the same time the upper surface of the ground should be level, or, still better, should have a slight fall to the rear, so as to conceal the ground in rear of the position from the view of an enemy, thereby masking the movements of the defensive troops. The position should not be commanded, within range, by heights which could be occupied by an assailant.

Very high ground is not necessarily good for defence, as the fire from it becomes too plunging to be effective, particularly at night; and if the slopes are rery steep, they cannot be, swept by the direct fire of the works; while, on the other hand, they can be surmounted by an assailant, unless they are so steep as to be precipitous.

## Field Fortification.

Works frequently have to be construeted on unfavourable ground; for instance, when the site occupied is commanded within effective range, or when the face and not the summit of a hill is the site of the work. In either case increased height of parapet is necessary, in order to affurd cover for even a short distance in rear; while, in the hater case, great difficulty would be experienced in draining the work, which from its position would intercept the water running down the face of the hill.
308. When a line of work occupies the summit of a gentle slope, it should be retired sufficiently from the crest of the hill to enable its musketry to defend the slope. This may be considered as effected if the fire can be directed within 3 feet of the surface of the ground. Considerable latitude in the choice of the actual position of a line of parapet on favomable ground will thus be allowed; for instance, a line of work occupying the summit H in Fig. 279, might have

its erest in either of the two lines $a b$ or $c d$, which represent lines of fire, each passing within 3 feet of the surface of the slope, and therefore properly defending it; or the erest of the parapet might occupy any intermediate position between these two lines, and be equally efficient for defence.
309. When a line of work occupies rising ground, the slope of which forms a decidedly convex curve in section, it will frequently be impossible to defend the entire surface of the slope, if the work occupies the highest part of the ground, as at A, Fig. 280. To obtrin such a defence

for the ground in front it would be necessary to advance the position of the parapet as shown at B, from whence its fire can evidently graze the slope; but this advantage is obtained in this case by occupying an unfavourable position for the work, which would require a high parapet on account of the ground rising behind it, and the work would, moreover, be very difficult to drain.

If the parapet were constructed at A, Fig 280, direct defence for the ground in front could only be completely obtained by paring the surface sufficiently to allow the musketry fire to be brought within 3 feet of it, but this operation would entail more labour than could usually be devoted to the purpose. It will, however, frequently happen, after having resorted to every practicable expecient, that there will remain some ground in front of a work which cannot be defended by a direct fire: when such is the case, endearours should be made to obtain a flank defence for it, and to obstruct, as much as is practicable, the approach of an assailant in that direction,
310. The defence of a slope of ground becomes more unfavourable as the slope increases in steepness, because the defensive fire requires greater depression to defend the slope; the superior slopes of the parapets require, consequently, to be made steeper, and the parapets are thereby weakened.

When the slope of ground is so steep as to prevent its being properly defended from a parapet, and yet not sufficiently steep to be inaccessible to an assailant, it is not usual $*$ to occopy the crest of the slope with works, which should be retired some distance, as in Fig. 281; for by so doing the ground in the immediate front of the works is well defended, and an enemy would have to pass over it after being disordered by the ascent of the slope, which should be flanked from convenient points so as to prevent an enemy being unseen while mounting it.

Fio. 281.-Scale $\frac{1}{\text { teo. }}$

311. When ground oceupied for defence is so steep as to be inaccessible to an enemy (which is a case of rare occurrence for any consilerable extent), the crest of the slope may be occupied by works which would possess the advantages resulting from a commanding position without the obligation of defending the ground inmediately in front. The steep ground should, if necessary, be made steeper by scarping, as shown by the dotted lines in Fig. 282, so as to form an insurmountable obstacle to an assault. A site of this kind forms an admirable position for artillery to assist in the defence.

A few examples are here given to illustrate the foregoing remarks; in each case it is assumed that the musketry fire of the work (or its superior slope produced) must be able to pass within 3 feet of the surface of the gronnd, and that the parapets are 8 feet in height, unless otherwise specified.
312. A salient angle is required to occupy the ground, shown in Fig. 288, by the contour lines.

Two faces, $a b$ and $b c$, are here shown, each parallel to the general line of the slope in their front, and sufficiently retired from its crest to be able to graze the slope by their musketry fire.

This will be evident from an inspection of the profiles, Figs. 284, 285.

The trace here given might be considerably modified : the faces might be retired as far as the lines $d e$ and $e f$ if a smaller work were required, or they might be advanced as far as the lines $g h$ and $h i$ if a larger work were desirable, without affecting the efficiency of the direct defence of the ground in front of the work. Again, if the direction of the line of parapet $a b$ were not


[^17]suitable for the five required from it, it might be made to accupy any position most desirable between $g l o$ and $d e$, as, for instance, $g c$ or $d h$.

Fig. 284.-Scale 36ा


Fig. 285.


This example illustrates a very favourable case; for as the work is situated on level ground at the top of a moderate slope, it can be easily adapted in outline so as to suit the shape of the ground, and to bring a fire into a required direction.
318. In Fig. 286 a less favourable case is illustrated. In this instance a low spur of a hill is occupied with a redan, as an advanced
 work from which a flank fire can be brought to bear on the slopes of the hill.

The slopes of the spur in front of the redan $a, b, c$, are not perfectly defended by the fire of its faces, as will be seen from the profiles given in Figs. 287, 288.

This would be better effected if the faces of the work were retired further back; but then a fresh defect would be the result, owing to the rapid rise of the ground in the interior of the redan, which would render it difficult to obtain proper cover in the work.

Notwithstanding these inconveniences, a position similar to that shown may frequently be occupied with an advanced work, either for the purpose of flanking the slopes of the main hill, or to see into ground otherwise hidden from view. The ground in its front should be defended by a cross fire from the main position in rear, from which also a view of its interior should be obtained.
A principal difficulty attending the construction and maintenance of a work in such a
position would be its drainage. As its salient oceupies lower ground than its gorge, it would be necessary to make drains leading under its salient into the ditch. Too much care can hardly be bestowed on this important point if the work be liable to be occupied for any considerable time.

314. Fig. 289 is an example of a bill occupied on its summit with a redoubt.

It is here supposed that the entrance opening is placed on the rear of the work $G F$; that the three front faces, $\mathrm{H} \mathrm{C}$,CD , and DE, are properly traced, as regarls their direction, for bringing a fire on to ground most requiring it, and that the remaining faces, $H \mathrm{G}$ and EF , are long enough to afford sufficient interior space to the redoubt, or to fulfil any other requirement. Such being the case, the work shown is well adapted to its intended object, for it fulfils the two important points of being able to bring a fire into the required directions, and of suiting the shape of the site on which it is constructed.

The profile of the front face on the line A B, Fig. 290, shows that the slopes of the hill are well defended by the fire from the work.

The outline of the redoubt might be considerably altered from that shown in Fig. 289, without losing the advantage of being able to defend the slopes of the hill, if the requirements of


Fta. 290.-Scale $\frac{1}{\text { To }}$


## Field Fortification.

the work demanded a different direction to any of the faces. For instance, the trace shown by the thick dolted line would be good, so far as regards its suiting the shape of the ground.
315. Fig. 291 is unother example of a hill occupied ou its summit by a work. In this case the site is sufficiently large to allow room for a fort of respectable dimensions, such as is shown in the figure.


Fie. 291.-Scale atoo


Two different outlines are here given, each of which would fulfil the condition of being suited to the site.

The outline shown by the continuous line has certain advantages over the dotted trace: it affords much more interior space to the work, and a more powerful cross fire in front of the main salients, while the latter are generally larger than in the dotted trace. At the same time it has the defect of having its re-entering angles dead, and the ditches of two long faces quite unseen from the parapets. This latter defect would be remedied by the construction of counterscarp galleries in the positions marked $c c$. Notwithstanding the defects here referred to, preference would be given to the trace shown by the continuous line over that shown by the dotted line, on account of the powerful cross fire that would be obtained on the ground in front of the work; and although the ditch is dead near the re-entering angles, that is cousidered as a very slight defeet compared with the advantages just mentioned, and it could be considerably lessened by the judicious use of obstacles arranged so as to prevent au enemy getting easily to the re-entering portions of the ditch.
316. A further illustration is given in Fig. 292 of the manner of occupying a particular site with defensive wooks. In the two preceding cases the dimensions of the sites occupied have fixed to a considerable degree the dimensions to be given to the works. In the present case the summit of the hill is of such large dimensions, that to occupy it properly with a single work, traced so as to be able to defend the slopes of the hill, would be generally impracticable, from the large
force that would be required to defend the work. For this reason, in Fig. 292, the angles of the summit of the hill are occupied with two enclosed works, A and B, traced so as to defend the slopes of the hill, and to afford mutual assistance to each other, while at the same time they are quite independent works. By this means most of the advantages attending the construction of one very large work would be obtained, while only a moderate garrison would be required.

Fic. 292.-Scale $\frac{1}{\text { Tw20. }}$


The space between the works A and B is a good position for artillery for offensive purposes, for the guns placed there would be in a very secure position, while they would have a clear view of the ground in front. In the figure, C represents a battery made for field guns; its parapet might be made about 2 feet in height, from the earth obtained by a wide trench in rear, about 1 foot in depth, affording a terreplein for the guns, which would thus be enabled to fire en burbette, and have a free range.

Trenches are shown connecting the battery $C$ with the works A and B : these trenches, and also the battery $C$, are not indispensable to the defence of the site shown in the figure, but they would add much to the offensive powers of the works, without in any degree crippling the defence.

## CHAPTER XII.

## MILITARY BRIDGES.

Military Bridges defined: their component parts. Trestle and Pile Bridges deseribed. Pontoon Bridges: description of Blanshard's Pontoon Beidge (large and small); its mode of formation and manourring; merits and defects of the Service (Blanshard's) Pontoons. Beidges of Boats: usual formation. Cask Bridgis : how to form a pier of casks, also rafits of casks. RAPT Bridges: advantages and defects; usual construction of. Elxing or Swinging Beidges: details for various cases. Ladder Bridams. Spar Bridges: single and double lever bridges. Rough Bridges over brekin arches, fo. Calculations for Floating Bididge with reference to buoyangx ard stiengeh of bealis, with examples.
317. Any bridge which can be quickly put together, and the materials of which can be transported and carried with an army, may be termed a Military Bridge.

Bridges used for passing rivers or streams will vary according to the nature of the obstacle to be bridged, and the materials available for the work, to an almost infinite extent; but in all cases where a stream is sufficiently broad to prevent beams being laid from bank to bank, without intermediate support, a more or less complicated structure will be required.

The component parts of an ordinary bridge are:-
1st. The Piers (a, a, Fig. 294).

2nd. The Arches ( $\Delta, b$ ), supported by the piers.
3rd. The Roadway, supported by the arches. And in a military bridge a similar method is pursued, in order to be able to carry a roadway.

1st. The Piers. These, in a military bridge, are made in one of two general methods : either they rest ou the bed of the riven, as in trestle or pile bridges (see Figs. 297, 298, 299, in advance), or they are composed of floating bodies (having sufficient buoyancy to carry the superstructure and the weights required to pass over), which can be made in a variety of ways, as for instance with xafts of timber (Figs. 816, 318) ; with empty casks connected together in proper number (Figs. 310, 818, de.); with boats (Fig. 307); or with regular pontoons (Fig. 302).

2nd. The drehes. These, in a military bridge, are superseded by strong beans termed baulks, laid from pier to pier, and therefore rumning in the direction of the roadway. In certain cases chains or ropes may be substituted for baulks.

Fig. 293.


8rd. The Foadway. This is formed of a flooring of planks laid across the baulks, and therefore at light angles to the line of roadway. The roadway should in all cases be finished by securing a ribband along each side (Figs. 298, 815), for the twofold object of stiffening the bridge, and also to aet as a kerb, and so prevent the wheels of carriages slipping over the side.

Each of the ordinary methods of establishing bridges across a stream will now be described.
818. Trestife Bridges. - These are applicable to shallow rivers, whose beds are sound and firm, and which are not subject to sudden floods during the periods within which a sure communication aeross them is required; but they are unsuitable for deep, muddy, and fluetuating streams.

Trestles have the advantages of requiring (compared with other bridges) but little timber, and of being portable, for materials to make a good trestle may be carried by one mule; and if these be previously fashioned, fitted, and the parts numbered, the trestles may be soon put together. Trestles so prepared should be fastened with iron bolts and keys; but if made on the spot, there to remain, wooden pins may be used.

Figs. 294 and 295 are an end and side view of a trestle of the usual construction. The
 capping plate, or head beam (A), should be a stout beam, $8^{\prime \prime}$ square, and will vary in length (according to the required* width of roadway) from 10 to 16 feet.

The legs $(l, l)$ should be notched to fit under the head beam, so as to support it well, and should make an angle with one another, so as to rest on a base about half their height, as in the end view, and they should incline longitudinally, but to a less extent, as in the side view. The braces $(b, b)$ give great strength to the trestle.

[^18]Sipernumeraries in passiog over need not occuly room in addition to that required for a section of fours.

The following dimensions are given in the French "Aide Mémoire," for trestles and beams, when the intervals between the trestles are to be 10 feet:-


After a trestle is got into position two additional legs should be fixed by driving piles into the bed of the river, one on each side of the trestle; these are then nailed to the head beam.
319. In forming a trestle bridge, if the river is so deep as to prevent the trestles being laid by hand, the first trestle may be placed in the following manner (see Fig. 296):-First lay two baulks (a) with their ends resting on the bottom of the river, at the place where the trestle is to stand-the distance between the baulks should be a little less than the length of the trestle; then place the trestle on the inclined plane so formed, as at $b$; lower it to the bottom, and then push the head outwards till the trestle is upright, as shown at c. Ascertain that it has a firm bearing on the bottom. The first set of baulks (usually 5 or 6 in number $\dagger$ ) ean then be laid, their shore ends resting on a beam (a, Fig. 297) sunk to receive them; the planks forming the floor are then laid, and the roadway completed as far as the first trestle. The extra legs for the trestle before referred to, if required, must be fixed before the planiks are completely laid.

Fie. 296.


Fig. 297.


The next trestle would then be fixed in position by laying two beams (b, b, Fig. 297) in an inclined position, resting on the bed of the river and on the first trestle, in a similar manner as before. The fresh trestle would then be laid on the beams, as shown at $c$, and afterwards placed in its intended position, as shown at $d$ : the baulks and planks would then be completed as far as the second trestle. The whole bridge would be completed in this way, trestle after trestle. This is a slow method, and would not be resorted to if the trestles could be laid by hand in shallow water, $\ddagger$ or from boats or rafts if the water were too deep to allow of their being laid by hand. After a trestle is placed, it may be further secured from the action of the current by heaping large stones round its base. This precantion, however, must not be carried to excess, as it contracts the water-way and increases the scour of the stream.
320. Pile Bridges.- In these bridges the piers are each formed with a row of stout piles ( $p, p$, Fig. 298) driven by some kind of pile-driver as far as possible into the bed of the river; their tops are then sawn off level with one another in order to receive a cap-plate (a, Figs. 298, 299). On this cap-plate the baulks are laid in the usual manner, and the roadway formed with planks. Braces $(b, b)$ should be added to each pier of piles. The outer pair of piles should be stouter than

[^19]the others, and it wonld be ndrantageots if they could be driven with a slight slope, as shown by the dotted lines in Fig. 298.

Pile piers should be ns fir apart as the length of the baulks procurable will admit, and should not be nearer to one another than 10 feet.

Pile brilges are suitable for dee日, and muddy rivers, and when the communication is required to last for a cousiderable period.

Piles are also very nseful for forming breakwaters to protect bridges in strong eurrents from the force of the stream, or from anything floating in it, whether by accident or set adrift by an enemy with the view of destroying the bridge. For this purpose three or more piles set in a triangular figure should be driven above each pier (whether of rafts, trestles, or boats), and fastened together by strong cap-pieces, well braced and planked, so as to form a powerful buttress or breakwater, presenting an angle to the current.


Pile bridges are unsuitable equally as trestle bridges for streams liable to sudden floods, and both natures have the objection of not allowing drifting matter to pass under the points of support, as is the case in floating bridges.

Todrive the piles.- When the bridge is intended for light weights, piles $6^{\prime \prime}$ or $7^{\prime \prime}$ in diameter may be used and driven by hand, with heavy mauls, as shown in the annesed sketch (Fig. 300 ); and in this way piers may be formed sufficiently strong to bear infantry on a front of two or three files, with open ranks, and not keeping step.

When piles of $8^{\prime \prime}$ in diameter, or upwards, are used for the piers of a bridge, they will require to be driven by some lind of pile-driving machine. When pile-drivers are constructed in the field, the ram (or weight used to drive the piles) might be made from an $8^{\prime \prime}$ shell filled with lead. The shot or shells of rifled guns would be still better for the purpose.

## FLOATING BRIDGES.

321. Pontoon Brmges will be first described under this heading, as they illustrate a Military Bridge in a form more nearly perfect than other floating bridges.

The pattern of pontoon adopted by different nations varies considerably; for example-
The Austrian, Belgian, and Prussian pontoons are open iron boats or bateaux. The French use open wooden bateaux ; so, also, do the Italians. The Russians use open canvas pontoons, with a wooden framework, which can be taken to pieces.

The English pontoon during the Peninsular War was an open boat of tin; these were superseded by others, proposed by Sir James Colleton of the Staff Corps, forming buoys: they were closed vessels of a shape between that of a cylinder and that formed by the junction of two cones nt their bases. The pontoons now in use are those proposed by the late Major-General Blanshard, K.E., and will now be described.
322. Blanshard's Pontoon Brioge is composed of pontoons made of tin cylinders, with the requisite baullss, chesses, \&c., for the superstructure.

The equipment is organized by Rafts ; each raft is packed and carried on one wagon, and is composed of two pontoons, with the superstructure necessary to complete two bays of the bridge, i. e., the two intervals between three adjacent pontoons.

As the pontoons are placed, when the bridge is formed, at intervals of $12^{\prime} 6^{\prime \prime *}$ from centre to centre, each raft (or wagon load) forms 25 feet of bridge. Each raft also is able to be rowed about on the water; the oars, boathooks, \&e., that are required for rowing, are afterwards used as ribbands to the bridge. One N. C. Officer and six men are required as a crew for each raft; they accompany their own wagon on the line of march, and on the water they manœuvre the raft, and form their portion of the bridge.
323. The following table shows the dimensions, weight, \&c., of one complete raft, forming a wagon load.

TABLE OF STORES OARRIED ON A PONTOON CARRIAGE.

|  | No. | dimensions. |  |  | WETOHT, |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Length. | Breadth. | $\begin{aligned} & \text { Depth or } \\ & \text { thickness. } \end{aligned}$ |  |  |  |
| Banlks | 12 | $\begin{array}{ll} \text { ft. in } \\ 14 & 2 \end{array}$ | $\begin{array}{ll} \text { ft. } & \text { in } \\ 0 & 4 \frac{1}{2} \end{array}$ | $\begin{array}{lc} \hline \text { ft. in, } \\ 0 & 3 \end{array}$ | cwt. | $\stackrel{\text { qrs. }}{1}$ | $\begin{aligned} & \text { libs, } \\ & 22 \end{aligned}$ |
| Chesses | 10 | 115 | 21 | 0 1112 |  | 2 | 18 |
| Half Chesses | 4 | 11 | $1{ }^{1} 0 \frac{1}{2}$ | 0 1 $1 \frac{1}{2}$ | 1 | 1 | 16 |
| Saddles. | 2 | 120 | 12 | $0 \quad 3$ | 1 | 1 | 27 |
| Saddle Lashings | 1 | 150 | $0 \quad 1$ | Rope. | 0 | 0 | 5 |
| Anchors | 1 | Shank. 310 | Flukes. $20$ | Flukes. $\begin{array}{ll} 0 & 1 \end{array}$ | 0 | 1 |  |
| Auoy... | 1 | 20 | 010 | 010 | 0 | 0 | $5 \frac{1}{4}$ |
| Outriggers | , | 115 | 0 ( $4 \frac{1}{2}$ | $0 \quad 3$ | 0 | 2 | 20 |
| Cable, 30 fathoms | 1 | 180 | $0{ }^{0} 8^{2}$ | Rope. | 0 | 2 | 7 |
| Pontoons | + | 223 | 28 | 28 | 8 | 2 | 0 |
| Carriage Lashings | 4 | 220 | $\begin{array}{ll}0 & 1\end{array}$ | Rope. | 0 | 0 | 7 |
| Oars | 7 | 140 | ...... |  | 0 | 3 | $24 \frac{3}{4}$ |
| Boat-hook | 1 | 160 | ...... |  | 0 | 0 | 9 |
| Body Lashings | 3 | $8 \quad 9$ |  | Webbing. | 0 | 0 | 20 |
| Rack Lashings | 8 |  | $\begin{array}{lll}0 & 2 \\ 0 & 1\end{array}$ | Rope. | 0 | 0 |  |
| Raek Sticks... | 8 | 10 | 0 1 1 12 | $0 \quad 1 \frac{1}{2}$ | 0 | 0 |  |
| Buoy Line | , | 60 | 0 | Rope. | 0 | 0 |  |
| Breast Line. | 2 | 60 | 0 | Rope. | 0 | 0 |  |
| Oar Lashings | 2 |  |  | Rope. | 13 | 0 3 | ${ }_{20}^{1 \frac{3}{4}}$ |
| Carriage weighs | . | ....... | ....... | ....... |  | 3 |  |
| Total weigh |  |  |  |  | 42 | 8 | $2{ }^{\frac{3}{4}}$ |

There are four distinct component parts in the bridge ; viz., the Pontoons, the Saddles, the Baulks, and the planks, termed Chesses.

The Pontoons (Fig. 301) are cylindrical in form, with hemispherical ends; they are made of sheet tin, framed round a series of light wheels constructed of tin, having hollow tubes one inch
 length of the pontoon. Each pontoon is divided into nine distinct water-tight compartments.

[^20]A serew plug ( $a, a$, Fig. 301) is fitted to each compartment, to allow of a pump being introduced. Five rows of sumken handles are provided to ench pontoon, to allow of its being carried by hand, or secured by lashings, do.
postoar (mianarand's).
Fxg. 301. a $\quad$ b $\quad$ a $\quad$ b

$a \alpha$. Pump holes. be. Partitions.

The Saddle (S S, Fig. 302) is a framework of fir, $12^{\prime}$ long and $1^{\prime} 2^{\prime \prime}$ broad, which is placed lengthwise on the pontoon, to which it is secured by being lashed to the handles; its object is to receive and secure the ends of the baulks extending from pontoon to pontoon. Each saddle is provided with six iron pins for that purpose.

The Baulhs are of fir; they are six in number, and are long enough to rest on the ontside beams of two saddles.

The Planks (termed Chesses) are of two sorts, viz. :-
(1.) Whole Chesses, each of which is formed of three planks comnected together by four . cleats on the under side, one at each end, and the other two, as shown in Fig. 302, projecting slightly beyond the planks, so as to fit into the cleats of the adjacent chesses.

(2.) Half Chesses, which are only half the breadth of a whole chess, and have no projecting cleats: they are placed over the saddles to afford ready access to the saddle pins, as seen in Fig. 802.

Outriggers for rowing are beams having three couples of cleats in each, which act as rowlocks. When used for rowing, they are fastened over, and in a parallel direction to, the saddles. At other times they are used with the oars as ribbands to the sides of the bridge.
324. There are two methods of forming this bridge from the shore.

1st. By independent rafts.
2nd. By booming out.
In the first case, each raft detachment forms its own raft independently at the edge of the water; and then rows to its place in the bridge, joins its baulks to the adjacent raft, and completes its portion of the bridge.

This method has the following disadvantages:-
1st. A considerable length of bauk of the river, varying with the number of rafts, is required to be occupied. This is a great inconvenience, particularly if the banks be steep and muddy.

2nd. Difficulty of supervision, owing to the work being spread over much ground.
325. The method of forming the bridge by booming out is as follows:-

Three saddles are first laid on the shore, and are connected together by pinning the baulks in their proper places. The framework thus formed is lifted by hand, and is then carried towards the water, until the men who carry the front saddle * are so far in the water that a pontoon can be floated and adjusted under it. The pontoon being put in position, the saddle is then laid on it, and immediately lashed to it. Directly a pontoon is thus inserted in its place and the saddle laid on it, the workmen bring up a fresh saddle and a fresh set of baulks, and connect them to the rear of those already placed; the object being to have always three saddles on the shore ready to be lifted, as shown in Fig. 302. The same operation is then gone through of lifting the framework of baulks and saddles; pushing (or booming) out the whole so as to be able to insert a fresh pontoon, which is then lashed to its saddle; and a fresh set of baulks and a fresh saddle are then connected on shore.

When the second pontoon is placed and lashed, the chesses covering the space between it and the first are passed on to the bridge from the shore, and are laid in their proper place, as in Fig. 302; afterwards, as the bridge is boomed out, pontoon by pontoon, the chesses for each separate raft or bug are brought up and laid in their places until the whole length of bridge is completed. At the same time the oars, \&e., used for rowing, are laid over the ends of the pontoons of each raft in succession, as the booming out proceeds.

While this operation is in progress, as above described, anchors are cast in their proper positions, above and below the bridge, by a hoat or raft used for that purpose; and the ends of the cables being brought on to the bridge, are held there by men told off for the purpose, who keep the bridge in position while it is being boomed out. When the booming out is completed, the cables are fastened to the handles of the saddles, which are termed the belaying cleats.

As soon as the booming-out is completed, if the bridge is required at once as a passage for troops, the oars, \&e., are laid along the sides of the roadway so as to act as ribbands, and are secured by racklashings to the baulks underneath. The baulks which join on to the shore should be connected to a beam (as $a$, Fig. 297) securely fastened in the ground. The bridge is then complete.

This method of forming a bridge by booming out from the shore has the following advantages :-

1st. A short length of bank only is occupied, which may be a most important consideration if the sides be steep and muddy, requiring rough roads to be formed.

2nd. The operation, being concentrated, can be properly supervised.
3rd. It is rapid, as there is a complete division of labour among the workmen, $\dagger$ and the operation can be (and is) reduced to a drill. So much is this the case that, even if a number of rafts are required to be put in the water to row elsewhere, and not to form a bridge on the spot, it is quicker and better to boom them out from the shore, and afterwards break up the bridge into rafts, than it is to form all the rafts independently.

Fig. 303 shows in plan four rafts (and part of a fifth) of a complete bridge. The dotted lines joining the pontoons of adjacent rafts represent breast lines, which are thin ropes, connecting the anchored rafts to those which have no anchors. $\ddagger$

If the bridge is required to be brought on shore, the oars, \&c., are unracked, and the bridge can then be boomed in, in a similar but reverse manner to that pursued in booming it out.
326. The method of breaking up a complete bridge into separate rafts, supposing it is required to be rowed away and formed elsewhere, will now be described. This operation can be carried

[^21]out, more or less perfectly, with most floating bridges, whether of pontoons, casks, or boats, nccording to their construction, but with the service pontoons it is reduced to a regular drill. The first step in the operation is to clear the rondway, by unracking the oars, c., which form the ribbands, and laying them temporarily across the ends of the pontoons of each raft (not bay).

The chesses of each bay are then lifted up, and are carried and laid, bottom upwards, on those of their own raft. The half chesses, which have no projecting cleats, allow this to be done with ease.

The baulks of the bays are then unpinned, lifted out of their places, and laid on their own rafts, three on each side ; the four centre banlks are first moved, and the two outer ones last: the saddle pins are immediately replaced, so as to keep the raft baulks secured. At this stage of the operation, the rafts without anchors are kept in their positions by the breast-lines before referred to.

The outriggers of each raft (two in number) are then lad over the saddles, and are secured to them by racklashinge, in readiness for the men to row.

The breast-lines are next unfastened; and the reserve rafts, Nos. 2, 4, 6, \&c. (those without anchors), then drop down with the current, clear of the line of anchors, which is marked by buoys attached to each, and form in rear of the mooring rafts, as shown in Fig. 304.

The final operation, that of weighing the anchors of the mooring rafts, is then performed as

Fio. 304.-Scale $\frac{1}{100}$.
 follows, by each of those rafts. The two eables hitherto secured to the handles of the saddles are cast off (unfastened), and are secured to one another with a sheet bend (Fig. 64). Each raft is then hauled by means of the cables until it comes over its lower anchor, which is then weighed. The raft is then havled in the direction of the stream (the cables being coiled as they come on board) until it comes overits stream anchor; the reserve rafts keeping at a proper distance behind the respective mooring rafts. Finally the stream anchors are weighed, which completes the operation, as the rafts are then free to row wherever required.

In rowing, three men work on each side, the raft being steered by the N. C. O. in charge, by means of an oar in the rear, as shown with the reserve rafts in Fig. 304. When rowing against the current, the mooring division lead; when rowing with the current, the reserve division is in front: by this means the operation of anchoring is not likely to be interfered with by the reserve rafts being carried by the current foul of the mooxing ones.
327. When the bridge is required to be formed from rafts, the converse of the preceding operations is gone through, according to the following order:-
(1.) The crews of the mooring rafts cast their stream anchors in the intended position.
(a.) They then drop down with the current (paying out the cable as they go) past the intended position of the bridge, and cast their lower anchors.
(3.) They then hanl back their rafts into their intended position in the bridge, unbend (unfasten) the cables, which they secure to the saddles.
(4.) The reserve rafts ( $\Omega, 4,6,4, \& c$. , without mehors) then come up into the intervals between the mooring rafts, and are secured to them by the breast-lines.
（5．）The outriggers having been umacked，the bay－baulks are then laid from raft to raft．
（6．）The chesses are next laid over the baulks of the respective bays．
（7．）Finally，the oars，outriggers，and boathooks are laid along the edges of the roadway，and are racked down．The bridge is then complete for the passage of troops．

328．In case a gap is required to be made in the bridge，to allow the passage of vessels or floating timber，\＆ce，past the bridge，a raft can quickly＊be moved out of the way by removing the superstructure of the bay on each side of it on to the adjacent rafts，and then allowing the raft to drop down with the current clear of the gap thus formed，which will be more than $30^{\prime}$ broad．

The foregoing is a general description of the nature and construction of the large pontoon bridge at present in use in the British service．When the pontoons are at open order（ $12^{\prime} 6^{\prime \prime}$ from centre to centre），the bridge is fit for the passage of infantry in fours，cavalry in file，and for light field artillery：when constructed at the intermediate order（ $10^{\prime} 5^{\prime \prime}$ from centre to centre），the bridge will support guns of the weight of the medium 12 －pounder，which weighs 18 cwt ．，or the Armstrong 20 －pounder，which weighs $16 \frac{1}{2} \mathrm{cwt}$ ．At the close order，the bridge is of course stronger and more buoyant，and would support heavy artillery；but it is not recommended to pass heary guns，such as the 50 cwt ．， 24 or 32 －pounders，or the 70 －pounder Armstrong gun，across a pontoon bridge．When such heavy artillery is required to pass a river by means of the pontoon equipment，a raft would be formed with four pontoons，at one half the distance apart of the open order，by which contrivance there is double the buoyancy that there is in the bridge at open order， while the strength of the baulks is more than doubled，as their bearing will be only $5^{\prime} 1^{\prime \prime}$ ，while at the open order it is $11^{\prime} 6^{\prime \prime}$ ．If necessary，a double set of baulks throughout the raft would be used， by fixing extra cleats on to the saddles．

329．The Infantry Pontoon Bringe．－The Infantry Pontoon Bridge is similar in general construction to the large bridge，but differs in the following details．The pontoons require no sunken bandles for carrying them；their ends are conical，with a ring at each extremity．The saddles are secured to the pontoons by girths，which is rendered necessary on account of there being no sunken handles in the pontoons to which they could be lashed．

The equipment is carried on carriages，each of which holds five pontoons with the necessary superstructure，according to the following detail：－
table showing the weight，dinensions，etc．，of one carriage load of infantry pontoons．

|  | No． | dminssions， |  |  |  |  | Wright of onk． |  | toial weloht． |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  | Length． |  |  | 淢 | $\begin{gathered} \frac{1}{4} \\ \stackrel{y}{4} \\ \hline \end{gathered}$ |  |  |  |  |  |
|  |  | $\begin{aligned} & \text { 蓸 } \\ & \text { 券 } \end{aligned}$ | Cone at end． |  |  |  |  |  |  |  |  |
| Baulks | 30 | ft．in． | ft．in． | $\begin{array}{cc} \mathrm{ft} & \text { in. } \\ 6 & 4 \frac{1}{2} \end{array}$ | $\begin{array}{\|cc\|} \hline \text { ft. } & \text { in. } \\ 0 & 3 \end{array}$ | $\overline{\mathrm{ft} .} \overline{\mathrm{in}} \mathrm{c}$ | $\frac{\mathrm{cwrt}}{0} \mathrm{qrse}_{0}$ |  | $\stackrel{\text { cwt．}}{1}$ |  |  |
| Chesses． | 20 | ． | ．． | $80^{2}$ | 14 | $0 \quad 0 \frac{3}{4}$ | $0 \quad 1$ | 2 | 5 |  |  |
| Saddles | 5 | ．． | ．． | $8 \quad 2 \frac{1}{2}$ | 0 | 0 21 | 0 | $22{ }^{\frac{3}{3}}$ | 1 |  | $4 \frac{3}{4}$ |
| Side Pieces ．．．．．．．． | 10 | ．． | ．． | $10{ }^{1}$ | 0 | 0 13 | 0 | 11 | 0 |  |  |
| Anchors | 2 | ．． | ．． |  |  |  | $0 \quad 2$ | 0 | 1 | 0 | 0 |
| Buoys | 2 | ．． | ．． | 18 | $\begin{array}{ll}0 & 9\end{array}$ | 0 | 0 | 5 | 0 |  | 10 |
| Cables | 2 | ． | ．． | 120 | 0 | Rope． | 0 | 18 | 0 | 1 | 8 |
| Pontoons | ， | ．． | ．． | 15 | 17 | 17 | 11 | 1 | 6 |  | 5 |
| Paddles．． | 10 |  | $\ldots$ | $510 \frac{1}{2}$ | 09 | ．． | $0 \quad 0$ | 4 | 0 | 1 | 12 |
| Girths，\＆c． | 10 | Webb． $38$ | $\begin{gathered} \text { Lashing. } \\ 86 \end{gathered}$ | 122 |  | 0 | 0 | $4 \frac{1}{2}$ | 0 |  |  |
| Racksticks \＆Lashing | 10 | 20 | 76 | $\begin{array}{rrr}12 & 6\end{array}$ | 0 | Rope． | 0 |  | － |  |  |
| Chess Lashing．．．．．． | 10 | ．． | ．． | 86 | $\begin{array}{ll}0 & 1 \\ 0 & 1\end{array}$ | Rope． | 0 |  | 0 | 0 |  |
| Buoy Lines ．．．．．．．．． | 2 |  | ． | 400 | 0 | Rope． | $0 \quad 0$ |  | 0 | 0 | $\stackrel{2}{3}$ |
| Breast Lines ．．．．．． | 2 | $\cdots$ | ．． | $60 \quad 0$ | $0 \quad 1$ | Rope． | 0 |  | 0 | 0 0 | 3 0 |
| Caxriages ．．．．．．．．．． | 1 | ． | ． |  |  | ．． | $9 \quad 0$ |  | 9 | 0 | 0 |
| Total weight | ． | ．． | ．$\cdot$ | ． | $\cdots$ | ． | ． | ． |  | 2 |  |

[^22]320. The briage is generally put together on hand, and conveyed complete to the water by men placed two at each end of every poutoon. The men hold on by racksticks passed through the rings at the extremities of the poithons. They launch the bridge gradually ; the men carrying the pontoous, as they rewch the wuter, in sucoession let go their hold. If theve be a stream runming, it is necessary to have anchors cust on the strean side of the bridge before this operation is effected. The side pieces, used u6 ribbands, are then brought on to the bridge, and are racked dorn.

The bridge cau be boomed out, broken up into rafts, mancenved and reformed into a bridge in a similar mamer to the lurge bridge. Paddles are used instead of oars for rowing.

8M1. Owing to its lightness, the infantry bridge can be carried by hand whea quite complete, snd fussed down very steep banks, or down the counterscarp of a fortress into a wet diteh. In oarryiug out such an operation, it is neeessary to lay two baulks, or ladders, on the bank, for the pontoous to slide on, and also to turn the chess which is over each saddle, back on to the next chess; the chesses must then be lashed (to prevent their slipping) to the baulks.

Owing to the haulhs being pinned only on one side of the saddle, the superstructare can be bent at every pontoon at a right angle, so that the bridge, on account of this pliancy, will pass down the ladders, and riguin become level on reachiug the water. Over this it will pass from the impetns acquired in its descent. Troops could then get on to the bridge by means of the laddera, and raise other ladders against the escarp; and in this mammer a coup-de-main might be sttempted aguinst a fortress with wet ditches, having a weak or ill-disciplined garrison.
352. The pontoons in this bridge are $5^{\prime} 4^{\prime \prime}$ rpart from centre to centre. When the bridge is racked down, it will carry infantry on a front of three; and with care, light field artillery may be passed over it.

The infantry bridge has the advantage of being light: one carringe-load weighs only 14 ewt. (carriage net included), and will form $26^{\prime} 8^{\prime \prime}$ of bridge, i.e. 5 bays each $5^{\prime \prime} 4^{\prime \prime}$ in length. The pontoons with their equipments are so light as to be easily transported by hand, if necessary, through difficult country. A raft forms a very good substitute for a boat.
338. Before describing other kinds of floating bridges, the merits and disadvantages of Blanslard's puatoons will be stated.

Their advuntages are the following:-
1st. The cylindrical shape allows the poatoons to be carried easily by hand, to be rolled down banks, where it would be inconvenient to carxy them (baulks or chesses being laid on the slope), and any part of a pontoon may be used uppermost in a bridge: this latter is a grent convenience, in case of holes being accidentally made in a pontoon while in the water, us it allows the pontoon to be moved round, so as to bring the damaged part to the top, when it can be temporarily repaired.

2nd. On acoount of the pontoons being elosed air-tight vessele, no hafm reoults from a sudden weight pushing them under water; consequently their total displacement may be taken advantage of,$\dagger$ which is not the case with uncovered pontoons or boats.

3xd. The air-tight compartments of each pontoon prevent the possibility of s single fracture rendering the pontoon unserviceable, thereby lessening the danger from accidents.

4th. The great facility with which the bridge san be beomed out, and the rapidity with which it can be formed from or broken up into rafts, are the chief adrantages of the system.

On the other band, there are serious defects inherent to the system which go far to counterbalance its peculiar udvantages.

1st. While the closed nature of the pontoon has its advantages, as before mentioned, it prevents the interior from being seen, and consequently renders repairs difficult.

2nd. The thinness of the material used renders the pontoons easily damaged, $t$ and unsuited to the rough usage of actual campaigning.

3rd. The bulk of the pontoons is u great inconvenieuce in transport, and also in embarking and disembarking them from ships. In pontoons formed of open batenus, their interior is more or less available for preking some of the stores in.

[^23]4th. The shape of the section of the ponteon (a eirele) prevents the bridge being stable when great weights (such as guns) are being moved across it, which is the moment when stability is most required.

This requires more detailed explanation, as it is perhaps the greatest defeet in Blanshard's Pontoon Bridge.

Sir H. Douglas' treatise on Military Bridges states, par, 51: "It is essential to the stability of floating bodies that their bearing should increase with the increase of their immersion vertically; that is, their horizontal sections should expand up to the plane of flotation or horizontal surface of the fluid in which the vessel floats. In cylindrical vessels this only takes place up to the immersion of their horizontal diameter (as $a, b$, Fig. 305), after which-that is, after they are half immersedthe section coinciding with the plane of flotation diminishes; and the nearer the ressel approaches to entire immersion, its descent in the water becomes greater and greater with every equal angmentation of load, which is just the reverse of what it should be. The bearing of a vessel of a trapezoidal, or boat-like shape, increases up to the extreme power of flotation; and this has ever been considered the grand desideratum in determining the configuration and providing for the stability of floating bodies."

Three sections are shown in Fig. 305, which are, or approximate to, those of pontoons of the most usual form, viz. :-

1st. A circle, the section of the cylindrical pontoon.
2nd. An isoseeles triangle, the section of the boatshaped pontoon.

3rd. A rectangle, the section of the flat-bottomed pontoons or bateaux.

For purposes of comparison they are drawn of

Fra. 305.
 equal area, in order to represent pontoons of equal ultimate displacement; and the same depth $\left(3^{\prime}\right)$ is given to each.

The following table shows their vertical immersion for each tenths of their total area:-

| Portion of Total Area immersed. |  |  |  | Tetal Vertical Immersion. |  |  | Increase of Vertical Immersion. |  |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
|  |  |  |  | Circle. | Triangle, | Rectangle. | Circle | Triangle. | Rectangle. |
| One-tenth.. |  |  |  | inches. $5 \cdot 65$ | inches. <br> 11.40 | inches. $8 \cdot 60$ | inches. <br> 8.65 | inches. <br> $11 \cdot 40$ | inches. <br> $3 \cdot 6$ |
| Two-tenths | . . | . | , - | $9 \cdot 14$ | $16 \cdot 10$ | $7 \cdot 20$ | $3 \cdot 49$ | $4 \cdot 7$ | 3.6 |
| Three-tenths | .. | . | . | $12 \cdot 24$ | $19 \cdot 72$ | 10.80 | $3 \cdot 10$ | 3.62 | 3.6 |
| Four-tenths | . | . | .. | $15 \cdot 16$ | 22.75 | 14.40 | $2 \cdot 92$ | 3.08 | 3.6 |
| One-half .. | . | . | . | $18 \cdot 00$ | 25.45 | $1 \times \cdot 00$ | $2 \cdot 84$ | 2.70 | 36 |
| Six-tenths | .. | . | . | $20 \cdot 84$ | 27.89 | $21 \cdot 60$ | $2 \cdot 84$ | $2 \cdot 44$ | 3•6 |
| Seven-tenths | . | . | . | 28.76 | $30 \cdot 13$ | 25.20 | 2.92 | $2 \cdot 24$ | 8.6 |
| Eight-tenths | .. | . | .. | 26.86 | 82.21 | 28.80 | 3.10 | 2.08 | $3 \cdot 6$ |
| Nine-tenths | . . | . | .. | $30 \cdot 35$ | $34 \cdot 16$ | $32 \cdot 40$ | 8.49 | 1.95 | $8 \cdot 6$ |
| The whole | . | . | . | $36 \cdot 00$ | $36 \cdot 00$ | $36 \cdot 00$ | $5 \cdot 65$ | 1.84 | $3 \cdot 6$ |
|  |  |  |  |  |  |  |  |  |  |

334. Bridges of Boats.-Bridges are frequently made across rivers which are too rough and broad for ordinary pontoons, by using the boats that can be procured on the river, as floating piers; and by connecting them by baulks fastened to a temporary trestle or saddle fixed in each boat; the chesses forming the roadway are laid in the usual manner, and are secured by ribbands to the baulks.

The following conditions should be fulfilled, as far as circumstances will permit:-
Boats of the same size should be used, as they will be equally immersed by equal weights, thereby keeping the roadmay as level as possible. With very large boats or harges this precaution is not so necessary, as their buoyancy will be much in excess of what is required to support the

## Field Fortification.

henviest weights likely to pass. Under such circumstancos, the intervals should be made as great as the timber procurable for baulks will nllow. The boat nearest to the shore at ench end should be stronger and more capacious than the others, as it has to withstand the pressure of heavy vehicles iescending from the banks to the bridge.

If small boats of different capacities are necessarily used in the same bridge, the intervals between them should be regulated accordingly.

The construction of the bridge should be such as to allow the boats to undulate a little with the swell, as the security of the bridge will thereby be much increased. This will be effected by securing the baulks to a trestle, the top beam of which rises above the gumwales, as in Fig. 306, as the boats can then incline considerably to either side without inconvenience to the roadvay.

It would be objectionable to lay the baulks, as shown in Fig. 807 in plan, where each baulk rests on both gunwales of the boats, if much motion in the bonts is probable, as such motion would be too much restrained, and would tend to break the baullis.

It would also be objectionable to lay the baulks as in Fig. 308, where each baulk rests merely on the nearest gunwales of two adjacent boats, as a heavy weight passing over the bridge would cause the boat to dip or heel very much. This objection, it must however be observed, gets less in degree us the boats used are large, and hardly applies at all to barges, lighters, and vessels of from tweaty to thirty tons or upwards.

Fra, 306.


Fig. 809.


Ets. 307.


The buoyancy of each boat should be such that the greatest weight to be carried shall not immerse it sufficiently to risk its being swamped at the moment of its maximum immersion; a height of $9^{\prime \prime}$ above the surface of the water is the minimum that should be allowed for the gunwale at the moment of its greatest immersion ; and to prevent the wash of waves at that time filling the boat, it is a good precaution to cover the boats with a light framework covered with eanvas.

In a bridge of boats, ench boat is usually anchored head and stern; and the boats are fastened together by pieces of timber lashed across their ends, 80 as to preserve the proper intervals and relieve the baulks from strain.

The saddle may be formed when large, strong boats are used, by laying a stout beam of the proper length, according to the intended width of the roadway, on other beams laid across the bont; but with small boats, the sides of whish are usually slight, it will be necessary to support the beam (A, B, Fig. 309) on the kelson.

When constructing a bridge, provision should be made for allowing a portion of it to be quickly withdrawn, in the event of its being necessary to pass vessels or floating timber, ice., through the bridge.
385. Cask Ermars.-After what has been deseribed in explanation of the construction of pontoon and boat bridges, it will only be necessary to consider casks with respect to their buoyancy, and the manner in which they are nsually connected together so as as to form the piers of a floating bridge.

When collecting casks for bridges, they should be carefully sorted. Large casks are to be preferred to suall ones, because, with them, piers are more easily put together; and with equal buoyancy a pier of large casls will weigh much less than a pier of small ones, - a matter of great importance should they require to be transported by land. The casks generally used for bridging
purposes at Chatham are those formerly used for water in the Navy, before iron tanks were introduced. Their length is $4^{\prime} 3^{\prime \prime}$, head diameter $2^{\prime} 2^{\prime \prime}$, bung diameter $2^{\prime} 9^{\prime \prime}$; their weight averages 174 lbs . each. Seven of these casks connected together in the manner about to be described, form an efficient substitute for a pontoon, each cask having a buoyancy of about 1170 lbs.

To form a pier with these casks, seven of them are laid together side by side, with the bungs uppermost; two beams termed gunwales are then laid on them, as in Figs. 310, 311, 312 , parallel to one another, and about $6^{\prime \prime}$ inside the ends of the casks; slings ( $s, s$ ) of strong rope are then passed from one end of each gunwale, under the casks and fastened to the other end; next, twelve small ropes $(b, b)$, called braces, are fixed to the sling, six on each side, at the intervals between the seven casks; each brace is then brought up, turned once round the gunwales and passed to the opposite side round the opposite brace ; it is then brought back, hauled tight, and fastened round its own gunwale: in this manner the seven casks are firmly connected together into a pier. Fig. 312 shows the manner in which the braces are fastened; $s, s$ represent the slings, and $b, b$ the braces, which are shown loosely fastened, for the sake of clearness.

Barrel-piers are put together on shore, and are launched separately; they are then connected in pairs by means of beams termed transoms ( $a, a$, Figs. 313, 315), and are formed into rafts by laying the baulks and chesses in the usual manner. The central intervals of the piers (both in a raft and a bay) are made $18^{\prime} 9^{\prime \prime}$. This distance is a mul-


Fig. 315.-End elevation.

tiple of $2^{\prime} 1^{\prime}$, the breadth of the pontoon chesses, which are nsed at Chatham for the superstructure of the cnsk bridges constructed there. When the superstructure of ench ruft is laid, that for the bay is packed on it, and the raft can then be rowed or bauled into its position in the briage. Moorings for each raft should be laid before the raft is brought to its station.
396. Rurt Bropges. - Rafts of timber used as floating piers are resorted to, when other kinds of floating piers aro not to be procured, but they have the defects of hnying low bnoyancy, und, if in the water for any length of time, are apt to become water-logged ;* they ure, ulso, comparatively clumsy, and require considerable time in their formation.

At the same time they have the merits of being able to be put together by inexperienced workmen; they cannot be sunk by an enemy, and if not disturbed will last for a cousiderable time.

In arranging trimks of trees or other large timber for a raft piex, the shape shown in Fig. 318 should be given to the pier, so as to present a sort of bow to the enrrent. Each pier should be not less than $45^{\prime}$ long, and the simbers should be connected by braces. A second tier of trees will frequently be xequisite, in order to obtain the proper buoyancy.



Figs. 316, 317, are a plan and section of the great bridge of rafts constructed by the Russians across the main harbour of Sebastopol in 1855 . The following short account of it has been translated from the journal of the siege, written by Marshal Niel, of the French Corps du Géníe.
" It was in the month of August 1855, that the Russians constructed the great bridge of rafts across the harbour of Sebastopol, 80 as to unite Forts Nicholas and Michael; it was undertaken at the suggestion of Lieutenant-General Buckmeyer, who constructed it with remarkable rapidity, commencing at both ends simultaneonsly.
"The construction of this bridge, which was more than 1,000 yards long, and the roadway of which was $17 \frac{1}{2}$ feet wide, afforded the Russians a communication more certain, easy, and rapid than that which could be effected by means of steamers, and it rendered Sebastopol a real bridgehead. The garrison could keep their reserves secure from the effects of our fire on the north side, and yet the whole Russian army could have united with the garrison during the night, and have attacked our siege works unexpectedly. If we became masters of the place, the garrison ran no risk of being taken prisoners, for they could at any time retire to the camps on the north side, and remove or destroy the bridge."

[^24]It was opened for the passage of troops on the 27th of August, and was entirely removed by mid-day on the 9th of September, or forty-eight hours after the Malakoff was assaulted.

Figs. 318, 819, show in plan and section a bridge of rafts thrown across the Dambe by the Russian army under Prince Paskiewitch in March 1854; it was designed by General Buckmeyer.

Each pier was formed of seven logs contiguous to each other, the thicker ends directed up stream, and pointed as presented in the plan. Two piers were formed into a raft, the interval being six or seven feet. The rafts formed in this manner were at like intervals, and were so connected by baulks as to allow of a motion adequate to the very slight movement which these long rafts could aequire from the small waves of the Danube. Each pier had an anchor up stream, the cable being made fast to a small wooden capstan fixed on a platform near the ends of the logs. There was also one anchor down stream for each raft, the cable being fixed to a small capstan on a platform between the piers. The roadway, which was 14 feet in width, was placed with its centre, not over the centres of the logs, but over the centre of flotation; and, in addition, there was a footway the whole length of the bridge, about $2 \frac{1}{2}$ feet wide, between the carriage-way and the large ends of the logs.

When the logs were small and insufficient, supplemental logs were placed in the intervals under them, as shown by $x x$, Fig. 319.

Raft Bridge thrown over the Danube in 18544
Fiff. 318.-Scale $\frac{1}{\text { Tis }}$


Fic. 321.


Fig. 322.

Fig. 319.-Section on AB. $y y$, Capstan platforms.
337. Flying on Sifinging Bridges.-A flying or swinging bridge is formed by anchoring a floating body in a river, so that it shall receive the action of the stream obliquely, by which a force is derived from the current to move the vessel across the river. The boat or raft (A, Fig. 320), fastened by a cable to the buoy B, securely anchored, will, in crossing the river from C , soon come
into the line of direction of the current ( BD ) , and if she be steered in a proper degree of obliquity, she will pass through the ascending part of the are to the opposite bank at $\mathbf{E}$, whence she may be made to recross to $O$ in a similar mannex. The angle that the keel of a bat should make with the ourrent has been calculated to be $54^{\circ} 44^{\prime}$, supposing the boat to move across the river in a straight line. The length of oable ( B C ) should not be less than $1 \frac{1}{2}$ times the breadth of the river; and intermediate buoys ( $1,2,3$, Fig, 820) will be required to support it, if it be long,

Long and narrow boats are most suitable for flying bridges, because the longer the boats that are used, the greater length of side there is for the current to act upon; and also the bow resists the action of the corrent less, when narrow, than when it is broad.

The oable, if secured on deck, should be fastened at about one-third of the leugth of the boat from the bow, in order to allow the boat to answer the helm properly.

If the river be rery broad, two flying bridges may be employed, regulated so as to meet one another in the cantre of the stream, where they exchange cables as in Fig. 321, where the boat D falling into the are E F resigns its path to the boat E.

If the current be too rapid for the bridge to encounter with safety the resistance during the ascending part of the are, as in Fig. 321, the passage can be made in a descending arc, as in Fig. 392, where the boat at A crosses to the opposite bank at B in a descending are, taking with her the rope B C , by which she recrosses from the point $D$ (taking with her the rope $E A$ ), to which point she must be hauled up from $\mathbf{B}$ when close to the shore.
398. Spar and other Bridges for Crosstng Smhll Streams, Bronen Arches, etc,-The bridges that have been hitherto described ave those ordinarily used for the passage of large streams; in general they require considerable preparations beforehand, in order to construct them with ease and rapidity; but small streams, ditehes, \&c., may form serious impediments to the movement of troops, and afford ample soope for ingenuity in devising methods of passing them with the materials that happen to be immediately procurable. Some of the methods that have been successfully followed in various cases will now be described.

Double Ladder Bridge. - This is shown complete in Fig. 328, and may be thus formed:A eart is run into the stream with a ladder secured to it (the limber of a field gum, with the boxes removed, may be used) ; the shafts are then raised into a vertical position, and secured by guy ropes to pickets on either shore. The second ladder is then passed to the opposite shore. The ladders are secured to a beam lashed across the shafts at a point which will suit the depth of the stream. The rungs of the ladders are then covered with planks. This bridge is suitable for infantry in single ratuk. In broad streams, two or more pairs of wheels may be used, so as to divide the whole length of the bridge into portions suited to the length of the ladders that are available.
339. A ladder laid on its edge forms a species of trussed bearn, and may frequently be used as such in the absence of strong beams. The following is a description of a portable bridge (shown in section in Fig. 984) which was used in the operations in Chinu in 1860, to enable the General and his cavalry escort to cross canals in reconnoitring the Peiho forts. Two beams 24' long were formed out of four scaling ladders, each $12^{\prime}$ long, by lashing them in pairs end to end,
by means of planks $3^{\prime}$ long at the junctions. The beams so made were laid across the canals, and set up on edge, the earth being banked up at their ends to keep them in position. Planks $4^{\prime}$ long were laid across, from beam to beam, to form the roadway; cleats were fastened under the outer edges of the planks to prevent their slipping off the beams.

This bridge, $24^{\prime}$ long, was laid and crossed in a quarter of an hour. Its total weight was 750 lbs ., or about 31 lbs , per foot run. It was crossed by half a company of infantry, marching two deep, in step, with files well locked up, without suffering the

Fig. 324.


A A. Ladders acting as beams. slightest injury.
340. Spar Bridges. - In the campaign in Portugal in 1811, the French closed a breach fiftyfour feet wide, made by the rupture of the arches of a bridge, in the following manner (see Fig. 325): -They first placed at each side of the aperture large trunks of trees obtained from the neighbouring forest, their ends projecting eighteen feet over the cavity; the butt, or lower ends, resting on the stones of the bridge, were then weighted by other logs laid across them, and then again by earth or stones ; logs were then laid across the projecting end of the trees, as a support for another strong $\log$ or trunk of a tree, which completed the closure of the gap. Smaller logs were then laid across and covered with earth, so as to complete the roadway and bring it to a level. A few hours were sufficient to complete this bridge and pass the army of Massena over it without accident.

Fist 325.

341. Figs. 326, 327, show what is called a Single Lever Bridge. To form it two spars are laid parallel to one another on each bank of the stream, and are connected together by a stout cross-beam $(c, c)$.

Fig. 326

Fig. 327.



The distance apart of the spars depends on the intended width of the roadway. The pairs of spars, thus connected together on each side of the stream, are then pushed into the water until their ends reach the points A, A, where they are required to remain. They are then turned over gradually on these points A, A, as centres (sheers being erected for the purpose, if necessary),
intil they meet nut mutually support one another on the cross-beams $(c, c)$. Baulks are then passed from the banks to rest on the cross-beam, and the roadway of planks is next completed.
842. Fig. 228 is an improvement on the last method, aud should be used in preference to it, if long spars (good stout scaffold poles will suffice) can be procured. The tivo pairs of spars should rest on one another at a point $A$, as high as possible. Other cross-beams ( $B, B$ ) are secured to the spars at the level of the intended roadway, for the purpose of carrying the buulks.

The advantages of this bridge over the one shown in Fig. Seb are, that the spars give a firmer support to the brilge, the angle they form with one another being smaller, and the breadth of the river is divided by means of the cross-beams (B, B) into three instead of two intervals, thereby allowing shorter and thinner baulks to be used.

Care should be tuken in setting up the spars to make the beams ( $B, B$ ) divide the span, as nearly as possible into three equal parts.

Fither of these spar bridges might be used to reopen the communication across a broken masonyy bridge, as shown in Fig. 329, provided that a safe support for their feet can be obtained in the masonry.


Fig. 330.


Ere. 311.-Plau of Spars.
343. When the spars are not long enough for two of them to reach across, the arrangement shown in Figs. 880, 331, may be adopted; it, however, necessitates the centre being supported until the whole arrangement of spars is completed. This bridge is termed a Double Lever Bridge.
344. Calculations for Floating Bridgos.-A bridge of any kind must be more than strong enough to withstand the greatest possible strain to which it is liable to be subjected, and this rule must eminently apply to all military bridges. Two distinct and separate conditions are required to be fulfilled in a floating bridge, viz.:-(1.) The floating bodies, whether formed with pontoons, boats, casks or rafts, must have sufficient buoyancy to sustain with safety, the greatest weight which can be brought to press on them. (2.) The baulks, which span the intervals between the saddles of the piers, must have the requisite strength.

Every pier in a bridge (as B, Fig. 31t) has to sustain the weight which may press on the space between the points $c, c$, which are in the centre of the intervals between the piers; the distance between these points $c, c$, is equal to the sum of the halres of two adjacent bays of the bridge. When the piers are arranged at equal intervals (as in Fig, 314) the distance (c,c) is evidently equal to the central interval of the piers, or of one bay of the bridge. For this reason the maximom weight to be borne by ench pier in a bridge will be composed of the maximum weight of passing bodies (troops, artillery, cattle, \&c.) that can be packed on the length of one bay, in addition to the weight of the materials of the bay itself.

As was remarked in Art 333, the whole buoyancy of closed bodies, such as the cylindrical pontoous, may be made available (a small allowance for leakage excepted); while with open boats, their grentest immersion mast not be so great as to risk their being swamped at the moment they are exposed to the grentest strain.
345. The following axe estimates of the weights brought to bear on a bridge by troops of the different arms in their usual order of march.


DOUBLE LEVER BRIDGE ${ }^{\frac{1}{6}}$


## SPAR BRIDGING.

343a. Standards in a spar bridge are the principal spars which support the entire structure. Their butts rest on the ground or other foundation for the bridge, in a manner similar to the legs of Trestles.

Transons are horizontal spars which connect the pairs of standards near the tips and frequently carry the baulks of the roadway. They therefore require to be stout and strong.

Ledgers are slight spars, used for the purpose of counecting together the pairs of Standards, close to the butts of the latter.

Braces are slight spars which connect the pairs of standards diagonally: where they cross each other, they are also lashed. Their use is to stiffen the frame formed by the standards, transom, and ledger. They will be most efficient when they cross each other at right angles. Their position is usually between the transom and ledger of each frame.
$343 b$. The principal lashing used in spar bridging is that used in ordinary house-scaffolding, and is here described as applied to a transom lashed to an upright spar, see Pl. B. In the description the transom is supposed to be in front of the upright.

A clove hitch is made round the upright below the position of the transom, the lashing brought under the transom, $\mathrm{up}_{\mathrm{p}}$ in front of it, horizontally behind the upright, down in front of the transom, and back behind the upright below the clove hitch, and so on, following round, keeping outside of and not riding over the turns already made. Six turns or more will be required. A couple of frapping turns are then taken between the spars round the lashing, binding the whole firmly together, and the lashing is finished off with a clove hitch, either round one of the spars, or any part of the lashing through which the rope can be passed. The lashing must be well beaten, while making the frapping turns, with a handspike or pick handle, to tighten it up.

343c. The first thing to be done prior to commencing a spar bridge is to measure the gap to be bridged, and to draw a section of it, with ropes and pickets, full size, on the ground. The width of the opening, and the depth of the sides to the abutments, decide the form to be given to the bridge.

Whatever number of points of support for the baulks can be obtained, their distance from each other should be nearly the same; the total width of the chasm on the section is then divided into as many parts as there will be intervals between the supports, and a picket driven in the line at each point to mark the position of a transom, the thickness of which is represented by a manl or piece of spar. The positions of the other spars can then be marked by lines or by the spars themselves, and the distance from their butts at which the transom will be lashed can be measured and marked on the spars to be used in making the bridge.

In lashing frames the butts of the spars should be further apart than the tips, to give greater stability. The splay may be about 1 in 20 .
$343 d$. The Single Lever Bridge is suitable for spans of about 30 feet or less. It is composed of two frames, which lock into each other, as shown in Pl. B.; these frames should not meet each other at an angle greater than $120^{\circ}$. The bridge can be erected by a party of 2 or 3 noueommissioned officers and 20 men, one-half on each side of the stream or chasm; if the spars are heavy the number of men may be increased up to 32 .

343e. The first operation is to take an accurate section of the gap, and to mark on the the positions of the shore transoms or sleepers $A$ and $B$, that of the centre transom $C$, and the points E and G , where the butts of the standards are to rest. The standards EH and G K, which represent one of each of the two frames, are then laid with their butts at the points $E$ and $G$ (allowance being made for sinking according to the nature of the bottom), and the positions of the main transoms H and K determined.

The object of making the section in the manner described is to obtain the distance of $H$ from the butt E , and that of K from the butt G .
349. The standaris for the two frames are got into position on each bank opposite the site for the bridge, their butts being placed towards thie stream, for one frame $10 \frac{1}{3}$ feet apart at the ledger and 0 ) feet at the position of the transom in the olear ; for the other frame $1 \frac{1}{2}$ feet farther spart throughout, so that one frame may fall inside the other when hauled across the stream. The ledgers are lashed on above, and the transoms beneath the standards at the positions marked; the dingomal braces are then lashed to the standurds (two butts and one tip above them) and to each nher. Two men work at each lashing, and great care must be taken that the spars are kept in their relative positions all the time, checking the measurements of the diagonals of the frames before the braces are lashed.

In the meantime the footings for the butts of the frames can be prepared, and pickets driven for the font and guy ropes. The pickets for the former should be about 2 paces from the bank, and 4 paces on eadiside of the central line; those for the guy ropes about 20 paces from the bank, mud 10 paces on ench side of the central line. The foot ropes can also be secured by timber hitches to the buts of the standards, the fore- and backguys to the tips, and the foregnys passed across to the opposite side by mens of spun yarn, \&c. The guys of the narrow frame should be inside the guys and the standards of the wide frame.

343\%. When all is ready, the frames are got into position, either one after the other, or both at the sume time, if there be sufficient men. One man is told off to ench foot rope, and one to ench back giy, to slack off as required, two turns being taken with ench of these ropes round their respective pickets. The other numbers raise the frame and launch it forward, being assisted by the men manning the foreguys on the other side of the stream, until the frame is balanced on the edge of the bank; the butts must then be gradually lowered into the footings prepared for them by slackening aff the foot ropes, the head of the frame hauled over till beyond the perpendicular, and lovered nearly into its ultimate position by slacking off the baekguys, the men on the foreguys assisting to guide it. It ean be kept in this position by making fast the guys to their pickets, until the other frame las been treated in a similar manner. The two frames are then gradually lowered by means of the backguys, and guider by the foreguys, until the standards of the narron one rest on the transnm of the other between its standards: the wide frame is then lawered, until the two frames lock into each other, their standards each resting on the others transom.

The centre transom $C$ is then passed from the shore and placed in the fork formed above the two frames.

The operations thus far described should not occupy more than 45 minutes, provided proper stores sre available, and in position on either side of the stream.

The roadway should be laid as described in paragraph $343 p$, and should not require more than twenty minutes, so that the whole bridge should be completed in a little over an hour.

If the bridge has to be made over a broken arch, do., where the footings for the frames are to be in masonry, one hour or more in addition should be allowed for forming them.

343h. The following is an estimate of materials and tools for a single lever bridge of 30 feet span;-


4 foot ropes, 3 inch rope, 6 to 9 fathoms each.
4 lashings, 2 inch rope, 8 fathons each, for main transoms.
$4 \% \quad 1 \frac{1}{2}$ inch rope, 5 fathoms each, for ledgers.
10 " $1 \frac{1}{3}$ inch rope, 5 fathoms each, for diagonal braces.
10 " 1 inch rope, 3 fathoms each, for rond bearers.
16 rack sticks and lashings ( 8 feet of 2 inch rope).
1 ball of spun yarn.
8 park pickets, 5 feet long.
2 mauls.

4 pickaxes.
4 shovels, field service.
2 rods, measuring, 6 feet.
2 tapes, tracing.
2 tapes, measuring, 50 feet.
1 bundle of pickets.

And the followirg, in addition to the above, when footings lave to be made in rock or masonry :4 crowbars.
4 striking hammers.
4 brick chisels or jumpers.

343i. The Double Lever Bridge is suitable for spans of 40 feet, and consists of two frames which lock into a connecting frame of two or more longitudinal spars, with cross transoms, as shown in PI. B ; the gap is thus divided into three spaces, and the span of the road bearers is about 14 feet. The bridge can be constructed by a party of two or three non-commissioned officers, and from twenty-fow to forty-eight men.

The section of the gap being taken and drawn on the ground, the positious of the shore transoms or sleepers, $A$ and $B$, are first marked, the distance, $A B$, is then divided into three equal spaces by the blocks (or maul heads), C and D, which represent the road transoms; the points, $\overline{\mathrm{F}}$ and $H$, where the butts of the frames are to rest being marked, the standards are laid in position over the road transoms (allowance being made for sinking, according to the nature of the bottom), the longitudinal spar is then laid underneath and tonching the road transoms, the positions of which are marked on it, and the positions of the main transoms, $K$ and $L$, can then be determined. The following measurements are then carefully made:-FM and $H N$ to obtain the positions of the main transoms on their respective frames; also AK and BL as a guide to obtain the final positions of the frames when slacking off the backguys.
$343 \%$. The side frames are then lashed on each bank in the sume manner as the wide frame of the single lever bridge, and are then launched and lowered down to a little above their final position, and held there by means of the backguys. Two road bearers are then got out from each bank to the main transoms, and two men go out to each of those transoms. The two longitudinal pieces are then got into position (if necessary, by a pair of sheers, or by a block and tackle lashed to the head of a standard) inside the standards, and the road transoms are then placed and lashed to the longitudinal spars at the points marked. The side frames are then lowered till they jam, and the framework is complete and self-supporting.

The operations thus far described should not occupy more than about two and a-half hours, and the roadway could be laid and the bridge completed in three hours. Extra time will be required if the footings have to be cut in masonry or rock.

343l. The following is an estimate of materials and tools for a double lever bridge of 40 feet span :-

4 spars of $25^{\circ}\left(7^{\prime \prime}\right.$ at tip) for standards.
2 " of 22 ( $7^{\prime \prime}$ at tip) for longitudinal pieces of commecting frame.
" of $16^{\prime}$ ( $9^{\prime \prime}$ throughout) for transoms.
" of $16^{\prime}$ ( 7 " throughout) for ledgers.
" of $20^{\prime}$ (4" at tip) for diagonal braces.
", of 12 (immaterial) for shore transoms.
of $20^{\prime}$ ( $0^{\prime \prime}$ at tip) for road bearers.
" of $20^{\prime}$ (slight) for racking down baulks.
50 planks, 9 feet, 1 foot wide, for roadway.
8 guys, 3 inch rope, 20 fathoms each, for foreand backguys.

4 foot ropes, 3 inch rope, 6 to 9 fathoms each. 8 lashings, 2 inch rope, 8 fathoms each, for transoms.
4 " $1 \frac{1}{4}$ inch rope, 5 fathoms each, for ledgers.
10 " $1 \frac{1}{2}$ inch rope, 5 fathoms each, for diagonal braces.
20 " I inch rope, 3 fathoms each, for road bearers.
20 racksticks and lashings ( 8 feet of 2 inch rope).

And, in addition to the above, spun yarn, park pickets, \&c. \&c., as detailed for the single lever bridge.

343 m . In all spar bridges where the bults of the spars require footings made for them, these should be so formed that the spars may be lowered vertically into them; also their bottoms should be in aplane, perpendicular to the direction which the spars are to take. If the footings are in mud, planks
on spars should be spiked or lashed to the butts to preyent them sinking. Great attention should be paid to the varions lashings and also to the positions of the transoms, and distances apart of the side spars, as on them depends the strength and stiffness of the bridge.
$343 n$. The framework and transoms being completed, as described in the preceding paragraphs, the longitudinal bearers (baulks) for the roadway have next to be gotinto position. For a roadway 8 feet mide, $\delta$ baulks are a convenient number to use, placed parallel to one another at equal central intervals. These may consist of ordinary spars, about 6 inches diameter at the tip, which are launched forwurd from each side by men standing astride each spar, facing in the direction of the bridge and gradually pushing and lifting it forward, assisted by men on the opposite side, hauling on a breast line made fast to the tip. Eight men are sufficient for a 30 feet spar. The tips of the spars should meet and overlap at the transoms, and where the ends of each pair of spars cross the centre transom they must be lashed together in two places, so as to prevent them pushing the roadway upwards, which they would otherwise do, on account of the camber at the centre.

At each trausom the road bearers should be all tips or all butts, in order that the planks may have an even bearing and there may be no sudden drop in the roadway of the bridge.

348o. The abutmeut for temporary bridges is formed by laying a horizontal baulk, or shore transom (sleeper), at right angles to the length of the bridge, and at a distance from the bavk, varying from 2 to 6 feet, according to its nature; this shore transom is partly buried and firmly secured in its place by 6 or 8 pickets driven into the ground. It should be 7 or 8 inches in depth, and 2 feet longer than the bridge is broad. The road bearers rest on this transom, and to prevent the earth from being forced by the wheels between them; a plank or edge should be placed against their flush ends and banked up with earth.
$313 p$. When planks are used for the roadway, they are cut to the required length beforehand (every fourth plank being notched to allow room for the racking down) ; two are carried by two men under their right arms, who advance by the right side of the bridge; when at the end of the finished part they wheel to their left, bringing the planks across the bridge, and hand them to two men, who stand on the outer spars facing the shore, and lay them down. The men who have brought up the planks pass off the bridge by the left, so as to avoid meeting the men coming up. If chesses be used, two men carry one in their right hands.

The racking down baulks (ribbands) are then brought up, and the whole racked down.
The operation of laying the roadway may be carried on simultaneously from each side, if stores for that purpose be previously in position. The roadway for a spar bridge 50 feet long can be laid by 16 men in half an hour, including passing across the road bearers and lashing down their tips. If the roadway has to be made of spars, the inequalities must be filled up with brushwood, clay, \&er.

In removing the planks or chesses, the men advance as before by the right side of the bridge, lift the planks as they are turned up by the men on the road bearers, and leave the bridge by the left side, carrging the planks under the right arm. By following these methods, the men do not get in each other's way, and there is a continuous supply of material brought on or removed from the bridge.
$643 q$. A ramp or slope of earth should be made at the ends of all bridges, where the roadway is above the level of the ground, to allow of the easy passage of carts, se., on the bridges : it should be covered with stones or planks if the traffic is likely to be heavy.

A handrail of rope on each side should be made by driving pickets at each end of the bridge, and making a clove hitch with the rope round the standards or other spars, about 3 feet above the level of the roadway.

Infantry in marching* over a bridge will be assumed as being four deep. It will also be assumed that each row of four men occupies 2 feet of the length of the bridge, $t$ and that the weight of an infantry soldier in marching order is 200 lbs. ; consequently, each row of 4 men will weigh 800 lbs., and, for all practical purposes, this weight may be considered as equally distributed. The greatest weight with which infantry can press on a bridge, when marching in fours, will therefore be at the rate of $\frac{800}{2}$ or 400 lbs ., for each foot of the length of the bridge.

Cavalry, when passing a bridge, would march in file ; each pair of horses would occupy, on an average, 10 feet of the length of the bridge. The weight of one cavalry soldier and horse in marching order is about 1300 lbs ; two of them would therefore weigh $8,600 \mathrm{lbs}$. For practical purposes, the weight of cavalry when filing over a bridge may be considered as equally distributed. The grentest weight with which cavalry in file can press on a bridge will, therefore, be at the rate of $\frac{2 \times 1300}{10}$ or 260 lbs ., for each foot of the length of the bridge. This is a much lighter weight than is brought by infantry in fours; consequently it may be assumed that a floating bridge, buoyant enongh to carry infantry in fours, is amply buoyant to carry cavalry in file.

Field artillery in passing over a bridge may either be horsed, or drawn by hand: in either case the necessary calculations will remain the same, because the weight of the gun, its carriage, \&c., as they press on the bridge, is so much greater than that of the horses drawing them, who are some distance in advance, that it is sufficient to calculate only for the gun and limber, withont considering the horses. A $9-\mathrm{pr}$, gun and carriage, with the limber containing 32 rounds of ammunition, weighs about 4,300 lbs., $\ddagger$ and oceupies about 14 feet of the bridge, which gives an average of $\frac{4,300}{14}$ or 307 lbs . (nearly) for each foot of the length of the bridge. This is a much less average weight than is brought by infantry in fours, but it is not equally distributed, see Art. 347.

It may therefore be assumed that, if a floating bridge has the buoyancy requisite for sustaining infantry in fours, it will be more than sufficiently buoyant to carry cavalry in file, or field artillery of the weight of 9 -pounders (S. B.).
346. Buoyancy of Bodies. - The broyancy in water of a closed body is found by subtracting the weight of the body itself from the weight of the mass of water it displaces, when it (the body) is fully immersed. When open vessels are used for the piers of floating bridges, the available buoyancy of each will be found by subtracting its weight from that of the water displaced, when it is immersed to its maximum intended depth.

When the central intervals between the piers of a floating bridge have been determined, the weight of the superstructure of one bay (baulks, chesses, ribbands, Sc.) can be calculated; the available buoyancy of one bay of the bridge will then be found by subtracting the weight of the superstructure of the bay from the available buoyancy of the pier.

In cases when it is required to determine the central intervals between the piers of a floating bridge, the dimensions and buoyancy of each pier being assumed to be known, it is necessary to estimate the probable weight of the superstructure of the bay: this weight of superstrncture being deducted from the buoyancy of the pier, will give the available buoyancy of each bay of the bridge, which latter (in lbs.) being divided by 400 (the weight in lbs. of infantry in fours ou each foot run of the briige) will give in feet the maximum interval between the centres of the piers.
347. Strength of Bauliks or Beams.- The strength of different beams of the same material

[^25]
varies directly with their breadth, inversely as their length,* and as the square of their depth. If, therefore, three beaus of equal length have their brendth and depth as here stated, viz: :-

their strength will be respectively as 1,2 , and 4 . No. 3 bean having the same sectional area as No, 2, will have the same weight us No. 2, although it has double its strength.

The baulls in a military bridge are liable to two different strains: either the weight pressing on them is equally distributed over their length, as is the case when infantry or cavalry are moving across the bridge, or the weight may be more concentrated, as when artillery or laden waggons are erossing. In this latter case, as regards artillery, the greatest strain is caused by the gun itself; for when limbered ap, one-third only of the total weight is borne by the limber wheels, the remainder being borne by the gun-wheels: consequently, when a 9 -pounder S. B. gun, limbered up, is moving over a bridge, the pressure exerted on the bridge by the gun-wheels will be $4,200 \times \frac{9}{3}=2,800 \mathrm{lbs}$.

When beams are supported at eaoh end, as is the case with the baulks of a bridge, they will support double the weight, if it be evenly distributed over their length, that they can do when the weight is upplied to their centres. Consequently the weight of $8,800 \mathrm{lbs}$. given above as the pressure exerted by the wheels of the 9 -pounder S. B. gun, is equivalent when it is over the middle of a bay (and therefore over the centres of the baulks) to double that weight, or $\delta, 600 \mathrm{lbs}$., equally distributed, as is the case when infantry are crossing. From this it will be apparent that artillery strain the baulks of a bridge in their passage over it, much more than is the ease with cavalry or infuntry, but the difference will be really greater than might be assumed from the foregoing, for two reasons:-(1) Because the weights allowed for are not in excess of the reality, as regards the passage of artillery, for the weight of a gun and its oarriage are fixed, as estimated above; whereas the weight of the infantry that is pressing on a bridge will in all probability be less than that estimated ( 400 Ibs . per foot run of bridge), on account of the men not keeping step, and therefore not closing up to one another. (2.) Because the wheels of the gun carriage will not press eveuly over the rhole of the baulks, especially if the planks forming the chesses are slight; whereas with infuntry the weight may be considered as equally distributed not only over the length of the bridge, but also over its breadth, and therefore equally on the whole of the baulks of each bay.

In pructice, the greatest weight allowed to press on a beam should not exceed one-half of its breaking weight; this may be termed the safe bearing weight.

The accompanying table shows the breaking weights, determined by actual experiment, of beams $7^{\prime}$ in length, and 2 inches square in section, the weights being applied in the middle. From this table the strength of other beams can be calculated, or the dimensions suitable for the baulks of a bridge determined.

| No. | materal. | Breaking weight applied in midule. | Safe bearing weight in middle. | Safe bearing weight, equally distributed. |
| :---: | :---: | :---: | :---: | :---: |
| 1. | Teak | 1 lbs , | 1 lbs | Ibs. |
| 2. | Ash. | 938 | 469 | 938 |
| 3. | Canadian Oak. . . . . . . . . . . . . . . . . | 778 673 | 386 | 779 |
| 4. | Pitch Pine... | 673 60.8 | 336 | 673 |
| 5. | Beech .... | 628 | 311 | 629 |
| 6. | English Oak | 598 450 | 296 | 593 |
| 7. | Riga Fir . . . . . . . . . . . . . . . . . | 428 | 225 | 450 |
| 8. | New England Fir .............. | 420 | 910 | 422 |
| 9. | Larch . . . . . . . . . . . . . . . . . . . . . | $\begin{aligned} & 120 \\ & 325 \end{aligned}$ | 810 | $\begin{aligned} & 420 \\ & 825 \end{aligned}$ |

[^26]
## 348. Examples of Calculations for Bridges.

1. It is required to find the greatest distance from centre to centre of the boats in a military bridge under the following conditions. The bridge to support infantry marching four deep; the floating bodies ere flat-bottomed boats, rectangular in section, 4 feet wide and 3 feet deep (Figs. 332, 333); the greatest immersion of the boats to be $2 \frac{1}{2}$ feet, the mean length of the part immersed being 15 feet. The weight of each boat is 1,000 lbs., and that of the superstricture of one bay to be assumed as 1500 lbs.


Here $15^{\prime} \times 4^{\prime} \times 2 \frac{1^{\prime}}{2}=150$ cubic feet; the quantity of water displaced by each boat, when at its maximum intended immersion.
$150 \times 62 \frac{1}{3} *=9375 \mathrm{lbs} .:$ the weight of water displaced;
Deduct $\frac{2500,}{}, \quad\left\{\begin{array}{l}1000 \mathrm{lbs} . \text { for weight of boat. } \\ 1500 \quad \text { superstructure of bay. }\end{array}\right.$
$\therefore \frac{6875 \mathrm{lbs},=\text { available buoyaucy of each bay. }}{400}=17 \frac{1}{4}$ feet (nearly); the required maximum central intervals of the boats.
2. Required the available buoyancy of each bay of the Service Pontoon Bridge at open order: i.e. at central intervals of $12^{\prime} 6^{\prime \prime}$. The weights to be taken from the table, Art. 323.

Weight of one pontoon .. .. .. .. .. .. .. .. .. .. .. .. 565 lbs .
Do. the baulks, chesses, \&c., of the superstructure of a bay .. .. .. 1066 "
Weight of one bay complete, the pontoon included .. .. .. .. .. .. 1631 lbs .
The solid content of a pontoon being $180 \dagger$ cubic feet,
$130 \times 62 \frac{1}{2}=8125 \mathrm{lbs}$, the weight of water displaced by the pontoon when fully immersed.
Deduct $\frac{1631}{}$ "the weight of one bay, as above.
$\therefore \overline{6494} "=$ the available buoyancy of each bay of the bridge.
3. In the question, Example 1, where the central intervals of the boats were calculated to be $17 \frac{1}{4}$ feet, it is required to know the least width that the baulks should have, supposing that the distance between their supports is 16 feet, that they are of fir, 6 in number, 4 inches each in depth, and that they are to bear the weight of $9-\mathrm{pr}$. S. B. guns, the wheels of which press with a weight of 2,800 lbs. on the bridge.

Here $\frac{2800}{6}=466 \frac{2}{3}$ lbs. ; maximum pressure on centre of each baulk.
$466 \frac{2}{3} \times 2=933 \mathrm{lbs}$. : the breaking weight of each baulk when applied to centre.
If we compare this baulk with that given in the table, as No. 8, the breaking weight of which is stated to be 420 lbs ., the required breadth will be

$$
2 \times \frac{933 \frac{1}{3} \times 2^{2} \times 16}{420 \times 4^{2} \times 7}=2 \frac{1}{2} \text { inches nearly. }
$$

N.B.-In practice the beams would be made broader than this calculated breadth.

- A cubic foot of water weighs $62 \frac{1}{2} \mathrm{lbs}$.
+ The solid content of one poutoon is that of a cylinder $2^{\prime} 8^{\prime \prime}$ diameter, and $19^{\prime} 8^{\prime \prime}$ in length, audded to that of a sphere $2^{\prime} 8^{\prime \prime}$ diameter.

Content of cylinder $=\pi r^{2} \times l=3 \cdot 1416 \times 1 \cdot 33^{2} \times 19 \cdot 66=119 \cdot 86$ cubic feet.
$\begin{aligned} \text { Ditto of sphere }=\frac{4 \pi r^{3}}{3}=\frac{4 \times 3.1416 \times 1.33^{3}}{3} & =9.93 \quad " \\ \text { Content of pontoon..................... } & =129.79, \text { say } 130 .\end{aligned}$
4. It is required to find the greatest weight that can be safely borne by the baulks of the Service (Blans'ard's) Pontoon Bridge, at open order; the weight being supposed to be applied in th: middle, as is the case when the gun passes over the bridge.

At open order the pontoons are at central intervals of $12^{\prime} 6^{\prime \prime}$; the saddle is $1^{\prime} 2^{\prime \prime}$ broad; consequently the bearing of the baulks is $12^{\prime} 6^{\prime \prime}-1^{\prime} 2^{\prime \prime}=11^{\prime} 4^{\prime \prime}$.

The baulks are $3^{\prime \prime}$ broad and $4 \frac{1}{2}{ }^{\prime \prime}$ deep.
The breaking weight of each baulk, applied in the centre, $=420 \times \frac{7 \times 3 \times 4 \frac{11}{9}^{2}}{11 \frac{1}{3} \times 2 \times 2^{2}}=1974 \mathrm{lbs}$.
$\therefore$.safe bearing weight in centre of each baulk $=\frac{1974}{2}=987 \mathrm{lbs}$.
$987 \times 6=5922 \mathrm{lbs}$. : the required safe bearing weight of the 6 baulks at their centre.

## SECTION IV.

## PERMANENT FORTIFICATION.

## CHAPTER I.

ON THE VARIOUS PARTS OF THE PROFLLE OF PERMANENT WORKS.
Same principles followed in Permanent as in Field Fortification: general description of the nature of ancient fortified places, and of the revolution in the art of defence caused by the invention of gunpowder and the introduction of Artillery. Description of the different parts of the profile of a modern permunent worle: the Rampart; Parapet; Ditch, Escapre, and Counterscarp; the Coveren WAT and Glacis. Conditions to be fulfilled in a prefile as regards its offensive and defensive powers, Mutual dependence of the several parts of a profile. Different kinds of ditches, their respective merits, \&c. Different kinds of solid retaining walls. Use and nature of Counterforts. Fuli Revetments, Demi-Revetmenis, and Cbemin-des-Rondes Revetments. Fausbebrate, its nature and defects. Casemates, use of.
349. In was stated in Art. 115, page 39, that the principles of Field and of Permanent Fortification were the same, but that the different conditions under which the two sorts were constructed accounted for the differences in their respective constructions: that while Field Works were almost invariably constructed in haste, and ordinarily with a deficiency of means, both as regards men and also materials of all kinds, Permanent defences were leisurely constructed, with every appliance necessary for the work, after having been carefully designed to obtain the maximum of strength against every lind of attack.

For these reasons Permanent defences will evidently illustrate the progress of the art of Fortification at the period of their construction.
350. Before the invention of gunpowder, fortifications usually consisted of strong masonry walls, strengthened and flanked by towers, placed at bowshot distance from each other. The profile of the walls was similar to the type showu in Fig. 334, where the main wall is surmounted by a parapet wall $(\mathrm{P})$, which was crenellated to allow arrows, \&e., being projected from behind it, by the defenders who stood on the terreplein (T), formed by the thickness of the top of the wall. Sometimes the parapet was provided with machicoulis, which allowed the defenders, while under cover, to shoot or throw various missiles downwards on the heads of those below.

The Towers were generally raised one or two stories above the walls; some were insulated from them, and thus were capable of a separate defence, obliging an enemy to select them for attack, in preference to other points.

Their height gave them the advantage of elevation above the moveable wooden towers and battering machines used in the attack, and thus enabled the stones, \&c., thrown down from them, to strike with greater effect. A Ditch separated the works from the country when the ground was favourable, and increased the difficulties of an attack.

In most cases a Keep was provided, as a means of prolonging the defence, after the main enclosure had fallen to the possession of the assailants.

s51. The strongth of these ancient fortresses was due to the height of their walls, and to their innccessibility, urising either from their being perched on the top of a height, or from their being surrounded by wet ditches, which increased the dificulty of bringing up the battering and other machines required in the attack, close to the walls.

From their position and general nspect these works had a most imposing appearance, and were frequently impregnable ngainst the methods of attack then in vogue
358. The invention of gunpowder, and the consequent, though not immediate, introduction of camnon in the attack, deprived these works of their strength, and created a revolution in the art of defence, for the walls could then be breached by artillery from a distance. It became therefore absolutely necessary to screen the walls from distant view, which was effected partly by sinking them below the ground, and partly by raising a glacis in front of the ditch ; and, in course of time, as artillery became used in the defence, as well as in the attuck, the ancient masonry wall, the top of which was used as a terreplein for defence, gave way to the broad earthen rampart of the present time, and the parapet wall on the top of the main wall was replaced by an earthen parapet. These alterations were progressive and gradual, not immediate, as they were the consequences of the gradual improvements in artillery, and its more extensive application to the operations of war.

The profile, so altered, remains to the present time, umaffected in its general conditions by the Inte improvements in firearms of all kinds, however much these may have necessitated alterations in detail.
353. The different portions of the profle of a modern permanent work of defence will now be pointed out (see Fig. 335).

The Rantart is a large embankment of earth, surrounding the place fortified; its object is to afford a terreplein ( $a, b$ ) of the proper dimensions for carrying on the operations of defence.

The height of the rampart ( $b, c$ ) is regulated by the command required to be given to the parapet, which is built on it, and the crest of which is usually $7 \frac{1}{2}$ ' or ' 8 ' above the terreplein. Ramparts vary much in height : in most fortresses the main ramparts vary from $12^{\prime}$ to $20^{\prime}$ or $22^{\prime}$ in height, according as the command is required to be $20^{\circ}$ or $30^{\prime}$.

The breadth of the rampart is regulated by the thickness of the parapet and its slopes, and the breadth proper for its terreplein.

Fte. 395.-Scale 3 㥿


The Terrepletn of the Rampart (a $\quad$ b, Fig. 385) is the surface on which the operations of defence are carried on; i.e, on which the artillery is worked, infantry employed, and men, materials, ammunition, \&e., moved from part to part as required. It has, therefore, to be wide enough for these purposes ; and on the principal ramparts of a place, the terrepleins are made $40^{\prime}$ broad, $*$ of which $20^{\prime}$ is required for the service of artillery, leaving $20^{\prime}$ for general communication.

[^27]The ramparts of outworks sometimes have terrepleins only $30^{\prime}$, which allows $20^{\prime}$ for the service of artillery, and $10^{\prime}$ for communications.

The terrepleins of ramparts are given a slight slope (about $\frac{1}{76}$ ) to the rear for drainage. In Fig. 335, $a$ is usually $6^{\prime \prime}$ lower than $b$.

The rear of a rampart is usually formed by an earthen slope of $\frac{1}{1}$, as in Fig. 385, but it is sometimes terminated by a masonry wall. The earthen slope lias the advantages of being economical, and of allowing men to move up or down it on emergencies. The masonry wall is used when it is desirable to save interior space, or when the wall is required as an obstacle (as in retrenching an empty bastion (Fig. 417), or wheu casemates are constructed under the terreplein, as in Fig. 441.
354. The Parapet, on top of the rampart, has to protect the defenders on the terreplein behind it from an enemy's fire ; the height of its crest above the terreplein of the rampart is usually $7 \frac{11^{\prime}}{2}$ or $8^{\prime}$.

The thickness of the parapet at the top has, until late years, been made 18 ; but at the present time all new parapets that are exposed to a direct fire of heavy artillery, are made $25^{\prime}$ thick. The slopes of the parapets have generally the same inclinations as in Field Fortification, except that the superior slope is not made steeper than 1 in 6 , and the exterior slope is frequently given a base greater than its height.

The parapet is pierced for embrasures or provided with barbettes for artillery, as may be required; wherever not occupied by artillery, it is provided with a banquette for infantry. Sometimes, for the sake of economy, the interior slope of the parapet is left at the natural slope of the earth, until the work is required to be placed in a state of defence, when the interior can be formed to the required slope.

Parapets are sometimes constructed of masonry, in which case their thickness varies usually from 6 to 9 feet, according to the quality of the masonry used. Masonry parapets have the advantage of saving interior space ; but the danger to the defenders from their splinters when struck by shot, and the ease with which they can be destroyed by the artillery of the present day, together with the impossibility of repairing them while exposed to fire, forbid their use in all but exceptional cases, where they are not exposed to the accurate fire of heavy guns. These cases frequently happen with sea defences.

Portions of parapets are now made of wrought iron, rolled into thick bars, anl connected together by bolts or other contrivances, so as to form a wall $10^{\prime \prime}$ or $12^{\prime \prime}$ in thickness. Such expensive constructions are suitable for special eases, where it is necessary to protect guns by every possible means. The comparative indestructibility of such a screen, together with the smallness of the opening that an embrasure in it forms, give to the defensive artillery great advantages.
355. The Escarp is sometimes detached from the rampart, but more generally it is a retaining wall, supporting the rampart either vertically, or at a steep slope.

Escarp walls have been given a variety of profiles, as will be hereafter explained, but in every ease it is important that they be covered from being breached by a distant fire of artillery. This is effected partly by sinking the wall below ground so as to screen a portion of the wall, and partly by raising a glacis high enough to screen the remainder: an enemy is thereby forced to bring his guns for breaching the escarp to the edge of the ditch, but to get them there he has to go through the operations of a regular siege.

The escarp is the main passive obstacle to an assault in a fortress; to be at all secure from an escalade it is generally allowed that it should be at least 30 feet in height, and at the same time should be well flanked.

With wet ditches, ramparts are sometimes constructed without escarps, the exterior slope of the parapet being continued, with or without a berm, to the battom of the diteh.

The Ditch of a permanent work is a broad and deep excavation; its objects are to afford an obstacle to an assault, to supply earth for the formation of the ramparts, and to assist, from its depth, in coveriug the escarp from view. The dimensions of ditches are most variable, and can be greatly altered to suit the conditions required to be fulfilled in any profile. Their width in ordinary cases varies from 15 to 40 yards; their depth, which depends to a great extent on their width, varies from 15 to 30 feet.*

* The depth of the ditch is frequently confused with the height of the counterscarp wall, with which it often coincides, but not necessarily so.

The front of the ditch is formed by the Cocxumscame (Fig. 385), nsually revetted with $n$ mnsonry wall, which forms in cousiderable obstacle to an attrack, and has ofther advantages which will he hereabter mentioned. It should be at lenst it feet in height. In wet ditches a revetted counterscarp is not so necessury as in dry ditches, and is then frequently roplaced by an earthen slope.
356. The Corenen War (Fig. 336) is formed by odvancing the glacis sufficiently in front of the counterscarp to leave a space
 between it and the ditch. The terreplein of the covered-way is $7 \frac{11}{2}$ or $8^{\prime}$ under the crest of the glacis, which forms its covering parapet. Its breadth, measured from the edge of the ditch to the crest of the glacis, is usunlly made 11 yards, which is sufficient to allow a breaith of $20^{\prime}$ for communication, clear of the banquette
und its slope, ns shown in Fig. 386.
The covered-way affords a concealed position in advance of the ditch, in which troops can assemble for the purpose of making sorties; it also allows a close and grazing fire of musketry to be brought to bear on the glacis, it renders a surprise difficult, and makes the operation of crowning the glacis by a besieger a work of great difficulty. It has been found from experience to be one of the most useful, while it is the least costly work of defence. Without a covered-way a garrison could not plaee sentries in advance of the ditcly (at night) with safety, as they could not be well supported, Bor could they retreat easily: a besieger ouuld consequently push on his approaches with comparative impunity; but when attacking a well constructed work, the mere fact of there being a covered-way wonid oblige a besieger to advance his approaches with great caution, and to support them with troops sufficiently numerous to cope with the sorties of the garrison.

As the covered-way is not protected from assault by an obstacle in its front, it is generally provided with a ront of palisades at the foot of the interior slope, as shown in Fig. 336, where the connecting ribband is fixed with its upper surface level with the orest of the glacis, and thus serves as a rest from which infantry can fire. The points of the palisades project $9^{\prime \prime}$ or 1 foot above the crest of the glacis, and are usually concealed from view by the grass growing in front of them,* Palisades are principally intended as a guard against surprise; they are not very useful against a regular siege, as the besieger's batteries would in all probability destroy them in the earlier periods of the attack, before their uses were apparent.

The breadth of the covered-way has been hitherto limited to 11 yards, because that breadth, while it allows a clear roadway of 20 feet for the service of the garrison, is not broad enough for an enemy to construct a battery in it to breach the escarp wall. An increase in the breadth of the covered-way would not only allow room for the construction of a breaching battery, but would increase the available space for an enemy's counter-batteries to silence the flanks.

The Glacis (Fig. 335) is given a sufficiently gentle slope to allow it to be swept by the artillery fire from the ramparts in its rear, and thereby afford no cover whatever to an enemy. Its object is to cover the escapp from the view and the fire of an enemy sufficiently to prevent its being breached by distant fire, and for this purpose the higher it is the better, provided that it does not interfere with the proper fire from the ramparts.
357. When determining the profile of a line of permanent work, the different parts should be arranged so as to fulfil the following conditions:-

1st. The artillery fire from the rampart should swerp the glacis. For this purpose the slope of the glacis produced should either pass through the soles of the embrasures of the main work,

[^28]or below them; or, in other words, the crest of the parapet should be either in or above a plane parallel to the surface of the glacis and $5^{\prime} 3^{\prime \prime}$ "above it.

When the command of the main work is sufficient to allow a fire of artillery to be directed parallel to the glacis and $3 \frac{1}{2}$ feet above it, it is considered possible to maintain a fire of musketry from the covered-way, simultaneously with a fire of artillery from the ramparts, sweeping the glacis, as the shot would pass 8 feet above the heads of the infantry in the covered-way; but although there are many advantages attending the construction of works with a great command, it is doubtful if any advantage would arise from attempting a fire of musketry from the covered-way under conditions so disturbing to the infantry.

2nd. The musketry fire of the main work should be able to defend the covered-way, and all the ground in advance. For this purpose it is necessary that the superior slope (usually at an inclination of $\frac{1}{0}$ ) of the main parapet when produced should pass within 4 feet of the edge of the counterscarp.

3rd. The escarp should be covered from distant fire. It has hitherto been generally considered sufficient for this purpose to make the glacis high enough to conceal the top of the escarp from the view of an enemy; but such is not the case at present, for experiments have proved that a wall can be breached from a distance even with smooth-bored guns, by using a pitching fire, provided that the covering mass is only high enough to conceal the wall from view, and is considerably in advance of it. This is still more the case with xifled guns, combining, as they do, the advantages of throwing heavy projectiles from long ranges with great accuracy. For these reasons, it has been considered necessary, in constructing the new forts in England, to keep the crest of the escarps considerably ( $12^{\prime}$ to $15^{\prime}$ ) below the level of the crest, \&e., of the glacis, which latter has also been brought closer than usual to the walls it covers, by making the ditehes much narrower than before.
358. From the foregoing remarks, it will be evident that the command of a work, the width (and thereby the depth) of the ditch, the breadth of the covered-way, and the slope of the glacis, are to a considerable extent mutually dependent, and that neither of these several details can be altered to any great extent, without necessitating alterations in the others; for instance, in Fig. 335, a great increase of command, without other alterations, as shown by the dotted parapet, would prevent the covered-way being under the musketry fire of the work, and it would become necessary either to have a wider ditch or else to raise the glacis and the covered-way behind it, in order to be able to defend the covered-way with musketry; the glacis would also require a gentler slope being given to it if its command were increased.

Again, a decrease in the width of the ditch compared with that shown in Fig. 335, without other alterations, would cause the covered-way to be imperfectly defended by musketry fire from the maiu parapet, for it could not be directed to within 4 feet of the top of the counterscarp. The covered-way would thus require to be raised, and with it the glacis, the slope of which would have to be altered to suit the new conditions imposed on the profile. Thus, as before remarked, the different parts of a profile are mutually dependent, and must be arranged accordingly.
359. In the profile (Fig. 885) referred to, no mention has been made of the position of the plane of site, and therefore of the absolute commands of the different parts of the protile, the relative commands only of which have been referred to. The position of the plane of site would have to be determined after the relative commands had been fixed, so as to equalize the remblai and deblai on a principle similar to that required in Field Fortification, but here more extended in its application, as it would have to embrace either the whole, or at least the half of a front, and not merely a single line of work.
360. The ditches of fortifications are of three kinds,-viz., 1st. Those which are always dry; 1 2nd. Those which are always wet; 3rd. Those which may be made wet or dry at pleasure.

A dry ditch has the great advantage of not impeding communications, as it allows the defenders to walk across it, and with proper precautions they can communicate with the outworks, and make sorties, at any period of the siege; they can also form in the ditch to dispute its passage.

A permanently wet ditch renders a surprise more difficult than is the case with a dry ditch

[^29]
## Permanent Fortification.

(provided that it is anl frozen over suffleiently to bear troops, when it censes to be a good obstacle).*

The communicutions neroar wet ditches are usnally by menns of bridges, which are liable to be destroyed by the enemy's artillery at manerly period of the siege, and it then becomes necessary to cormmunioute with the outworks by means of boats or rafte, which are very imperfect substitutes for bridges, and cannot be used during daylight at the period when an enemy is advanced near enough to observe the ditehes. The defeuce is consequently cramped, and the outworks badly defended or prematurely nbandoned, because they are provided with no secure retreat. $\dagger$

The adyantnge of a ditch of this kind, hesides preventing surprises, is that an enemy is forced to constrict some lind of a bridge across it, and cannot give the assault on such a broad front as could be done with a dry ditch; but, on the whole, dry ditches, well revetted, are considered decidedly superiok to wet ditches of the ordinary lind which have no current rumning through them. When wet ditches have a current runaing through them, the difficulty of crossing them on the part of a besieger is greatly increased.

Wet ditches are usually made broader than dry ditches, in order to increase the difficulty an enemy would experience in effecting their passage, which is to a great extent measured by the lengtio of the bridge he would have to construct.

A ditch that can be used either as a dry or as a wet ditch is the best of all, as it combines the advantages of both the dry and wet ditches, without their disadvantages; for during the early periods of an attack, when sorties are required to be made, and in fact until the outworks have been captured, the ditches would be kept dry to facilitate the active defence. After the defence has become confined to the enceinte, the ditches would be filled with water in order to incrense the diffioulty of erossing it; and if the garrison have great command of water, so as to be able to fill and empty the ditch at pleasure, and cause a rapid current through it, the difficulties of crossing it are so great as to be almost insurmountable.

Dry ditches, and also ditches that can be used either wet or dry, are usually provided with cunettes ( $\epsilon$ Fig. 385), which are excavations running along their centre, about 12 broad and $8^{\prime}$ deep. They act as drains to the main ditoh, and also increase the difficulty of an assault.

A deep and narrow dry ditch, provided it con be properly flanked, is preferable to one that is shallor and broad; because, 1st. It gives less room for an enemy on which to construct a counterbattery at the salient. 2nd. The escarp is better protected by the glacis (supposed to have the same height in each case) from distant fire. Srd. The fire from the ramparts becomes more plunging on the enemy's lodgment $\ddagger$ on the glacis. 4th. The relief of the works may be made greater, thereby allowing higher and better covered escarps, and greater security from escalade. 5th. To breach the wall from the bottom the enemy's bresching gons would require a greater depression.

The reverse of the above apply to the disadvantages attending the use of broad dry ditches.
361. Retaning Walls (whether escarp or counterscarp) are built either solid or with vaults behind, in which latter case they are termed Counterarchen, or Faulted Revetments.

The Corlon of a revetment is a coping-stone laid on its upper surface; it is usually 1 foot deep, and projects 1 foot from the face of the revetment, and is generally rounded. The Cordon forms the Magistral line in Permanent Fortification.

Solid revetments hare been constructed in four different forms,-named from their profile as Slopiny, Countersloping, Rectangular, or Leaning Revetments.

The Sloping Revetment (Fig. 387) is a retaining wall having a slope given to its exterior surface, usually of $\frac{5}{7}$ or $\frac{6}{1}$, while its back is vertical. Vauban constructed his revetments of this form, making the slope 5 in 1 . The Sloping Revetment has the defect of allowing wet to run down the slope: this induces vegetation in the joints, more particularly in brickwork and rubble masonry, and renders necessary frequent repairs.

[^30]The Countersloping Revelment (Fig. 338) has its face vertical, while its back slopes. It is the most usual form of solid revetment now used. This revetment has the advantage of resisting the effect of the weather better than the sloping revetment, as its surface can be kept dry by means of the cordon.* The usual counterslope is $\frac{s}{1}$. The back is not built at a regular slope, but in a series of steps or offsets, as in Fig. 388, the base and height of which are in proportion to the slope.

The Rectangular Revetment (Fig. 939) is rectangular in section, and has both its face and back vertical. Its use is confined to exceptional cases, such as facing a rock, \&o.

The Leaning Revetment (Fig. 840) has both its front and back inclined to the horizon; and its use is also confined to exceptional cases, similar to those mentioned for the rectangular revetment. In building a leaning revetment, the courses of masonry or brickwork are laid perpendicularly to the slope, while in the other kinds they are laid horizontally; and with the leaning revetment the earth requires to be filled in, as the masonry rises, which is a defect.

362. Counterforts are masses of masonry somewhat like buttresses, built at intervals at the back of a revetment wall, to increase its strength. Buttresses, projecting as they would to the front of a wall, are inadmissible in works of defence, on account of the cover they would afford to an enemy from the flanking works. Counterforts act as ties (while buttresses act as struts), and they increase the strength of a wall by relieving it from a certain amount of pressure of the earth behind, which presses on them instead of on the revetment; consequently the wall may be built thinner than would otherwise be necessary. Counterforts also render the formation of a breach by artillery more difficnlt, as they retain the earth between them, after the wall is cut through, at too steep a slope to be accessible, and it becomes necessary to destroy them to make a practicable breach. It was for this reason that counterforts were first used, and they were, in consequence, confined at first to escarp walls, $\dagger$ but they are now used for counterscarps, and for all retaining walls generally.

Counterforts have been built in three different forms, named from their shape in plan, Dininished, Pectangular, and Dovetateed, as shown in Figs. 341, 342 . In each case $a, b$, the junction of the wall with the counterfort, is termed the root of the latter; $c, d$, is the tail. The length of a counterfort is measured from the root to the tail, as $e, f$, Fig. 341.

Counterforts are placed at central intervals of about 16 or 18 feet.
363. Escarp walls, that are not detached from the rampart, have different names, according to their height, as follows :-

[^31]A Full Reverment is one which is carried up to meet the superior slope of the parapet, as in Fig 843.

A Dem-Revetmest (Fig. 844) is one which is not carried to meet the superior slope of the parapet, which latter is supported by an exterior slope, which terminates either with or without a berm, at the level of the crest of the wall.

A Revetment with a Chemin-DEs-Rosdes * is one having a wide berm (Fig. 345), which forms a patrol path, the front of which is usually protected by a parapet wall, which must not be so high as to interfere with the artillery fire of its own rampart. This wall is either loopholed or provided with a banquette, to enable the defenders to fire over it. The defenders communieate with the berm by meaus of passages eut through the parapet, or by galleries leading under them.

These three revetments are compared in Figs. $343,344,345$, each of which figures represents a profile having the same relief ( $45^{\prime}$ ) and a glacis of the same height, as shown by the dotted line.

Fra. 343.
Fte, 34.
Fig. 345 ,


The Ful Revefament has the advantage of great height, and, consequently, of security from escalade : and if an escalade be attempted, the tops of the ladders, when placed against the escarp, are visible from the parapet, and the assailants are prevented from assembling unseen in considerable numbers, before coming into contact with the defenders, who have it in their power to mount the superior slope and overset the ladders by main force; or contend, with every advantage, with the assailants as they reach the top. This revetment also encroaches less on the interior space than the others.

On the other hand, a full revetment has its upper part visible from the country, and so is liable to be breached at any place against which an enemy constructs a battery; $\ddagger$ the fall of this portion of the revetment would bring the parapet with it, and expose the interior of the work. Therefore, while a full revetment is a good one to resist a coup-de-main, it is not good against a regular attack.

The Demi-Revetment has the advantage of being concealed from distant view, and the parapet, therefore, is not so liable to be breached from a distance. Its defects are as follows :As it is a lower wall than a full revetment (for the same relief of work), shorter and lighter ladders can be used to surmount it, and the assailants are further concealed from the direet view of the garrison as they leave the ladders, by the exterior slope of the parapets, on which they may assemble in considerable numbers, prior to rushing into the work en masse.

The Chemen-des-Rondes Revetment combines, to a considerable extent, the advantages of both the full and demi-revetment, without their disadvantages. Its capability of resisting an escalade is very great, for its height is greater than that of the demi-revetment (although not quite so ligh as the full revetment), and the ladders, when reared against it, can be reached and overset

[^32]by the defenders, who can also reach the assailants with the bayonet as they arrive at the top, and before they step off, the ladders. The difficulties in the way of an assailant would be further increased by the double tier of fire which this profile allows.

Should the covering wall be breached, the parapet remains uninjured, and the work is in as effective a state as it would be had no mur-des-rondes existed.

Against a regular attack this revetment is also very effective, for it is as well covered from distant fire as the demi-revetment.

The covering wall is usually (though not necessarily) raised above the level of the glacis (as in Fig. 345), and therefore exposed to distant view, and liable to be destroyed by distant fire; but, as above remarked, this does not interfere with the effectiveness of the escarp in other respects; and even if the escarp itself is breached, the whole of the parapet will not fall with it, owing to its being retired some distance behind the wall.

The wide berm, whether provided with a covering wall or not, gives to the defenders the power of repairing the earthen parapets. This advantage will be more precious to the defenders in future, than it has been in past sieges, owing to the very destructive nature of the shells fired from rifled ordnance, which will quickly ruin any earthen parapet, whatever may be its thickness, if there does not exist a facility on the part of the defence for repairing damages. In both the full and the demi-revetment, when any earth is knocked away from the parapet it falls into the diteh, where it is practically lost; but with a wide berm it lodges there, and can be thrown back by working parties employed at night.

The defect urged against the chemin-des-rondes is, that the berm allows an assailant, when he has reached it, to pass to the right or left along it unseen from the parapet, and so to enter the work at many places. This is the case if no provision is made to prevent it, but in modern constructions the berm itself is provided with cross walls loopholed, which not only prevent an enemy passing along it, but also provide a close musketry flank defence for it. Another defect of the chemin-des-rondes revetment is, that it interferes with shells, \&c., being rolled from the parapet into the ditch. This would only be the case at those parts where the parapet wall had been destroyed, for shells could be rolled into the diteh from the walls.

The advantages of this revetment, on the whole, are so great that it is in general use at the present time.

The Faussebrate (Fig. 346) was formerly constructed with the view of giving to the defenders a superiority of fire. The relief of the work was divided in two by the lower line of work, which was so low as to be concealed, or nearly so, by the glacis. The Faussebraie had so many defects as to lead to its entire abandonment. The escarp of the upper line being exposed to view, was easily breached; its splinters rendered the lower work almost untenable, while the divi-

Fta. 346, -Scale $\frac{1}{\text { 3ain }}$
 sion of the relief into two greatly facilitated the escalade. The lower line of work was concealed by the glacis, and could only come into use after the crowning of the glacis; but at this period of an attack the besieger could enfilade it, and bring a plunging fire into it from his lodgments.
364. Counterarched Revetments (Figs. 347, 348)-Revètements en décharge-are those that are strengthened by vaults constructed at their back. In this mode of construction the counterforts of an ordinary revetment become lengthened so as to form the piers of arches, which are turned from one pier to another: these arches support the earth above them, and relieve the front wall from all, or nearly all, pressure ; aud, consequently, it (the front wall) may be made merely thick enough to be proof against stray shot.

The arches may be in one or more tiers, according to the height of the revetment.

These walls greatly increase the diffeulty of forming a breach by artillery fire; for as the front wall is a mere mask, it is necessary,


Fig. 348.
Seotion and elevatiou on A B.-Scale $\frac{1}{\text { mow }}$
N.B. The profile on CD is the escarp in Fig. 441. after its destruction, to bring down the arches by cutting away the piers. This would be a long operation compared with that of cutting through a solid revetment. It was for this reason that vaulted revetments were first used in escarps; but they have other advantages, which render them very serviceable for countersearps also.

By forming doorways through the piers, and by loopholing the fiont walls, these revetments are made into galleries, either escarp or countersearp, from which a musketry fire can be directed on to the ditch. The back of the vaults is sometimes closed by a masonry wall, as in Fig. 347, when they become available as stores, or even barracks: * this is generally done in escarps; sometimes they are left without a back wall, as shown in Fig. 442, where the piers are made sufficiently long to keep the earth so far from the front wall as to enable the revetment being used as a gallery. The absence of a back wall in a gallery facilitates mining operatious.
365. Casemates are vaulted bombproof chambers. They are often formed behind escarps, provided with embrasures or loopholes, so as to facilitate the defence of the diteh, and may be used as barracks, without lessening the beight of the escarp. Several tiers of them have been used in the flanks of old fortresses.

Casemates, when required to be used only as barracks, are frequently placed under the terrepleins of ramparts, where they are protected from direct fire by the mass of the front part of the parapet and rampart.

Casemates are more fully described in Chapter VI., "Vaulted Works,"

## CHAPTER II.

## THE WORKS GOMPOSING A BASTIONED FRONT.

Polygons: Frone and Ststen of Fommptcation defined; the two Systems in preseat use, Basrlose, their shape, position, Gc: distance copart of. Construction of a bastioned front, the relief boing given. Lenglhs used for fines of defence, formerly and af the present time. Construction of a front, the exterior side heing given. Fuws and Empry Bastrons. Coontrisecaep, hour traced. Object, nature, foc, of Rayecins; odeantages of large navelins. Object and nature of the
 defects. This Gulors. Comoruntoatrone of fortresses, twon Kinds. Description of Posterpns, Caponniteres, Raitps, Stepg, and Saulipports. General description of the ordinary (peace) communications used in fortified towns.
366. When a place is fortified it is surrounded by a polygon (which is regular or irregular in form, according to the nature of the site) ; and on each side (as a b. Fig. 349) of this polygon, an arrangement of works called a Front of Fortification is traced, baving its own flank defence

[^33]complete. The various lines of work constituting the trave or outline of a front, form what is
called a Sustem of Fortification. called a System of Fortification.

There are two methods of flanking the ditehes of fortresses :-1st. By means of the flanks of bastions, in the Bastioned System.

2nd. By means of powerful casemated kaponiers in the ditches, in what is termed the "Polygonal System," which allows of the works assuming a polygonal, or nearly polygonal figure, without being broken up by the flanks. It is with the former system only that we now have to deal.
367. The Bastions oceupy the position held by the towers of ancient fortifications; they are of a pentagonal form, and should be so far apart as to allow the whole of the escarp wall of the curtain between them being de-

Fio. 349.-Scale 250 yards to 1 inch.
 fended from the flanks: this will be effected if the musketry fire of the flanks, at the greatest admissible depression ( 1 in 6 ), can reach to within 4 feet of the bottom of the ditch, in front of the middle of the curtain. The lenyth of the curtain will therefore depend on the relief given to the flanks; and for this reason, in the Bastioned System, the trace is dependent on the relief of the works.

At the same time the salient of each bastion should be within effective range of the flanks of the adjacent bastions, in order that it may be properly flanked by them; and provided that these two conditions are fulfilled, it will be advantageous in a bastioned front to make the curtain as short as possible, and the faces of the bastions as long as possible.
368. The main line of work, or that immediately surrounding the place fortified, is called the Body of the Place, or (by the French) the Enceinte. The ditch surrounding the enceinte is the Main Ditch. Works separated from the enceinte, but within the glacis, are termed Outworks; those in advance of the glacis, but within musketry range of the main work, are termed Advanced Works; and those situated so far in advance of the main works as to require to have their own flank defence, are termed Detached Works, and usually form separate, independent works.
369. The construction of a bastioned front will now be described, supposing the relief of the flanks to have been decided on, according to the profile, Fig. 350,

Fre. 350.-Scale $\frac{1}{\text { giou }}$, or 80 feet to 1 inch. where a relief of 45 feet has been given. Draw the line $a c$, at an inclination of 1 in 6 , to represent the greatest admissible depression of musketry, and continue it until it intersect a plane $b c$, $4^{\prime}$ above the bottom of the ditch. Then the ditch beyond the point $c$ will be under the musketry fire of the parapet $a$.

In the plan (Fig. 351) parallel to the flank E G, and at a distance from it equal to $b c *$ in

[^34]
## Permanent Fortification.

the profile, draw a line $f 0$ : this line $f 0$ will represent the intersection of the plane of the superior slope of (or of makketry fire from) the flank, with a plane $4^{\prime}$ above the bottom of the ditch; consequently, the whole of the ditch to the right of the line $f \in$ will be under the musketry fire of the left tlank, E G. If both flanks have the same relief, and the ditch be level, Ge will be half the curtain; if not, $t$ H way be determined in a similar manner from the relief of the flank, FH. From this it will be evident that a great relief necessitates a long curtain.


The flanks E G and FH are usually made long enough to contain five or six guns each, such being the number that a besieger can mount in his counter-batteries ( $x$, Fig. 352 ), which are placed on the crest of the opposite glacis for the express purpose of silencing those of the flank. The flarks should be perpendicular to the lines of defence.

The lines of defence, GB and HA , are drawn from each end of the curtain through the point $D$; the line e D being drawn perpendicular to, and $\frac{1}{5}$ * of the curtain.

The length of the curtain, GH, being thus determined, as also that of the flanks, the actual length of the exterior side, A B, will depend on the length given to the lines of defence, A H and $G B$.

The maximum length of the lines of defence of fortresses has been, until of late, considered to be 300 yards, in order to keep the salients flanked within range of case-shot, grape-shot, and wall pieces, fired from the flanks. This dimension, owing to the improvements in artillery and musketry, may be now assumed as $500 \dagger$ yards.
370. The exterior side may be determined in two ways, when the length of the curtain has been fixed.

1st. By making the lines of defence, AH and GB, of a determined length, as in Fig. 351 on the left, where $\mathrm{A} H=300$ yards. By so doing, the length of the exterior side, $\mathrm{A} B$, is obtained, and also that of the faces of the bastions.

Lines of defence should be made as long as cenvenient, for many advantages will result: the faces of the bastions become longer, the bastions themselves larger and more roomy, and the exterior sides are increased in length. Many advantages arise from having large bastions: the operations of defence, generally, are more easily carried on, and vertical fire has less effect in a large work than in a small one; there is also more room for traverses, and, in general, the larger a bastion is the more formidable as a work it becomes. The advantage of long fronts is, that fewer fronts are required to surround a given space, and therefore fewer hastions (or points of attaek) have to be guarded.

2nd. By making the length of the faces of the bastions bear a certain proportion (usually $\frac{1}{2} \mathrm{rd}$ ) to that of the exterior side.

In this case (see Fig. 351 on the right), the line of defence, GB, will be drawn of indefinite length; from the end H of the curtain, set off along the line of defence, $\mathrm{H} b$, equal to one-third of the curtain; join $\mathrm{F} b$, and through $H$ draw H B parallel to Fb ; the intersection B of this line

[^35]with the line of defence, will fix the salient. By this construction B F will be one-third of the length of the exterior side.*

It will be evident from this Figure 351, that e D bears the same proportion to the curtain GH, that C D does to the exterior side, which in polygons of six sides and upwards is one-sixth.
371. The usual method of arranging the fronts of a fortress is, as before mentioned, to surround the space to be fortified with a polygon, each side of which is of a suitable length for the exterior side of a bastioned front, which, with the ordinary relief of 45 feet and the old maximum of 800 yards for the lines of defence, was about 400 yards.

On each side of the polygon so determined, the following construction is executed, similar to that described in Art. 219 for the front of a field bastioned fort.

Bisect the exterior side AB (Fig. 352) in C, draw CD perpendicular to A B, making it either $\frac{1}{8}, \frac{1}{7}$, or $\frac{1}{8}$ of $A B$, according as the polygon is a regular square, pentagon, hexagon, or superior polygon. Draw the lines of defence from $A$ and $B$ through $D$, the inner end of the perpendicular ; on these lines set off AE and B F, each one-third t of the exterior side AB, and through the points E and F draw the flanks E G and FH perpendicular to the lines of defence ; lastly, join G and H to obtain the curtain.

$$
\text { Fio. 352.-Scale } \frac{\text { т } 12 \pi 0^{\circ}}{}
$$



The curtain GH being thus determined, the maximum relief to be given to the flanks may be found by reversing the operation described in Art. 369.

By producing the curtains an interior polygon is formed, the sides of which are termed the interior sides ( $y z$, Fig. 352); the main polygon being termed the exterior polygon, and its sides the exterior sides of the fortification.

Those bastions which have their interior filled up to the level of the terreplein of the rampart, are termed Full Bastions (Fig. 352); those in which the rampart of the faces and flanks is limited to the usual width, are termed Empty or Hollow Bastions. Full bastions are best for defensive purposes, as good retrenchments can be made in them, and the movements of the defenders are less cramped than in Empty Bastions, which latter are, therefore, usually placed ou the sides least liable to a regular attack.

The Counterscarp of the main ditch is rounded at the salients, with a radius equal to the usual width of the diteh, the flanked angle being taken as a centre; the counterscarp is

[^36]directed trigential to these curves, to the shoulder angle of the opposite bastion. By this means the fire of the whole of the flank oan be directed on to the ditch.

372 The ground about the capitals of the bastions, in a place nuprovided with outworks, is very weakly defended, as only the distant fire from the flanks can bear on it; and if the ground fall rapidly to the front, even this defence cannot take place. To remedy this defeet is the principal nse of the Ravelir, which is a work formed of two faces meeting in a salient angle, constructed as in Fig. ${ }^{352}$, in advance of the main ditch, the counterscarp of which forms its gorge. The faces of the ravelin are traced so as to be flauked by those of the bastions. The ditch of the ravelin rums into the main ditch : its countersearp is traced parallel to its faces, and is rounded at the salient, the width being generally 20 yards,

By this arrangement of Lavelins and bastions all the advantage of cross fire on the salients that is obtained in the trace of the field star-fort is also obtaned here, as the bastions and ravelins mutually defend one another, without the attendant defect of dead re-entering angles. The other advantages of ravelins are, that they cover (or ought to do so) the shoulders of the bastions from distant fire ; they protect the commumications, which are made in the middle of a front; and, when they have sufficient saliency to throw the bastions into a re-entering position between the ravelins (as in Plates 3 and 4), they prevent the bastions being attacked until after they have been captured. Consequently, large ravelins which have considerable saliency and breadth of gorge, are preferable to small ones. Large ravelins have the further advantage of affording sufficient room in the interior for a permanent Reduit (as in Plates 3 and 4), which greatly increases the difficulties of a besieger, who would be forced to make himself master of the reduit before attacking the bastions.

Ravelins were originally termed Demilunes, on nccount of their plan resembling a half-moon; they were then small works placed in front of the centre of the curtain, intended to cover the gateways leading into the place through the curtain. As their other advantages becarae apprecinted, they were enlarged with every successive improvement of the Bastion System, until they reached their maximum size in the trace termed the "Modern French System," which is exhibited in Plate 3.
373. The Tenaflet is a work of low relief placed in the open space between the flanks and curtain, from each of which it is separated by an interval, usually of 11 yards. The lines of defence form the magistrals of its faces, which thus make a re-entering angle. The relief of the renaille is made as high as can be done withont interfering with the artillery fire from the flanks, directed so as to defend a breach in the face of the opposite bastion.*

The uses of the tenaille are numerous, but more passive than active. It brings a fire into the interior of the ravelin and of its reduit (when there is one), and prevents these works being attacleed by the gorge; passively it acts as a traverse to cover the escarps of the flanks and curtain from being breached, either from the interior of the ravelin or from the salient of the covered-way of the bastions, and thereby prevents any retrenchments made in the bastions being turned, and for this purpose the higher it is the better: it also covers the main postern in the curtain, and it greatly facilitates sorties in the ditch, as the space between itself and the curtain is a good position for their assembly. In a wet ditch the tenaille also sereens boats, de., which are used for communicating across it.

The tenaille has the defeet of shielding parts of the main ditch from the fire of the flanks.
374. The Covered-Wax (already described as regards its profile, in Art. 356) follows the line of the counterscarp round the fortress. In order to facilitate sorties, it is enlarged at the salients and at the re-entering angles, forming what are called Salient and Re-entering Places of Arms.

The Salient Places of Akms (88, Fig. 352) ave formed by rounding the counterscarps at the salients, while the crests of the glacis are not rounded, but meet at a salient angle; they are bounded laterally by the traverges on either side. Their uses are to allow small bodies of men to assemble for the parpose of impeding the works of a besieger when he arrives near the fortress, and from their advanced position they afford a favourable place from which to bring a mnsketry fire on to the works of a besieger.

Thr Re-entering Place of Arms ( $r$ r, Fig. 852) is a considerable enlargement of the

[^37]
## Permanent Fortification.

covered-way at the re-entering angle. Its glacis is either formed of two faces, each of which makes a flanking angle of about $100^{\circ}$ with the branches of the covered-way, or it is formed in one curve (as in the Modern System) in order to be more secure from enfilade.

The Re-entering Places of Arms are the places of assembly for troops prior to making sorties in force. From their position in a re-entering angle they are naturally strong, as they are protected by the branches of the covered-way on either side, the fire from which can be used to protect the advance, and to cover the retreat of the sortie. They also afford a flanking musketry defence to the glacis of the salients, which at night is more effective, both from its grazing nature and short range, than that from the ramparts in rear.

The Branches of the Covered-Way are the portions of it between the Salient and Reentering Places of Arms.
375. The covered-way, forming as it does a series of salients, is generally exposed to enfilade fire; and also, as its terreplein is on or near the level of the ground, it can be enfiladed with full charges. As a protection from enfilade, it is provided with traverses, which run across its terreplein; and since these traverses are useful in defending the covered-way, they are built in the form of parapets which fire towards the salients. The traverse nearest to the salient of each branch of the covered-way, is always placed in the prolongation of the faces of the parapet of the work (Fig. 352), as in that position it occupies ground that is not well defended, either by the direct fire of the work or by the fire which flanks the work. The traverse nearest to the reentering angle is made to enclose the re-entering place of arms ; its length is perpendicular to the line of the covered-way. These two traverses are often sufficient for a line of covered-way; but when the branches of the covered-way are long, as is the case with large ravelins, one and sometimes two intermediate traverses to those above mentioned may be required.

The traverses occupy the whole breadth of the terreplein of the covered-way. Passages are cut in the glacis round their ends, so as to form a pathway for communication, from 6 to 12 feet wide on the ground. They are made in either of the two following manners.

Fig. 353 shows what is termed the double crotchet passage : in this case the crest of the glacis retains its ordinary direction, parallel to the counterscarp, the passage being merely cut into the glacis.

This method has the defect of rendering the pathway opposite the end of each traverse dead, as it cannot be seen either directly from the work, on account of the traverse, or in flank, on account of the crotehet. Its advantage is that the traverse occupies the prolongation of the line of banquette in its rear, which it therefore protects from enfilade.

Fig. 354 shows the single crotchet or cremaillère method. Here the glacis is indented or formed en cremaillere, so as to allow the passage opposite the end of the traverse to be defended by the flanking work; consequently there is no dead ground there.

The objection to this method is that the banquette is not covered from enfilade by the traverse; and although it is more modern than the other method, it is doubtful whether it is preferable.

In both cases the following defects exist: the traverses encumber the covered-way, interfere with the communications of troops along it, and occupy room that could otherwise be provided with a ban-


Fre. 354.-Scale $\frac{1}{1050}$ quette. With regard to this last-named defect, a narrow masomy banquette is sometimes built to the glacis round the ends of the traverses.

Another defect of these traverses is, that the defenders of the covered-way can only retreat round them on the side nearest to the glacis, which would be extremely difficult in the event of the covered-way being taken by assault, as such line of retreat would be that nearest to the enemy.

To obviate this evil, a pathway 4 feet broad is somotimes left between the countersoarp and the inner end of the traverses (as in the Modern System, Plate 8). This is not a good contrivance, as in remedying one defect it crentes another,-viz, that of uncovering the terreplein behind, by shortening the traverse. The lenst objectionable method appears to be to build projecting stones, such as $a$ a, Fig, 353 , into the counterscarp, on which to lay planks when required.

On the whole, the defects of these traverses in the covered-way are considered to ontweigh any advantages they may possess : in new constructions (as in Plate 5) they are suppressed.

The whole covered-way is supposed to be palisaded, as described in Art, 956. Esch traverse is also provided with a row of palisades at the foot of its interior slope, which are joined to those of the glacis, by a barrier gate closing the passage, as seen in Fig. 360.
976. The Gracis covers a breadth of from 50 to 70 yards, ns its command is usually about 8 feet, nad its slope, regulated nocording to the conditions described in Art. 356 , is from $\frac{1}{50}$ to $\frac{1}{2}$ -

Having described the ordinary works which form a regular front of a Bastioned Fortuess it should be here remarked that there are very few fortresses which sgree exactly with any individual system described in books, thongh most resemble one or other very nearly, or consist of combinations of them. The systems which bave been wholly or partly carried into execution are, of course, the most interesting, and form valuable subjects of study. A knowledge of their advantages and defects, and the best methods of attreking and defending them, will enable the stadent properly to appreciate works which have been or are to be constructed, or the operations by which particular fortresses have been or may be captured.
377. Ture Compunionmoss used in fortresses are of two kinds,-viz, those which are used by the garrison when defending a besieged place; and those which are used in ordinary times for the traffic of the place with the exterior. The former are by means of Poslerns, Caponnieres, Ramps, Stairs and Sally-ports, and should be so situated and constructed as to be covered from the view of a besieger as he gets possesssion sucussively of the outworks; and they should also allow of the passage of troops of all arms.
378. A Pobtemn (Fig. 355) is a vaulted passage or gallery leading under a rampart. Its breadth is usually $8^{\prime}$, which is sufficient to allow guns to be taken though it; its height is $6^{\prime}$ to the spring of the arch, which rises $9^{\prime}$, and thus makes the clear height in the centre $8^{\circ}$. When a postern is necessarily inclined, its slope should not be steeper than 1 in 6 . In every bastioned front there is usually a postern which leads under the centre of the curtain, and gives access to the main ditch from the body of the place; its exterior opening is usually made in a dry ditch 6 feet above the bottom of the ditch, as in Plate 1 , as a security against surprise: a temporary ramp of woodwork, made when the communications are required to be thrown open, completes the descent. If the ditch be wet, the opening of the postern is made 1 foot above the highest level of the water. The tenaille masks this opening from the front. Both ends of the postern are usually closed with strong gates, which are sometimes loopholed.
379. A Caponniere is a work extending across a ditch, for the purpose of affording a protected passage aoross it.


Fis. 356.


A Dourle Caponnière (Fig: 356) is formed of two parallel earthen parapets which face outwards ; the superior slope of each is continued (hike a glacis) to the bottom of the ditch, the interval between the two parapets being wide enough for a roadway of communication. Each parapet is provided with a palisaded banquette for musketry; the real use of the parapets is, however, to act as traverses to cover the communication between them. A Single Oaponsicire, called also a Demi-Caponniene, is formed of a single glacis parapet, and is used in situationa where it is required to cover a communication from one side only, as is the cuse in crossing the ditch of a ravelin or
other outwork. The slope of the glacis parapet should be such that it can be defended from the flanking works by a grazing five of musketry.
380. A Ranp is an inclined road leading from one level to another; generally from the interior of works to the terrepleins of their ramparts. Ramps are usually made 10 or 12 feet broad ; their slope varies with the height to be ascended: the higher the ascent, the less steep they should be. Up to heights of 9 feet they may be made at $\frac{1}{14}$; from 9 to 12 feet, $\frac{1}{8}$; from 12 to 15 feet, $\frac{1}{10}$; and for greater heights, $\frac{1}{1 .}$.

In the body of the place two ramps are usually allotted per bastion: in full bastions they lead up, in rear of the curtains, to the terreplein of the bastion, as shown in Plates 1 and $3:$ in empty bastions, they occupy the rear slope of the rampart of the flanks, as in Fig. 357, where a ramp 12 feet in breadth and having a rise of 1 in 10 is shown, ascending a slope of 15 feet in height.

Ramps should always be used in preference to steps for the principal communications of a fortress, as they are practicable for troops of all arms, and are easily repaired when damaged by the explosions of shells, \&c. Communications are also more rapid and easy with them than by means of steps, particularly during the night, or in time of frost,



Fig. 359.-Elevation.
381. Masonry Steps, Figs. 358, 359 (French, Pas-de-Souris), are generally used to ascend the counterscarps and the gorges of outworks. To a great extent they are superseded in modern works by ramps, except when required only for infantry, and then only in situations where there is not room for proper ramps. The width of the staircase is generally $6^{\prime}:$ each step rises $8^{\prime \prime}$, and has a base (or tread) of $12^{\prime \prime}$; consequently the slope of the stairease will be $\frac{8}{10}$ or $\frac{4}{3}$. The steps sometimes commence from a landing-place 6 feet above the bottom of the ditch, to render a smrprise more difficult; temporary ladders or steps of woodwork being used to complete the communication when required. The steps are usually made in double flights, both at the reentering angles of the covered-way, as in Fig. 858, and also sometimes at the salients, as in Plate 1; but in this latter position they are defective, as they open a line of retreat for the defenders of the covered-way, out of their proper course, which is from traverse to traverse.

Masonry steps have the defects of being practicable for infantry alone, of being liable to destruction from vertical fire, and of being very difficult to repair during a siege.
382. Sally-ports are ramps cnt in the glacis from the covered-way; they are usually made only in the re-entering place of arms. Their width is 12 feet, and their ordinary slope is 1 in 8 . They should be seoure from enflade, either by being made sufficiently curved, or by being directed, if made straight, on to a projecting salient. They are closed by barrier gates in the line of the palisades of the covered-way, as shown in Fig. 360. The term Sally-port is sometimes also applied to a postern.
388. The Communications of a Fortress for the use of the garrison and inhabitants in time of peace are those by which the great roads of the country enter the place. They are taken through the strongest fronts of the fortress; usually there is a gateway to every three or four fronts. The details vary in different cases, but the general arrangement is as follows :-An
arched gateway, providing a rondway for curiages and footpaths for pedestrians, leads through
 the middle of the curtain ; a drawbridge, connected with a fixed bridge, gives access to the tenaille, through the parapet of which an opening is made; another bridge (sometimes provided with a drawbridge) leads thence to the interior of the reduit of the ravelin, or the ravelin itself, if there be no reduit; similar gateways through the ramparts of the reduit and ravelin, and bridges over their ditches, lead to the covered-way, from whence a winding cut is made in the glacis ; beyond the glacis the road
is directed so as to be enfiladed for a considerable distance by the guns of the place.
These communications require permanent guards ; and as they are sources of weakness to a place, they are limited to what is strictly necessary. The bridges are of timber, or of slight constructions in iron, in order that they may be easily removed.

During a siege, those gateways on the fronts not attacked are available for sorties. If the front of attack be provided with them, the bridges should be removed and the arches built up; the military or siege communications would then be thrown open.

## OHAPTER III.

## VAUBAE'S FIRST SXBTEM.

Fauban's great reputation as a Militory Kngineer. His worls divided by his Successors into three types or systems. Details of construction of a front of Vauban's First System, Commands anal reliefs of the system, Communioutions of a front. Defects. of the systens.
384. Vauban (a Marshal of France, bom in 1633, died in 1707), from his remarkable genius as an Engineex, and the many opportunities that the wars of Louis XIV. afforded him for its display, both in the construction and in the attack and defence of fortresses, is still looked up to as the greatest Military Fingineer of modern times. He repaired and strengthened the fortifications of 800 places, built 33 new ones (nearly all of them of the type about to be described), conducted 58 sieges, and was present in 140 actions. The most remarkable improvements introduced by him were in the attack of fortresses; for while his First System-viz., that used by him in his earlier days-was but a slight improvement on the system in use before his time, he so improved the method of attack, principally by the introduction of parallels and the invention of ricochet fire, that the science of attack, at the present day, remains almost as be left it.

We have no memoir from his pen describing the proportions he approved of for bastioned fronts; but his successors, in comparing the various fortresses which he constructed, have classed them into three types or systems. To the first belong, as already mentioned, about 30 fortresses, which he entirely constracted, and also many others which he improved; the second is found in the fortresses of Befort and Landau; and the third (a slight improvement on the second) at Neuf

Brisach. But it must be remembered that Vauban had no fixed System ; in every case he rather adapted his works to the sites, than followed any particular type.
385. The following is the construction usually assigned to his First System (see Plate 1).

The exterior side (A B) is 360 yards. Vauban varied it, in fact, between 820 as a minimum and 400 yards as a maximum.

The perpendicular $C D$ is $\frac{1}{6} A B$ for hexagons or superior polygons.

| 3 | 1 A B pentagons. |
| :--- | :--- |
| 3 | $\frac{1}{4}$ A B squares. |

The capitals of the bastions bisect the angles of the polygon.
The faces of the bastions (A E and B F) are each $\frac{1}{7}$ th A B.
The flanks are drawn by making them chords of ares described from one shoulder ( E or F ) as a centre, with the distance to the opposite shoulder as a radius, their inner ends being terminated on the line of defence.*

The curtain (G H) joins the inner ends of the flanks.
The main ditch has its counterscarp rounded at the salients, with A and B as centres, and radii of 32 yards ( 80 metres), and is directed tangent to these arcs on to the opposite shoulder angles. In wet ditches the breadth at the salients was made 38 yards ( 36 metres).
386. The Salient (K) of the Ravelin is found by striking an arc outwards with one angle of the flank, as H, as a centre, and with the distance H E to the opposite shoulder, as a radius, until it meets either the perpendicular produced, or a similar arc having its centre at $G$. The faces of the ravelin are directed from $K$ to points $L$ and $M$, on the faces of the bastions, 11 yards (10 metres) from the shoulders. The main countersearp terminates the faces of the ravelins, and forms the gorge wall of that work.

The counterscarp of the ravelin is drawn parallel to its faces, at a distance of 21 yards ( 20 metres) in a dry ditch, or 25 yards ( 24 metres) in a wet ditch, and it is rounded at the salient by taking the flanked angle (K) as a centre, and the width of the ditch as a radius.
387. The Tenathle has its faces coinciding with the lines of defence; its gorge wall is parallel to and 17 yards distant from its faces. A short curtain, or centre face, is sometimes added by making its gorge wall parallel to the curtain, and 11 yards from it, the thickness of the tenaille at this point being also 17 yards. The ends are terminated parallel to the flanks, and 11 yards ( 10 metres) from them. $\dagger$
388. The Covered-way is 11 yards ( 10 metres) broad; its crest (that of the glacis) being parallel to the counterscarp, and 11 yards from it.

The Re-entering Places of Arms are traced by giving them a demi-gorge measured on the line of the countersearp of 36 yards ( 32 to 40 , as the exterior side varies between 320 and 400 yards), or $\frac{1}{10}$ th of the exterior sides, and by drawing their faces from the outer ends of the demi-gorges to form flanking angles of $100^{\circ}$ with the counterscarp, until they meet in a salient angle.

The foot of the slope of the glacis is parallel to its crest, and 50 yards distant.
The Covered-way is provided with traverses, 18 feet in thickness, measured on the superior slopes: those at the salient have their crests in the prolongation of the crest of the bastions and ravelins; those enclosing the re-entering places of arms have their crests drawn perpendicular to the covered-way, from the outer extremities of the demi-gorges. The passages round their ends are made on the double crotchet method, as in Fig. 360, which is drawn on a sufficiently large scale to show the details of the passages.
389. The re-entering places of arms are provided with a couple of sally-ports, one in the middle of each face. They are 12 feet broad: they may be drawn in a curve, taking the salient as a centre, and terminating them 10 yards from the crest of the glacis; or they may be made straight, and directed on to the neighbouring salients.
890. A double Caponnière leads across the main ditch, between the tenaille and the gorge of the ravelin. The erests of its parapets are 12 yards apart, and parallel to one another; the

[^38]superior slope of each parapet has a base of 30 yards. The Caponuiere is separated from the gorge of the ravelin by a pathway 8 yurds hroad.
891. The Commands and Reliefs of the varions works in this system are given bolow in the table, and are also shown in the profiles in Plate 1, which are the profiles of the various works composing a front. It should, however, be remembered, that only a type of Vauban's constructions is here presented, and that the various commands and reliefs were suited to the particular circumstances of each case.

COMCKANDS, ETC., OE VAUBAN'S FIRST SYSTMM,

392. The communications of each front are similar to those described in the preceding Chapter.

A Postern in the middle of each curtain leads into the main ditch; thence, another postern ander the tenaille (its floor being on the level of the ditch) conducts to the double caponniere which gives access across the main ditch.

A double flight of steps is made in the gorge of the tenaille, the gorge of the ravelin, and at each salient and re-entering place of arms. These steps sometimes commence from the bottom of the ditch, as in Figs. 358,359 , page 175; and, at others, they spring from a landing-place fi feet above the bottom of the ditch, to render a surprise more difficult, as described in Art. 381.

The sally-ports give access to the glacis; and the passages round the traverses to the various parts of the covered-way.

The usual ramps afford communication with the terrepleins of the ramparts of the different bastions and ravelins, as shown in Plate 1.
393. The defects of this system are as follows:-

1st. The bastions, in the inferion polygons, are too small and contracted at the gorge. In later construetions (Vaubat's Second and Third Systems) this defect is remedied by making the faces $\frac{1}{3}$ rd instead of $\frac{2}{7}$ ths of the exterior side, and by making the flanks perpendionlar to the lines of defence.

2nd. The angles of defence being less than right angles, the defenders of one flank would be liable to throw their fire into the opposite bastion.

3rd. The ravelins have so little saliency, that the bastions can be attacked (except in cases of large polygons) at the same time as the ravelins; in other words, the ravelins do not, in a regular attack, delay the fall of the place, but merely force the besiegers to construct the batteries and other works necessary for their capture. Moreover, as a besieger has generally to attack three salients, he is able, when the ravelins are not sufficiently salient, to attack two bastions and one ravelin simultaneously, instead of being forced first to capture two ravelins, and afterwards to penetrate to the bastion between them, thereby attacking the body of she place at a single point only.

4th. The ravelins are not sufficiently broad at the gorge to protect the parapet of the shoulders of the bastions from being breached from a distance; the curtain wall can also be breached through the opening of the tenaille, by batteries on the glacis.

These defects are important, for the breaching of the shoulders exposes the guns in the flonks to enfilade fire through the opening; and that of the curtain would enable a besieger to turn any retrenchment that may have been made in the bastion.

5th. The Ravelins and Re-entering Places of Arms are too small to contain good reduits of earth and masonry; while the stockade retrenchments which may be formed in them can be eusily destroyed by artillery.

Bth. The commurications between the works are very much exposed; so much so that it would be difficult to communieate during daylight with the re-entering place of arms, after the

## VAUBAN'S FIRST SY

OCTAGON.
Scale ${ }^{\frac{1}{880}}$


Profile on the line $x, y$ scule

besieger was lodged on the glacis, for the steps leading to the re-entering place of arms are visible from the salients of the covered-way of both ravelins and bastions, and so, also, is the greater portion of the main ditch.

7 th. The full revetment allows the parapet to be destroyed, or greatly injured, from a distance. This defect, together with that of the ravelin uncovering the shoulders, would render the flanking guns liable to be silenced with ease, from a distance, by artillery fire.

See also Art. 404, page 183, for a statement of the defects of most old fortresses.

## CHAPTER IV.

## THE ATTACK OF FORTRESSES.

Remarks as to the desperate nature of an Escatade of a fortress, whether by Surprise or by OPEN Foroz. General description of the operations of a Bombardmient, a Blockade, and a Regulak Sibge; their respective merits, of a
Operations of a regular siege illustrated by an attack on a Fortress on Vauban's Fibst System.
Usual mode of apportioning the garrison and armament of a fortress; and of estimating the strength of a besieging army and the ordnance, materials, foc, required for a siege. Causes of the present superiority of the attack over the defence. Operations of the Attack and Defence (in parallel columns) during the following periods of a Regular Siege. 1. During the Investment of the Fortress.
2. From the Opening of the Trenchms to the formation of the Second Parallel.
3. From the commencement of the Second Parallel to the commencement of the Third Parallel.
4. From the commencement of the Third Parallel to the commencement of the Crowning of the Covered Way.
5. From the Crowning of the Coversd Way to the Capture of the Place 5. From the Crowning of the Coversi Way to the Capture of the Place.

Explanatory notes to the operations of the Attack and Defence. (1.) Attack on Fhushing; an illustration of a successful bombardment. (2.) Pampeluna, an illustration of a successful blockado. (3.) Advantages for siege purposes of rifled ordnance. (4.) Artillery and Engineer Parks. (5.) Description of the attack named "The Armileery Atpack." (6.) Sap-eollees, their use, dimensions, \&c. (7.) Parallels and Demi-Parallels, their object, position, and eatent : distance of first parallel; tracing and execution of a first parallel described; profile given to parallels. (8.) Zigzags of approach, returns to approaches, use and mode of tracing. (9.) Covering Pakties, use of; where posted. (10.) Siege Batteries, their natube, construction, etc.: the three profiles given to sioge batteries; details common to the whole. Trace of an Flevated Battery for a given armament; number of men required. Trace of a Sunken Battery; number of men required. Trace of a Half Sunken Battery. Comparative advantages of the three sorts of batteries. Details of Sphinter proof Traverses, Powder Magazines, Gun and Mortar Platforms, as in present use. Positions for, and advantages of Enfilading Batteries. Positions for Countrer-Batyeries, when used. (11.) Traveraes required in a fortress. (12.) Use and nature of Counter-Approaches, (13.) Masking embrasures of batteries. (14.) Rifle Pits, their nature and use. (15.) Second Parallel, its position and extent: operation of Flying Sap described. (16.) Battery in a parallel; how arranged. (17.) Effeot of shells. (18.) Demi-Parallels, necessity for. (19.) Two objects for which sorties may be made. (20.) Sapping, its nature; when resorted to. Details of execution of a SINGLE (KNEELING) SAP; its estimated rate of advance. Standing SAP, details of. Combination of Full and Flying Sap. (21,) Commencement of Third Parallel a critical period of the attack. (22.) Mode of Crovening the Covered Way by assault. (23.) Use of Crecolar Portions. (24.) Double Sap, its nature, when used: description of Jebs's Direct Double Sap. (25.) Thench CAYALIERS; use, position, and mode of formation. (26.) Ihificulties of the attack after the Crowning of the Covered Way. (27.) Countre-Batteries on the crest of the glacis. (28.) Brbaches tin mscarps; position for breaching batteries; difficulties of their construction; sapping out the embrasures. Mode of forming a breach; ammumition used in actual cases. (29.) Descent into ditch, by means of Great Galleries, Blinded Galiektes, of by blowing in the Counterscabr. (30.) Passage of a dry ditch; of a wet ditch without a current; and of a vet ditch with a current. (31.) Remarks on the Asbault of Beeacems. (32.) Formation by sap of a Lodqment on A breach. (33.) Defeenee of a breach.
394. Preliminary Observations.-Fortresses properly constructed and garrisoned, sufficiently provided with artillery and warlike stores, and commanded by men of energy, can seldom be suceessfully attacked but by a long and laborious process, which requires for its successful prosecution ample resources in men, artillery, and material.

Were an open assault attempted by daylight, the heavy fire that would be brought to bear on the assailing columns, whilst at a distance and during the whole of their advance, would have such an effect as to render them unable to contend with the defenders advantageously posted and well covered, and under all ordinary circumstances the assault would fail. If attempted at night, as a surprise, the assailants would, probably, reach the ditch with much less loss than if attacking by daylight; but the difficulties inherent to night operations, against an enemy advantageously posted, and on ground with which he is well acquainted, are such as to render this method of attack almost equally dangerous and uncertain.

Such a mode of attack would be justified only by very peculiar circurnstances,-as, for instance, by the defences being badly constructed, and being manned by a weak garrison; or by
the fact of the attacking force having but the option of gaining possession of the place without loss of time, or of retreating from before it.

Unlees attacked by Surprise, a fortress is usually gained possession of, either by Bombardment, by Blockade, or by Siege, either regular or irregalar, according to circumstances.
895. A Bombardment is an attempt to overwhelm a place by throwing into it a great quantity of shells, curcasses, hot shot, rockets, \&c, from batteries of guns and mortars, with the object of burning and destroying the town (not the fortifications), and forcing, by means of the pressure put upon the Governor by the inhabitants, the surrender of the place, without the attncking force having to go through the more tedious operations of a siege.

This method of attack is undertaken when the assailants are unprovided with the means, or cannot spare the time, necessary for a siege. Against a well constructed fortress it would be ineffective, as the garxison are protected by being lodged in bombproof buildings, and suffer but little from the effects of vertical fire, which falls principally on the inhabitants. It might succeed against a very small place, unprovided with bombproof cover; or where the Governor is a wenk man, whose sense of duty yields to his feelings of humanity; or where the garrison is insufficient to keep the inhabitants in subjection under the miseries inflicted on them. (1.)*
396. Blockade. - To blockade a place is to surround it with superior forces, sufficient in number to prevent any communication between the garrison and the country, until a surrender becomes unaroidable from want of provisions. It is simply an attempt to starve out a given garrison.

Its success will depend on the vigour with which the investment is maintained, and on the time the garrison oan hold out before they can be relieved.

A blockade is usually undertaken by an army unable to attack a fortress in any other way, either by surprise, bombardment, or by regular siege, as its duration is greater than that of any of these methods of attack. (2.)
397. A SIEGE is the most certain, the best and the most usual method of attacking a fortress, properly constructed and garrisoned, provided that the besieger is in a position, as regards resources in men and material, to carry it on with proper vigour. But when a siege is attempted without sufficient means, experience has shown, that no operation of war is more difficult of success, or more disastrous in its effeets, if unsuccessful.

In a regularly conducted siege a fortress is approached with superior forces, so disposed in the environs as to confine the garrisou to the immediate vicinity of their works, and to exclude any supplies from without, of men and of warlike material. After this is effected, the besiegers determine the most favourable side of the fortress to be attacked ; they then construct batteries for guns, mortars, \&c., to silence the fire of the works of the fortress in their front, protecting such batteries from the attacks (sorties) of the garrison, by keeping a sufficient force in their neighbourhood under cover, in trenches made for the purpose. Approaches by means of open trenches disposed so as to avoid enfilade, other trenches for the protection of the guards, and further batteries are now made, and, in time, the besieger is able to construct batteries on the very edge of the glacis, to batter down the escarp wall, and to carry his trenches up to the foot of the breach. The besieger's troops being thus enabled to march in security to the breach made in the walls of the town, can assault it, being in general superior in numbers to the garrison defending it; and as they (the assailants) are assisted by a fire of artillery and musketry directed on the defenders of the breach, which fire can be maintained until the very moment of personal contention, withont injary to the assailants, the breach, if properly attacked, is generally earried, and this lemds, in all probability, to the captare of the place.

[^39][^40]For the immediate security of the place 440 men per front are allotted, of whom 10 are cavalry, 60 artillery, and 20 Engineers, the remainder being infantry,

To withstand a siege double the above number of men are allotted to those fronts which are susceptible of attack.
399. The Artillery Armament for a fortress is considered under the same heads.
(1.) The quantity necessary for the inmediate security of a place in war time, and which is supposed to be constantly mounted, is calculated at 8 pieces per bastion, 2 of which would be in each flank, the others in the faces and salient.
(2.) The artillery requisite to stand a siege, in addition to the above, will depend on the extent of the works, as more guns can be mounted on the fronts collateral to that attacked in fortresses with many fronts, than in those with few sides.

The best authorities consider that
Fortresses of 1 st class ( 10 sides and upwards) should have 150 pieces.

| $\# \quad$ 2nd class ( 6 sides to 10 sides) | $"$ | 100 | $"$ |
| :--- | :--- | :--- | :--- |
| $" \quad 3 r d$ class (4 sides or 5 sides) | $"$ | 50 |  |

Thus, in a decagon there will be required $10 \times 8+150=280$ pieces; and in a hexagon $6 \times 8+100=148$ pieces.

The proportion of the several pieces is $\frac{\pi}{10}$ guns or shell guns, $\frac{1}{10}$ howitzers, $\frac{3}{10}$ mortars, $\frac{1}{10}$ field guns.
400. The necessary strengti of a besieging Army varies in its proportion to the strength of the garrison, and should be, as a general rule,


These comparative numbers result "from "the consideration that as many workmen are required to break ground and carry on the works of the attack against a small fortress, with fionts of (about) 360 yards, as against one on a superior polygon. The number of men required for guards of the trenches increases with the garrison; the number of men on duty in the trenches at a time, ought to be equal to $\frac{3}{4}$ of the garrison, this proportion of the latter being considered to be the utmost that can be spared at a time from the fortress for a sortie.

In addition to supplying workmen for the service of the trenches, and guards for their protection from sorties, a besieging army has to carry on other work, such as regimental and camp duties, pickets, escorts with stores and provisions, \&o. : the number of men required for these duties will vary according to the good will or hostility of the people in whose country the siege is carried on, and also to the nature of the position occupied, \&c., and therefore cannot be accurately estimated beforehand, but it may be here assumed to be $\frac{1}{10}$ of the whole army.

Guards of the trenches should have three reliefs (i.e. for every man on duty at a time there must be three men available, so that each man will be off daty for a period twice as long as his tour of duty); but the working parties, and the men for the general duties of the camp, require at least four reliefs, as their work is more onerous.

The duration of each relief (that is, the time each set of men are actually on duty) is usually twenty-four hours for guards of the trenches, and eight hours for the working parties, which latter, under particular circumstances, is increased to twelve hours. But the duration of a single relief or tour of duty does not affect the number of reliefs of men there should be.
401. On these data a besieging army, to attack a fortress garrisoned by $5,000 \mathrm{men}$, should be thus calculated:*-

Guards of trenches in three reliefs . . . $\frac{3}{4} \times 5,000 \times 3=11,250$
Working parties in four reliefs . . . . $\quad 2,000 \times 4=\frac{8,000}{19,250}$

[^41]Guards of Trenches and Working Parties, brought over
10,250
General duties of the camp, one-tenth of the whole army, $19,250 \times-4$ in four reliefs

Total, independent of sick and casualties
32,080
And for a garrison of 10,000 , the calculation would be,-
Guards of trenches, in three reliefs $\quad . \quad$.. $\quad \frac{3}{4} \times 10,000 \times 3=22,500$
Working parties, in four reliefs $\quad . \quad . \quad . \quad \quad 2,000 \times 4=\frac{8,000}{80,500}$
$\begin{aligned} & \text { General duties of camp, \&c., one-tenth of the whole army, }\} \frac{80,500 \times 4}{6}=20,380 \\ & \text { in four reliefs .. }\end{aligned}$
Total, independent of sick and casualties .. .. $\overline{50,830}$

If there be any oavalry in the garrison, the guard of the trenches requires to be supported by a number of cavalry posted on any convenient spot on the flanks of the attack, equal to the total of that arm in the fortress, with the reserve of one-half more posted at the mouth of the trenches, so that, whichever flank may be attacked by cavalry, the reverse moving to that flank will make the defensive (besieger's) force at that point equal to the enemy's entire force.
402. The number of pieces of ordnance required for the attack of a Fortress has not so much reference to the number mounted on its ramparts, as to the construction of the works themselves; for the hesiegers never willingly oppose artillery by a direet fire, but generally contrive, by skilfully placing their batteries so as to enfilade or take in reverse the works fired at, to render one gun in the attack superior to many in the place. Only those lines of work that cannot be enfiladed would be silenced by direct fire. In counter-batteries* there should be at least an equal number of pieces to the number of thase which it is intended to silence, and, if possible, double that number.

In an actual siege the number of pieces of ordnance required for the attaek oan only be aceurately ascertained by the joint labour of the Commanding Officers of the Artillery and Engineers, after the general plan of attack should have been decided on. Sir John Jones gives the following as a necessary battering train to carry on the attack of a regular fortress with vigour:-

$$
\begin{aligned}
& 24 \text {-pounders } \dagger \text {........................ } 40 \\
& 18 \text {-pounders, or heavy howitzers } \dagger \ldots . . .{ }^{4} \text {. } 80 \\
& \text { Mortars of } 8^{\prime \prime} \text { and upwards................ } 80 \\
& \text { ind }
\end{aligned}
$$

The following table exhibits the number of pieges of ordnance employed in the defence and attack of some remarkable sieges of modern times :-

|  |  | Defence. | Attack. |
| :---: | :---: | :---: | :---: |
| 1798 | Valenciennes. | 175 | 167 |
| 1806 | Gaeta. | 171 | 109 |
| 1807 | Schweidnitz | 250 | 43 |
| 1810 | Lerida | 110 | 40 |
| 1810 | Ciudad Rodrigo | 86 | 50 |
| 1810 | Tortosa | 177 | 50 |
| 1811 | Tarragona | 290 | 66 |
| 1811 | Badajoz | 170 | 54 |
| 1812 | Ciudad Rodrigo | 119 | 68 |
| 1812 | Badajoz....... | 140 | 78 |
| 1818 | San Sebastian | 63 | 88 |
| 1829 | Silistria | 238 | 88 |
| 1832 | Antwerp. | 145 | 148 |

[^42]403. The quantity of materials required for carrying on a Siege is very great, and ean only be calculated, in any actual case, after the plan of operations shall have been decided on : but to give an idea of the vast quantities used, it may be stated that at one of the French sieges, towards the close of the seventeenth and commencement of the eighteenth centuries, there were expended 80,000 gabions, 300,000 fascines, 200,000 sandbags, 270,000 bags of wool, and 30,000 entrenching tools.
404. The superiority which the besiegers have over the defenders of a fortress is partly attributable to the faulty construction of fortresses, and partly to improvements made of late years in the processes of attack.

The disadvantages of the defenders, arising from the faulty construction of fortresses, are as follows:-The exposure of the works to vertical, enfilade, and reverse fires; the liability, in nearly every case, of the front of attack being encompassed by the besiegers' batteries, and so being made the focus of an overwhelming fire; the insecurity of the communications with the outworks and the country in time of siege; the advantage of position which an outwork, when taken, gives to the besiegers; the expense and imperfect nature of the palisades, barriers, \&c., which, in the defence of the covered-way, serve as obstacles to the enemy; the insecurity of the covered-way, and its inconvenience, both for the advance and retreat of troops; in consequence of which sorties in force become nearly impracticable after the second parallel is formed, unless the besiegers are very negligent in their arrangements ; the inability of one part of the fortress to assist another in its interior defence; and lastly, in most of the old fortresses, no advantage being taken of the barracks and other publio buildings to improve the defences of the place.*

The improvements in the means of attack consist in the more extensive employment of vertical fire, and in the great improvements made of late years in artillery (3) and musketry, and which are considered to tend to the advantage of the attack (at least against an ordinary bastioned fortress), on account of the besiegers being able to encompass the front of attack and making it the focus of a concentrated fire. But on this subject there is, at present, great difference of opinion; many Engineers being of opinion that the defence has profited more than the attack, in consequence of the improvements in artillery, \&c.

The following account of the process of Sieges will be understood to be very general in its nature, and merely intended to illustrate what may be, and very often is, done in the several stages of the Attack and Defence of Fortresses. There is, in point of fact, every passible variety in both, according to the circumstances attending the attacking and defending parties.

## OPERATIONS OF THE SIEGE.

405. FOR THE ATtACK. The Investment.
As a preliminary operation to a siege, the besieging army has to invest the fortress; i.e., to surround it (suddenly and unexpectedly, if possible) so as to cut off all communication between the garrison and the country. The troops destined for this duty should arrive before the place by different routes, and endeavour to surprise the advanced posts of the garrison.

They immediately form a double chain of posts around the fortress, strengthening their position where necessary by field works: the outer chain, to prevent relief; the inner one, to prevent any of the garrison leaving the fortress.

FOR THE DEFENCE.

## During the Investment.

As soon as the garrison are informed of the intentions of the enemy, all posts without the place are reinforced, and arrangements made for securing their retreat.

These posts are to obstruct the investment, and cover the introduction of convoys and reinforcements.

[^43]The inner chain of posts is pushed eloser to the fortress nt night, to confine the garrison to their works.

A recomaissance of the place is made under the protection of a sufficient force, with the following objects:-

18t. To verify the plan of the fortress, if the besiegers have one; if not, to make one.

2nd. To determine the point of attack, by observing the nature and condition of the works generally, whether the escarps are covered to a sufficient height (5) ; the counterscarps, whether revetted or not; the ground, whether rocky, marshy, or liable to be inundated; the bastions, whether retrenched or not, \&o.

To mislead the garrison a reconnaissance shonld be made of those parts not intended to be attacked.

The camps and parks (4) are established, if possible, concealed from view, and from 3,000 to 4,000 yards distant from the fortress.

During the investment, gabions, fascines, sap-rollers (6), \&c., are made, in the nearest woods, and transported to the parks; supplies of all kinds necessary are brought up, until the besiegers are in a position to commence active operations without fear of being afterwards delayed for want of materials.

The guns of the place fire from the barbettes and cavaliers, upon everything hostile within range.

Small detachments are stationed all round the place at 800 or 1,000 yards, to retard and surprise the enemy's reconnoitring parties.

To favour this object they should be concealed in broken ground or ruined buildings; they retire into the covered-way at night.

The garrison prepare everything in readiness for the construction of batteries, blindages, bridges, palisading, and tambours.

During the night, lightballs are frequently thrown all round in order to discover the time and place of the opening of the trenches.

If there is not already casemated covering for half the number of the garrison, blindage covering should be immediately formed. A good position for a leaning blindage is against the counterscarp of a main ditch.

## 406. From the "Ofening of the Trenches" to the commencement of the Second Parallel.

The besiegers break ground the first night, by forming the 1 st parallel ( $\mathcal{T}$ ) and the zigzags (8) leading from it to the nearest cover in rear; if possible, some of the batteries are begun.

At daybreak the troops who have been covering ( 9 ) the workmen, retire into the parallel, or behind the nearest cover.

During the day the besiegers take up the prolongations of the works to be enfiladed, and also the capitals of the salients to be attacked.

The batteries (10), if not commenced the previous night, are commenced on the second night, the elevated ones being first begun, as they require the longest time for their construction; the sunken or halt-sunken batteries are commenced on the following night. Batteries sre made to enfilade all lines of work requiring to be silenced, the prolongations of whose terrepleins can be occupied: if this oannot be done, courter-batteries are made to silence them by direct fire. Within a period of from 36 to 60 hours the hatteries will be completed, with their respective traverses, expense magazines, and

The garrison fire with every gun and mortar they can bring to bear (even without platforms and embrasures at first), as soon as they dis. cover the position of the first parallel.

Their fire ought to be well sustained, as it is unopposed by the artillery of the besiegers.

Small sorties of light eavalry are made to harass the working parties; they endeavour, also, to penetrate into the parks, in order to destroy the siege materials, and make prisoners.

The front of attack being now known, the defenders begin to lay their bridges, place their cannon in battery, work at the traverses (11), flêches and counter-approaches (12), and begin their retrenchments.
platforms, and will be armed. The batteries, as soon as ready, open their fire simultaneously, their embrasures being unmasked (13) together. In about 24 or 36 hours' firing, the artillery of the fortress ought to be well subdued, their traverses demolished, and platforms broken; after which, the enfilading siege batteries keep up a steady fire night and day, to prevent the garrison repairing any damages, or mounting fresh guns.

REGULAR SIEGE.-FIRST GRAND EPOCH.
Frg. 361..-Scale 350 yards to 1 inch.

a a. First parallel.
b b. Trenches of approach.
c. Redoubt on flank of parallel.
$d d$. Returns to trenches.
Zigzags of approach on the capitals of the salients attacked are pushed forward in advance of the first parallel for a distance of 100 or 150 yards.

Rifle pits are made in advance of the

$$
\begin{array}{ll}
\text { ee. Probable future position of first parallel. } \\
\text { f. } & \text { Probable future position of the first batteries, } \\
\text { I. II. Elevated counter-batteries, } \\
\text { III.-VII. Sunken ricochet enfilading batteries, }
\end{array}
$$

They hoist howitzers and mortars into the salient places of arms, to ricochet along the capitals, and shell the approaches.
trenches, wherever convenient ; their occupants serve is advanced sentries by night and as marksmen by day (14). At all periods of the siege, rifle pits may be used with considerable advantage.

Rifle pits are constructed by the garrison, if sufficiently strong, as a means of retarding the attack.

TEEGULAR BIEGE, -OPELATKOKS AS FAE AB THIED PARALGIL
Fre. 36 - Scale 350 yards to 1 inch.

407. From the commencement of the Second Parailel to the commencement of the Third Parallel.

The second parallel (15) and its communications to the rear, with those already formed, are executed by flying sap.

Batteries are formed in the second parallel (if necessary), the guns being brought up from some of the batteries of the first parallel (16).

The approaches on the capitals of the salients attacked are pushed forward, and the demi-parallels are formed (18), if possible, by flying sap.

The ends of the demi-parallels are converted either into mortar batteries to shell the

The defenders ricochet along the lines of the capitals with shot and shells; and the attack having arrived now within easy musket shot, that arm is extensively employed from the covered-way, fléches, and counter-approaches.

The defenders fire on the batteries with full charges, and endeavour to pitch salvos, or volleys of shells (17), into their parapets.

They make frequent and vigorous sorties (19), especially on the flanks.
covered-way, or into howitzer batteries to enfilade the covered-way.

All work in advance has now to be commenced by regular sap (20), the trenches being afterwards widened to their required dimensions by infantry workmen.

The approaches (zigzags) in advance of the demi-parallels are continued until the foot of the glacis is reached (about 80 yards from the salients), when the third parallel is commenced (21).

As the trenches are completed, they are occupied by infantry marksmen, who keep up a steady fire of musketry on the garrison. The same is done from rifle pits. All the batteries maintain a steady (but not rapid) fire, on the defences. The small mortars are now used with great effect: they can be carried by hand and moved from place to place as required.

They fire upon the saps, especially upon the heads of them, with grape, case, and musketry; for the latter purpose, picked shots are stationed in the covered-way, under cover of sandbags, fascines, or gabions.

They finish their retrenchments,
408. Fron the commenoement of the Third Parallel to the commencenent of the Crowning of the Covered-way.

The third parallel (21) is executed by sap, each zigzag as it reaches the foot of the glacis branching off to the right and left to form the parallel.

The third parallel is armed with mortars at its extremities to shell the collateral fronts, and with others, at various places in its length, to shell the covered-way, places of arms, \&c., of the front attacked. Pierriers can be now used with great advantage.

It is now decided in what manner the covered-way is to be crowned. If it is to be done in the regular manner, and not by assault (22), then the besiegers break out of the third parallel by means of circular portions (23) on each capital approached; from these they continue by direct double sap (24) until within about 30 yards of the salients, when a single sap branches to the right and left, and the trench eavaliers (25) are formed. As soon as these latter are completed, and occupied with infantry, the defenders of the covered-way must abandon the salients; single saps are then directed from each trench cavalier towards the salients, proceeding to within 7 or 8 yards of the crest of the glacis, when they turn to the right and left, and are directed parallel to the crest, thus commencing "the crowning of the covered-way" (26):

Those batteries whose fire is masked by the trenches, are dismantled; the remainder

The defenders make sorties, if possible, to interrupt the construction of the third parallel, and their riflemen fire at the heads of the saps,

Guns are run up on the barbettes of the collateral fronts, and howitzers are placed in the re-entering places of arms, to fire grape, canister, and shrapnel shells into the saps and crowning trenches.

Showers of one pound and half-pound shot, and grenades, and shells, are thrown from pierriers or the small mortars, wherever they can be placed in comparative security.

Feep up their fire, Musketry fire is kept up from all parts of the trenches and lodgments. Vertical fire from mortars of all lands.

## 409. Fron tal Crowning of the Covered-way to tem Cafture of tife Plach.

The cromping of the sovered-way is extended towards the re-entering rogles, as far as it is required for the construction of the counterbatteries and the breaching batteries.

The counter-batteries (27) which are required to silence the fire flanking the ditches where the breaches will be situated, and also the breaching batteries (28) to form the breaches, are constructed, armed, and open their fire.

The great galleries of descent (29) into the ditches of the faces breached, are commenced and completed by the time the breaches are formed.

The passages of the ditches (30) are made under cover of the fire from the counterbatteries.

The breaches, when practicable, are reconnoitred; if they are not retrenched,* and the garrison contimue to resist, they may be carried by assunilt (31).

If the breaches are retrenched, they are crowned ( 32 ) in the manner that may be determined on; saps are extended right and left towards the counterscarp of the ditches of the retrenchments: the retrenchments may then be breached either by mines or by artillery; or if they are not properly revetted, they are open to assault.

The defenders place cannon on the curtains, to fire on the breaches at the flanked angles of the ravelin, and they prepare to oppose the passages of the ditches.

They prepare to fire from the retrenchments, if any, as soon us the enemy shows himself on the breaches of the ravelins.

They continue the vertical fire of small balls, and shells, and grenades tied up like grape-shat, from pierriers and small mortars, as mentioned in the preceding period. They fire from the flank of each collateral bastion, and from oblique embrasures in the curtains, upon the passages of the main ditch.

Sorties ought now to be made into the ditch, the troops passing through the caponnières, along the countersearp, and firing apon the sappers employed upon the passage of the ditch. Other sorties may pass through the troued of the teuaille, along the face of the bastion, and destroy the épaulement of the passage. These sorties should be frequently repeated by small detachments during the night.

If the garrison can command a flow of water through the ditches, this is the time to open their sluices and inundate the besiegers' work. Should the besiegers then attempt to make a floating or a sunken passage, the water may be drawn off, or the besiegers' bridge or dam blown to pieces by large charges of powder floated down the current against it.

The garrison may now withstand the assault, and defend (33) the breach; also dispute the possession of the terreplein of the bastion, inch by inch, with musketry and grenades, from retrenchments, or, when powerless for further aseful effort, they may capitulate.

## EXPLANATORY NOTES ON THE ATTACK AND DEFENCE.

410. (1) The attack on Flushing in August 1809 is a good illustration of a bombardment, both as regards the reasons for such is mode of attack being followed, and its effects on the place and its inbrbitants. The place was invested on August 1st, and reconnoitred early next morning, with the view of determining the plan of attack. A regular attack was considered impracticable on account of the garrison being able to inundate the ground in front of the fortress, with the

[^44]exception of two dykes, along which it would be both tedious and hazardous to direct an attack: "Therefore, the garrison being composed of bad troops, the inhabitants disaffected, and the place altogether destitute of bombproof cover, it was decided to try the effect of a bombardment to induce a capitulation."

On the 18th August the bombarding batteries opened their fire with thirty-two 2t-pr. guns, two 10 -inch howitzers, two 8 -inch howitzers, fourteen 10 -inch mortars, and six 8 -inch mortars, aided by gun and mortar boats from the fleet. Fire was kept up night and day until the capitulation of the place, which took place at 1 p.M., on the 15 th August.

Effect of the Bombardment.- "On entering the town the left bastion and the houses in its rear were found almost in ruins, and the sea defences were a good deal injured: but the works on the land fronts were in a perfect state. The loss of the garrison had not been great, as General Monnet kept all the troops off duty on the right, under shelter of the ramparts; but 335 of the inhabitants were killed, and a still greater number wounded. The Stadthouse, two churches, and 247 houses were utterly destroyed, and the whole of the left of the town more or less injared."

| Thirty-two 24-pr. Guns fired .. .. .. .. 6,582 rounds. |  |  |  | '. | - | 6,582 |  |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Fourteen $10^{\prime \prime}$ Mortars | " | . . | . | . | .. | 1,743 | " |
| Six $8^{\prime \prime} \quad$, | " | . | . | $\cdots$ | .. | 1,020 | " |
| Two 10" Howitzers | " | . | . | . | . | 269 | " |
| Two 8" " | " | .. | $\cdots$ | . | . | 380 | " |
| Total |  | . | . | . | $\cdots$ | 9,994 |  |

411. (2) Such was the case at Pampeluna in 1813, which the Duke of Wellington invested on June 25th, with the view of immediately besieging it; but the works were found, on being reconnoitred, to be so strong and well constructed (while the garrison was known to exceed 4,000 men, with 200 pieces of ordnance), that the force at his disposal was considered insufficient to carry on a siege, and a blockade was substituted.

The blockade was maintained with such vigour as effectually to prevent the garrison from once communicating with their friends for the long period of three months, in spite of sorties, and the efforts made to relieve the place.

The place surrendered on November 1st, on which day the last provisions had been served out; the garrison had, however, driven off their submission to the latest possible moment, as according to an intercepted letter from the Governor to Marshal Soult, dated September 28th, they had been living on horse-flesh from 17 th August, and had only had ten ounces of bread a day per man from 24 th September.
412. (3) The rifled ordnance now in use in the service, and proposed for a battering train, possess the following great advantages for siege guns, viz.:-
(1.) Lightness, compared with the weight of projectile thrown; for while the smooth-bored 32 -pr. siege gun weighs 50 cwt ., the Armstrong $40 \cdot \mathrm{pr}$. weighs only 85 cwt .
(2.) Long and accurate range, which will allow the first batteries to be constructed far in rear (if desirable) of the first parallel.
(3.) Small charges, only $\frac{1}{7}$ th of the weight of projectile.
(4.) Large bursting charges of shells, which will render their fire very destructive to parapets, traverses, and earthworks generally.
413. (4) A park of Artillery is the locality where the guns are arranged, so as to be ready for service when wanted, and where the artillery stores are kept. The Engineers' park is the enclosure in which are deposited all the materials and tools requisite for the construction of batteries and the service of the trenches; such are sandbags, gabions, fascines, platforms, shaft and gallery-cases, splinter-proof timber, pickaxes, shovels, \&c., \&ce.

Both in the Artillery park and in that of the Engineers, the different sorts of stores are carefully and regularly arranged with respect to the places of the heaps or rows, and to the number in each, in order that a particular quantity of any store may be issued without confusion during the night.

11．（5）If the escaups are exposed to a distnint fire，and the counterscarps are too low，the operations of a siege may be much shortened by resorting to the following mode of attack，which is generally known as the＂Artillery Attack．＂

In this formidable attack the breach is made at a distance of 500 or 600 yards from the place （sometimes even more，for Gaëta was breached at 1,200 yards）：it should not be at a less distance than 350 yards，that the artillerymen may not be much exposed to the effects of grape，common case，and musketry shot，fired from the works；such missiles being very destructive to them while serving in the ordinary breaching batteries at the crest of the glacis．The approaches are then pushed forward as rapidly as possible up to the ditch，with（generally speaking）but one parallel． As soon as they are completed，the breaching batteries open，and when powerful they effect a breach in one or two days，so that the defenders have not time to make efficient retreuchments． In order to hinder them from soarping and barricading the breach during the night，a constant fire is kept up from all the disposable mortars and howitzers．

The flank breach at Ciudad Rodrigo was made in 1⿳亠丷厂犬 days；that in the curtain，of very bad masonry，at Badajoz，was made in 1 day．

415．（f）A sup－roller consists of two gabions，each 6 feet long，and respectively $4^{\prime}$ and $2 y^{\prime}$ in diameter；the small one is placed concentrically within the other，and the space between the two is stuffed with fascines and long pickets driven in from each end，which renders it perfectly musket－proof．

The use of the sap－roller is to cover the men working at the sap from a front fire of musketry．

Three men oan make a sap－roller of the above dimensions in about 17 hours，and it will weigh 6 or 7 cwt ．

416．（7）Parallels and demi－parallels，termed also Places of Arms，are trenches runming in a direction parallel，or nearly so（whence their name），to the general contour of the works attacked．

Their object is to support the batteries and other works of the attack（in case of sorties being made from the garrison），by holding a guard of the trenches sufficiently strong to repel such attempts．Hence，fresh parallels should generally be made as soon as the heads of the zigzags of approach are midway between the covered－way and the last parallel．At the same time they afford a covered commanication between the different works of the attack，and allow of a great amount of musketry fire being kept up from them on the garrison．Their extent must be such as to embrace the salients attacked，and also to support any batteries that may be made on the flanks of the attack． They are terminated by returns，to bring a fire of musketry on sorties attempting to get round their flanks ；sometimes their extremities are strengthened by redoubts，as in Figs．361，362，on the left of the first parallel．

417．The distance of the first parallel from the place has been hitherto about 600 yards（it may be more or less，according to the nature of the ground and other circumstances），that distance being beyond the effective range of grape and common case shot，beyond hearing distance，and entirely beyond the former rauge of musketry；whilst，if smooth－bore guns are used，it allows the ricochet batteries，placed within 100 yards in front of the parallel；to be within efficient range of the works to be enfiladed，

In future sieges，the position of a first parallel will not be so dependent as it has been，on the intended position of the first batteries of the attsck，which are certain to be placed considerably in rear of the parallel．In any case advantage should be taiken of accidental circumstances，which may permit the parallel being established closer than usual to the place．

## TRACING THE Hirst paradlel，

418．The position of the first parallel having been previously decided on，it is traced shortly before dark ly Engineer Officers，assisted by squads of Bappers，each of whom is provided with a ball of white tape， 50 yards long，and a white picket．＊Each Engiveer numbers off his squad of Sappers，and marches them to the ground in single rank．On arriving at the spot from which the

[^45]tracing is to commence, he halts No. 1 Sapper, and, taking the end of his tape, walks on with it in the direction of the proposed parallel, followed by the other Sappers.

As soon as the tape of No. 1 Sapper is extended, the Engineer halts No. 2, and proceeds in like manner with his tape ; and so on with the rest. As each Sapper is halted, he fixes his picket in the ground (without noise if possible), attaches his tape to it, and stands on the side nearest the fortress, but facing the point of commencement: the Sappers thus extended act as markers for the guidance of the working parties, the white tapes indicating the line of the parallel.
419. Parading and Marching up the Working Parties.

At least an hour before sunset* the working parties are paraded at the depôts in close column of sections, each 25 strong and in single rank, and placed under the direction of Engineer Officers. On the reverse flank of each section a Sapper is posted, who is provided with a white 6 feet measuring rod; and every man of the working party is supplied with a pickaxe and a shovel.

The working parties are marched off as soon as it is dusk, and are halted (in column) a few yards in rear of the point from which they are to be extended. As soon as it is ascertained that the trace of the parallel is complete, the divisions ( 25 men ) are successively filed off and extended, commencing with the leading division, which will occupy the tape between No. 1 tape marker and No. 2 tape marker; No. 2 division will then be extended along the tape between No. 2 and No. 3 tape marker, and so on with the other sections. The length of the tasks of 6 feet are either shown by cross pieces sewn on the tape, or are measured by the Sapper with his rod. Each man, preserving the strictest silence, sits or lies down behind the centre of his task, having marked it by laying his shovel parallel to and close behind the tape, and the pickaxe perpendicular to it, with the iron part towards the place.

As soon as all the workmen are posted, a whisper is passed to commence work. Each man begins by digging a hole 3 feet deep in the centre of his task; in this he stands, and from thence enlarges it to the right, the leff and the rear, until the allotted task is completed; leaving a berm of 18 inches within the tape, and throwing the earth beyond it. The extension of the working party can be executed without hurry, at the rate of 100 men in five minutes. Not more than 400 men should be extended from one point.

Working parties are sometimes armed: the arms, when taken, are placed on the ground, three paces in rear of the men, with bayonets fixed, pointing to the rear, before they commence work.

## TASKS FOR THE EXECUTION OF A FIRST PARATLEL.

420. The task to be executed by each man of the first relief, who may be assumed to commence work at 8 P.m., is, in difficult soil, $6^{\prime}$ long, $3^{\prime}$ deep, and $5^{\prime}$ wide, or about $3 \frac{1}{3}$ eubie yards, which ought to be finished in 4 or 5 hours.

The second relief of men commence at daybreak ( $4 \mathrm{~A} . \mathrm{M}$. ); they widen the trench formed by the first relief $4 \frac{1}{2}$ feet, making it $3 \frac{1^{\prime}}{2}$ deep in rear, and with the turf and stones they build up a step in front $1 \frac{1}{2}$ feet high and broad, as shown by the shaded portion in Fig. 364.

The third relief commence work at noon: they complete the parallel to $10^{\prime}$ broad at bottom and $3 \frac{1}{2}$ feet deep in rear, with a reverse slope of $\frac{1}{\mathrm{~T}}$, as shown in Fig. 365. They form drains or cesspools in the low parts, to receive drainage water.

In easy soil, the parallel can be executed

[^46]

## Permanent Fortification.

in two reliefs. The first relief of men excavate to a width of $\tau^{\prime}$; the second relief form the front step and finish the pardlel.

## TLATHOD OF FORMING PARARLELS, BTC., TC ONEAVOURABLE GROUND.

In excavating the parallels or other trenches, rocks, roots of trees, do., may be mef with; in which case these may be removed by blasting. Should the ground be such as will not permit an excryation to be made, a parapet must be formed with earth brought from a distance in saudbags or baskets, or with sap-faggots, woolpacks, \&c. These methods may also be resorted to in the construction of batteries, when a very concentrated fire on them renders their coustruction in the ordinsxy mamer difficult.

In marshy soils, where water is fonm near the surface, a profile similar to Fig. 366 is given to trenches. As a greater height of parapet above ground is here required than with the ordinary profile, the excavation must also be larger:


SECTLON SOMTABLE FOR A PARALLEL ON A AFARSHY BITR.
421. (8) The trenches of communication (named either "zigzags," "approaches," of "boyaux,") are traced in zigzag directions, crossing (generally) the capitals of the works attacked, in alternate directions ; each line of trench is directed so as to have its prolongation fall elear of the most advanced salients of the fortress, thereby securing it from enfilade from them, and it is further protected by the trench in advance being prolonged to the rear so as to overlap it from 5 to 10 yards, forming what is called a return ( $(\mathrm{d}, \mathrm{Fig}$. 361). These returns further serve as depôts for tools, stores, \&e., and also facilitate the communications, as they allow carts, \&e., to be moved out of the way while troops may be passing.

Approaches are made 6 deeper throaghout than the parallels, because being obliquely directed towards the fortress more cover is required; if provided with a banquette (berm acting as such), it is only made 1 ' broad. They may be revetted or not, as required.

Approaches are not necessarily traced on the capitals of the works attacked, but they usually are ; for in those positions they are exposed to less fire than elsewhere, they interfere less with the fire of the batteries, and they form the most direct road to the salients, which have ultimately to be crowned.
422. (9) The roorkmen are protected against sorties by "Covering Parties." The troops for this duty are posted at the "opening of the trenches," a few yards in front* of the workmen, and they detach to their front small bodies, who throw out sentries (who may, perhaps, be able to lodge themselves in rifle-pits) still more in advance ; these are directed, in general, not to fire unless they are quite sure that the advancing sortie is in force, but to retire upon the main body, who will repulse the sortie with the bayonet. If every small sortie which the garrison may make at this period, for the express purpose of harassing the working parties, were fired upon, the latter would probably leave off work at each alarm, and it is exceedingly diffieult to colleet them again it the dark.

At daybreak the "Covering Parties" must take refuge either in the parallel or behind any available natural cover; henceforth they are termed the "Guards of the Trenches."
423. (10) Stege Battertes, their Nature, Constrection, efc.

A Bultery is a line of parapet protecting a number of guns, mortars, \&c., together with all

[^47]necessary traverses, epaulments, \&c., for the protection of the gans and gunners, and of platforms and magazines for the service of the guns.

Batteries are named either enfilading batteries, direct or counter-batteries, breaching batteries, \&c., aceording to the nature and object of their fire.

Three different profiles are given to siege batteries, as under,-
Elevated Battcrics (Fig. 367) are those whose terreplein is on the level of the ground; the whole of the cover (parapet) is raised above ground, the earth being supplied entirely from a ditch in front.

Sunken Batteries (Fig. 368) have their terrepleins sunk $3^{\prime}$ below the ground level, the earth from the trench so formed being sufficient to form the parapet.

Half-Sunken Batteries (Fig. 369) have their terrepleins sunk 2'; the parapet being formed partly with the earth from the trench, and partly from a small ditch in front.

profile through an embrasure of an blevated battery,

profile through an embrasure of a half-suneen battery.
424. The following details are common to all Siege Batteries of whatever profile:-The crest of the parapet is made $7 \frac{1^{\prime}}{}$ above the terreplein; the interior slope is revetted at a slope of $\frac{4}{7}$ (in a Mortar Battery it need not be revetted at all, as the mortars fire over the parapet); the superior slope is $\frac{1}{1}$, or falls 1 ineh in 1 foot; and the exterior slope is $\frac{3}{4}$, the base being made greater than the height, on account of the fire it is certain to be exposed to.

The parapets are usually $18^{\prime}$ thick, but would require to be 25 feet thick, where exposed to a heavy fire of artillery.

The berm is from $2^{\prime}$ to $4^{\prime}$ wide ; generally the latter dimension is given to it.
The ditch is not regarded as an obstacle, but merely as the most convenient position from which to get the earth for the parapets; for this reason the sides are made vertical, for convenience in excavating.

The trenches of all sunken gun batteries are $16^{\prime}$ broad at the bottom, to allow room for the

## Permanent Fortification.

platforms; they are made $\mathrm{f}^{\prime \prime}$ shallower in rear than in front, to suit the slope of the gun platiorms, and have a reverse slope of $\frac{1}{2}$.

The length of a battery (which is measured along the foot of the interior slope) is determined by allowing is feet per gun or howitzer, 15 feet per mortar, together with 6 feet ( 8 ' in suaken and half-sumken batteries) for ench splinter-proof traverse. If either flank has an extra halfmerlon $\ddagger$ (which is necessary where there is no epaulment), an additional length of $12^{\prime}, 9^{\prime}$, or $8^{\prime}$, must be allowed, according as it is an Elevated, Sunken, or Halt-Sunken Battery.

As a smnll object like a battery must be outflanked, either on one or ou both flanks, by the works of n fortress, it is necessary to add epaulments to those flanks, to cover the guns, \&C., from oblique fire. A length of 25 feet is allowed to epaulments of all batteries, and when exposed only to oblique five (the usual ease) their thickness is made 12'.

Epaniments are usually laid out at a slope of 1 in 4 with the parapets of the batteries. Fig. 370 is the profile of an Epaulment to an Elevated Battery.
Ftc. 370.-Scale tion


PROFILE OF EPAULDEENT. ELEVATED BATTEESY,
425. To trace an Elevated Battery. - The lines requiring to be marked on the ground are the foot of the interior slope, and the outer berm (or escarp line). These lines may be termed the building and cutting lines.

Where guns are used it is usual to drive pickets in the central lines of the embrasures (thus marking the centre of the gun portions): with mortars, the extremities of the mortar portions only are so marked.

Fig. 871 shows the trace of an Elevated Battery for two guns and two mortars, together with one splinter-proof traverse, one epaulment at its right flank, and an extra half-merlon at the other. Its length will be thus determined, -


The profiles (Figs. 367,370) will show that the cutting lines of the parapet and epaulment are respectively $32^{\prime}$ and $29^{\prime}$ away from the building lines. The shoulder of the battery is rounded with the lesser dimension as a radius; the centre being a point in the line of the epaulment produced, $3^{\prime}$ (or $32^{\prime}-29^{\prime}$ ) from the building line,
426. Number of Wormmen for an Eifevated Battery, - To every gun or mortar portion in easy soil, and with a gabion revetment, 9 men are allotted-viz., 4 Diggers, who are placed, along the outer edge of the berm at 4 $\frac{1}{2}$ apart; 3 Shovellers, who pass on the earth supplied by the diggers; and 2 Rammers, who ram the parapet. If revetted with fascines, 2 men per gun portion, making 11 in all, are added, to build the revetment; and if with sandbags, 4 men per gun portion, making 13 in all, are required per gun portion.

[^48]An epaulment is treated as equivalent in labour to two gun portions; a traverse portion, and an extra half-merlon, each as half a gun portion.

Estimate of the number of workmen required to commence the battery shown traced in Fig. 371, and completed in Fig. 372:-
$\left.\begin{array}{llcccccc}2 & \text { Guns and } 2 \text { mortars } & \ldots & . . & . & \text { require } 4 & \text { gun portions. } \\ 1 & \text { Epaulment } & \ldots & . & " & 2 & " \\ 1 & \text { Traverse portion } \\ 1 & \text { Extra half-merlon }\end{array}\right\}$ together equivalent to $\begin{array}{lllll} & . . & 1 & "\end{array}$
Total .. .. .. 7 gun portions.
FIG. 371.-Scale $\frac{1}{300}$.


TRACE OF AN ELEVATED BATTERY,
N.B. The dotted lines shown on this plan are not marked on the ground.

Fig. 372 -Scale $\frac{\cdot 1}{360}$.


Fig. 373.-Rear Elevation.

Therefore, $9 \times 7=68$ men are required if revetted with Gabions.

$$
\begin{array}{rlll}
9 \times 7=0 & " & " & \text { Fascines. } \\
11 \times 7=77 & " & " & " \\
18 \times 7=91 & " & \text { Sandbags. }
\end{array}
$$

After the ditch is 10 feet broad, an extra line of shovellers ( 3 per gan portion) can be employed with advantage.

Elevated gun batteries


TEADE OF A SUNEEN BATIERY,
Fig. 375 ,
 have been constructed at Chatham, in daylight, in from 11 to 22 hours of actual labour, according to the soil. At a siege it may be assumed that either two or three nights, with the intermediate days, would be required, according to the soil, allowing for the interruptions caused by the enemy's fire, and also for the work being entirely, or almost entirely suspended, during daylight.
427. To trace a Sunken Battery.-The foot of the interior slope of the parapet is first traced (Fig. 874), marking with pickets the different portions; then the inner berm line is traced this latter must be taken round the traverses, as these are built on the natural ground, The earth for the epaulments is obtained from a ditch in front, as also the earth for the parapet in front of the traverses: this is necessary, as the trench of a Sunken Battery will supply earth ouly for the parapet immediately before it. The inner berm for the epaulment is made $3^{\prime}$ broad.
Fig. 374 represents the trace, as above, for a Sunken Battery for 2 guns and 1 mortar (the portion of parapet for which is unrevetted), with 1 splinter-proof traverse, 1 epaulment, and 1 extra half-merlon. The length of the battery is thus made up,-


Fig. 375 is a plan of the completed battery which is traced in Fig. 374.
438. Number oe Workmen required for a Sunken Batcery. - To each gun portion, ie easy soil 10 men are allotted,-viz., \& Diggers, 4 Shovellers, and 2 Rammers.

For the battery traced in Fig. 374,

consequently $6 \times 10=60$ men will be required for the work, if revetted with gabions; and extra men, if revetted with fascines or sandbags, as mentioned for Elevated Batteries.

Sunken Batteries have been constructed at Chatham, in daylight, in from 5 to 10 hours of actual work, according to the soil.
429. To trace a Hale-Suniken Battery. - The same method as described for Elevated and Suuken Batteries is followed; the lines to be actually marked being the foot of the slope of the revetment, also the outer (ditch) and inner (trench) berm lines.

The number of workmen required for the gun portion is 14 ,-viz., 8 Diggers ( 4 in the ditch and 4 in the trench), 4 Shovellers, and 2 Rammers. The time required to construct a Half-Sunken Battery is the same as for a Sunken Battery.
430. Remarks on the comparative advantages of the various kinds of Batteries.

Elevated Batteries require more labour to construct than the others, and offer a larger (because higher) mark for the enemy's fire.

They have, however, many great advantages : they are simple to construct; the earth, as it is passed from the ditch, to form the parapet, need not interfere with the men building the revetments; the terreplein being on the level of the natural ground, also favours drainage, and allows the traverses to be built, and the platforms laid, at any time most convenient, after the parapet is well in hand, thus avoiding the necessity of commencing every detail at the same time.

Sunken Batteries do not require so much labour as Elevated Batteries, and they can be easily formed from existing trenches, by widening them to the proper dimensions. During the latter operations of a siege, this is the only method in which batteries can be made, the trench being first formed by sap. But Sunken Batteries are very difficult to drain, except when favourably situated; and as the gun fires just above the level of the ground, a slight rise of the ground in front may mask the object fired at from the view of the gunners.*

They are inconvenient to construct in the dark, as the earth to form the parapet has to be thrown past the builders of the revetment: the platforms also cannot be laid until the trench is completed; consequently the difference of time required for their construction at Chatham, where they are made during daylight, compared with Elevated Batteries, will not be equally apparent at a siege.

Half-Sunken Batteries have most of the inconveniences of Sunken Batteries; they are difficult to drain, and incouvenient to construct in the dark, as a great number of men are concentrated in a small space, and the earth from the trench has, as in Sunken Batteries, to be thrown past the revetters, to the great inconvenience of the latter. The platforms also can only be laid after the trench is completed. Although doubly manned with diggers, the experience gained at Chatham shows that Half-Sunken Batteries take as long to construct as Sunken Batteries, although the diggers have far less work: this confirms the maxim, that the increase in the number of workmen, beyond a certain limit, is never attended with a proportional increase in the quautity of work done, while it increases the difficulty of supervision, and (at a siege under fire) also the casualties among the workmen.
431. Siege batteries, although they may be exposed only to a direct fire, require traverses for the protection of the gunners from the splinters of shells. Traverses to be splinter-proof should be $4^{\prime}$ thick at the top; they should be at right angles to the parapet; their sides should be revetted steeply, in order to save room (as it is necessary to add to the parapet of the battery a

* To determine whether a gun battery may have the sunken profile on a given site, the observer should lie down and look from the ground level towards the object to be fired at. If it be then visible, a sunken battery may be used, but not otherwise.


## Permunent Fortification.

length equal to the breadth of ground occupied by each traverse) ; they should extend to a distance of 18 feet from the interior of the parapet, in order to cover the meu working the guns ; and in Elevated Batteries they should be separated from the parapet by a pathway 2 feet broad. In Sunken and Half-Sunken Batteries they are necessarily joined to the parapets.

Splinter-proof traverses are usually arranged as shown in the plan, Fig. 372, where the pieces of ordnance are arranged in pairs, with a traverse between them.

The puafies of these traverses are shown in Figs. 376, 377, 378, where they are revetted with gabions (the best reyetment). The part below ground in Figs, 377 and 378 would be revetted with fascines, if necessary, but not otherwise.
182. Tal Magazises of Siege Batcertes are made of a fixed pattern, the woodwork being arranged so as to be able to be put together with ease. The service pattern is termed the Rectangular Field Powder Magazine, and is shown in Figs. 379, 380.


The body of the magazine which is sunk below the ground is a rectangle, about $19^{\prime}$ long by $6^{\prime}$ broad (nearly) ; the sides are lined with planks, which are kept in their places by rectangular woodeu frames, and it is roofed over by stout beams $6^{\prime \prime}$ thick and $9^{\prime \prime}$ deep, which are almost on a level with the ground. The magazine is provided with an entrance passage (roofed) 3 feet broad, on the side furthest from the battery, to which communication is afforded by the trench and ramps shown in the figure. The earth obtained from the body of the magazine, the entrance, and the trenches of communication, is used to cover over the roof. Small cesspools are made in the angles, at the bottom of the ramps.

This magazine holds abont $4,000 \mathrm{lbs}$. of powder.
The rectangular* magazine has two advantages,-viz., convenience of stowage, owing to its flat roof; and security from fire, as it is practically entirely under ground. Vertical fire is most to be feared with field powder magazines. To each magazine a supply of filled sandbags is lsept ready with which to fill up the crater formed by the explosion of a shell in its earthen top, as soon as formed. One magazine is requisite for every 3 or 4 guns in a battery, to hold powder: when shells are much used, a separate magazine is allotted for the purpose of filling them, arranging and fixing fuzes, \&e., and is then termed the "Laboratory Magazine."

In batteries of 6 guas or less the magazines might be placed on the flanks, but in large batteries some are necessarily constructed in rear, to avoid the otherwise long distance the ammunition would have to be carried.

The "Lean-to," or triangular magazine, formerly much used at sieges, is now superseded by the rectangular; $\dagger$ as a regular pattern; but it may be frequently used with advantage both in siege and field works. Those used in the British sieges in the Peminsula are thus described by
Sir John Jones :-
"Splinter-proof timbers for magazines were eut 12 feet in length and from 8 to $10^{\prime}$ in breadth

[^49]and thickness, and were placed against an epaulment parallel to the place, at an angle making the base equal to half the height. They were then covered with a tarpaulin, extending well over the top of the epaulment, over which were laid one or two rows of filled sandbags, so as to prevent the possibility of the tarpaulin being cut by splinters of shells: a second tarpaulin was usually thrown over the exterior in rainy weather. On this construction the magazines were found to be perfectly dry and sufficiently spacious, and of their strength no doubt can remain, as the sandbag covering was frequently knocked off by large shells, and in no instance were the splinter-proofs broken.
433. Platforms for guns and mortars are composed of a floor of planks resting on beams termed sleepers; the planks are kept in their places by means of a ribband laid along their edges at each side of the platform, which, being fastened to the sleepers by means of rack-lashings, secure the planks.

Gun platforms (Figs. 381, 382, 383) are $15^{\prime}$ long and $10 \frac{1^{\prime}}{2}$ broad; they rise to the rear $\frac{1^{\prime \prime}}{}$ in every $1^{\prime}$, their slope thus being $\frac{1}{4 \pi}$. This slope is necessary to check the violent recoil of the guns, and also to facilitate their being run up after loading. It is made as slight as possible, so as not to expose the gunners more than is necessary.

Fics. 381.-Scale $\frac{1}{\text { 160. }}$
Fig. 384.



Fio. 385.

The sleepers are five in number. The centre one is first laid in the line of fire of the gun produced; a groove has to be cut for it in the earth; the two outside sleepers are then laid at a similar slope to the centre one; lastly, the two intermediate sleepers are laid, care being taken that the upper surface of the 5 sleepers are in the same plane: the space between them is then filled with earth and well rammed; the planks are then laid on the top of the sleepers; finally, the ribbands are laid in their places and secured to the baulks by the rack-lashings, 5 on each side of the platform.

The efficiency of a platform greatly depends on the care with which the sleepers are laid in the proper plane, and on the earth being well rammed between them.
434. Mortar platforms (Figs. 384, 385, 386) do not require to be so large as gun platforms, owing to the small breadth of the mortar-bed, and to the slight recoil of the mortar when fired, and for this latter reason they are laid horizontally; but they require to be much stronger,
as mortnrs act very violently on their platforms, owing to the high angle of elovation at which they are fired.

The planks are laid on 5 sleepers, which are stouter than those of gun phatforms, and nearer together; these 5 sleepers rest on 8 others, underneath them; which latter require, of conrse, to be first hiid. The cibbands are racked down as in gun platforms.

Both the Gun and Mortar platforms here described have the following advantages for siege purposes.
(1.) The planks being all of the same length, any one plank can be laid at any part of the platform.
(2.) The method of rack-lashing allows them to be relaid in different places, without injury to the timber, which was not the case formerly, when nails or screws were used for the purpose of fastening the planks to the sleepers.
435. Pobitrons of Batreries.-All batteries for guns should be traced perpendicularly to their intended lines of fire. When this cannot be done, the interion slopes should be indented, as shown in No. 5 embrasure of Fig. 213.

Enflading Tatteries are placed on the prolongations of the terrepleins to be enfiladed, and when ricochet fire with smooth-bored guns is used they should not be further than 650 yards from the object; but with rifled guns, enfilading batteries may be much further off, as from recent experiments ticochet fire from these guns has been carried on with effect at 1,050 yards. Three or four pieces are required for enfilading the terreplein of the work, one or two more for the covered-way, and in addition to these it is necessary to have two or three $8^{\prime \prime}$ or $10^{\prime \prime}$ mortars to search into those parts which are protected (by traverses or otherwise) from the enfilade fire of the guns or howitzers.

In tracing the enfilading batteries, one gun should be placed on the prolongation of the crest of the work to be enfiladed, and the remaining guns on the inside as regards the lipe enfiladed. When the covered-way is parallel to the work, there will be a space between the guns, which should be oceupied by mortars: this is the case with batteries IV. and VII. in Fig. 361. When the prolongations of a work and its covered-way converge, the guns should be together, with the mortars on their inner flank, as regards the work enfiladed. This is the case with batteries III., V., VI., and VLII., in Fig. 361.

The advantages of silencing works by an enfilade fire are the following:-
1st. Few pieces of orduance are required.
2nd. Every part of the line enfiladed is searcked out.
3rd. The consumption of ammunition is small, as the charges for ricochet firing are very small, averaging about $\frac{1}{10}$ th the weight of shot.

4th. Fire can be kept up with effect by night as well as by day. This is practicable since the object fired at is the terreplein of the work, $30^{\prime}$ or $40^{\prime}$ broad, and usually more than 100 yards in length; and by fastening battens of wood to confine the trail and the wheels of the gun-aarriage to the proper line, the gun is sufficiently accurately aimed to strike the terreplein enfladed.
496. Counter-Batteries are placed in front of the line of worls to be silenced, bat they need not be exactly opposite to it, for as they fire directly at the guns to be silenced, which are visible in the embrasures, any position for them will suffice, from which the enemy's guns can be seen. This evidently allows of a great choice of position, which is the principal advantage possensed by counter-batteries. Their disadvantages, as compared with eufilading batteries, are :-
(L.) Many guns ave requived; at least a number equal to those to be silenced.
(2.) The comsumption of ammunition is very great, as service charges are used, and generally the firing is more rapid than in enfilading. The heavy charges used injure the ernbrasures so much, that they reguire rebuilding every night.
(3.) The liue fired at is not searched into, and all shot, Ec., which clear the parapet pass to thie reard and ouly those which actually strike the guns, or the cheeks of the embrasures, do any serviceable damuge; consequently, the garison have it in their power to reserve their guns by

[^50]withdrawing them from the embrasures and keeping them behind the merlons, until required to act.
(4.) Fire can be kept up only during daylight, as the object fired at (a gun in an embrasure) is too small to be able to be struck in night firing. This allows the garrison to repair damages and remount fresh guns every night.

Counter-batteries may be required in the following eases :-
(1.) The defensive works requiring to be silenced may be so traced, owing to advantage of site, that their prolongations fall on ground that a besieger cannot occupy, as on inundations, marshes, ravines, \&c.-or,
(2.) The prolongations may fall on ground that a besieger will not occupy, as, for instance, when by so doing an enfilading battery would be situated so much on the flank of the attack, as to come under the fire of other faces of the fortress which are not silenced.

This is illnstrated in Fig. 861 . If the enfilading battery $(x)$ shown by dotted lines had been constructed to enfilade the right face of the ravelin, it would have come under the fire of the bastion and of the ravelin beyond; consequently other batteries would have had to be made to keep under the fire of those works.
437. (11) Besides casemates and blindages (Chap. VI.), traverses are used to cover from enfilade the pieces of artillery on the ramparts; they ought to be from 12 to 18 feet thick at top, and between every two gnns. Where guns are not exposed to enfilade, splinter-proof traverses only are requisite, similar to those used in Siege Batteries.
438. (12) Counter-approaches are works thrown up by the garrison in advance of the glacis, usually opposite to the flanks of the attack, as soon as the front of attack is known. They are connected with the covered-way by means of trenches and parapets. Their object is to obtain the advantage of an advanced position from which to enfilade or take in reverse, or otherwise annoy and impede the works of the attack.
439. (18) Prior to opening fire, the embrasures of the batteries are masked, by placing gabions loosely covered with earth at their mouth: by this means the positions of the embrasures are concealed from the garrison, and in some cases the situation of the battery may be concealed, as its parapet may be mistaken for a portion of the trenches. Sometimes the batteries are constructed with solid parapets, the embrasures being cut out and revetted shortly before the batteries are required to open fire.
440. (14) Rifle pits are thus formed : a line of double sentries (each composed of 2 men) are posted at nightfall at a convenient distance in advance of the works of the attack; their distance apart may vary, but must not be so great as to allow a person to pass between them without being seen. Each file of men is provided with a pickaxe, a shovel, and a few sandbags; and when posted, while one man watches, the other digs a hole $4^{\prime}$ in diameter and $4^{\prime}$ deep, spreading the earth on the front and sides so as to form a parapet, a sandbag loophole being previously made on the level of the ground. When the parapet is finished, the loophole is scarcely visible from the front: a small step is cut in rear to enable the men to get out of the hole quickly, and the rear of the pit is deepened so as to drain it.

At daybreak the sentries occupy the pits, and from them keep up a fire of musketry on the defences. Such fire is most efficient: the riflemen are well covered; and as the objects to be fired at, such as a gun in an embrasure, \&e., are at a fixed distance, which is accurately determined after a few trial shots, the full advantage of arms of precision is obtained.*

In eases where the fire of a fortress is well kept under, a line of rifle pits could be converted into a trench, by the occupants of the different pits working towards one another ; the advance of the attack would thus be much hastened.
441. (15) The second parallel is constructed midway between the first parallel and the fortress ; it is thus situated to prevent the zigzags being at any time nearer to the salients than they are to the supporting parallel in rear. The second parallel should be long enough to embrace the salients of the works attacked.

The execution of the second parallel is attended with much greater difficulty than that of the first parallel, not only on account of its greater proximity to the fortress, but also because the garrison will be prepared beforehand to retard the work, as they will be aware almost of its exact
*The same may be said to apply generally to the works of a siege, on account of the ranges being constant.
situation ; consequently it is not undertaken, until the fire of the place is greatly subdued (about the fifth or sixth night of the siege), and it is executed by the method called "Flying Sap," by which cover from musketry fire is very quickly obtained.
449. Before executing a trench by flying sap, it has to be traced with white tape in the manner already described in Art. 418.

The workmen are then marched up from the nearest trench in rear, each man carrying two gabions, with a pickaxe secured in one and a shovel in the other, and are extended along the line of the tape, each man placing his two gabions on the line, and touching each other.

As soon as the gabions are all placed, each man commences digging behind his two gabions, leaving a berw of $1 \frac{1^{\prime}}{2}$ and throwing his earth into them; after the gabions are full, the workmen throw the earth just over them, so as to form a parapet of the height of the gabion as soon as possible. In this way musketry cover is obtained, in favourable soil, in a very few ( 10 to 20) minutes of actual work.

The principal diffionlty attending the operation of flying sap is in marching up the men and posting them correctly for work; after they huve commenced digging, they have every inducement to do the work as quickly as possible, as their safety depends on their individual exertions.

If the gabions have to be conveyed a considerable distance, each man may carry one gabion, and alternately a picknxe and a shovel. After the gabions are placed in position, either one-half the workmen may be retired, thus leaving one workman to every two gabions, or the whole of the men nre retained, each couple of men relieving one another every fer minutes.

In all cases where a trench is commenced by flying sap, the second relief of workmen, who are posted for work under cover, sre placed at intervals of 6 feet.
448. (16) When a battery is constructed in a paxallel (which can be done in one relief), a communication should be formed round the rear of the battery, to avoid the necessity of troops, ke., passing through the battery.
444. (17) Large shells bursting in the parapet of a siege battery will frequently blow away in an instant the result of hours of labour.
445. (18) As the approaches to a fortress get nearer to it, they require to be more closely supported. The demi-parallels are necessary for the support of the "heads of the attack,"* when they reach about 150 yards from the salients. They then form an intermediate support between the second and third parallels, the latter of which invariably requires to be constructed about 80 yards from the salients, in order to support in an efficient manner the further operations of the attack.
446. (19) Sorties ave made by a besieged garrison generally for one of two purposes,-either to destroy some important battery or other work of the attack; or to harass and alarm the workmen, and thereby impede the progress of the attack. In the former case they would be made with large bodies of troops, sometimes with cavalry and artillery, as well as infantry; while, in the latter case, only fen men would generally be employed, and the sorties would be frequently repeated.

In making sorties in force, the troops of all kinds would first form in those re-entering places of arms which are most convenient for the purpose; if the communications to the covered-way are by steps, and not ramps, the eavalry and artillery would have to make use of the nearest public roads of the place.

In making minor sorties, infantry alone are generally used; at the latter period of a siege, when the trenclies are drawing near to the salients, they would issue from the salient places of arms, or the branches of the covered-way, in order to have the shortest distance to traverse. Small ladders should be provided to enable them to surmount the palisades.
417. (20) Sappisg is a method of forming trenches (even in daylight) under musketry fire, without exposing the workmen uncovered to such fire. It has to be resorted to when flying sap, owing to the proximity of the fortress, becomes too dangerous an operation to attempt. When that particular time may happen, would depend on the manner in which both the attack and defence are carried on, and cannot be arbitrarily fixed; but it is here assumed that the second parallel may be constructed by the flying sap, and the third parallel by the regular (or full) sap,

[^51]and that the change from one method to the other would have to take place somewhere between these two parallels.

When a trench formed by regular (not flying) sap has a parapet on one side only, it is termed a Single Sap; when it has a parapet on both sides, it is called a. Double Sap.

In the regular or full sap, a trench is formed by prolonging its extremities foot by foot, and is executed in the following manner (see Figs. 387 to 392).


Fig. 387.-Scale $\frac{1}{180} 0^{-}$
plan of a single sap in progress,
448. A sap-roller is placed across the head of the trench, so as to roll in the required direetion. A Sapper behind this roller works on his knees, and excavates a trench $1 \frac{1}{9}$ feet wide and deep, which is sufficient to supply earth to fill a row of gabions. A berm $1 \frac{1^{\prime}}{}{ }^{\prime}$ broad is left between the excavation and the gabions. The leading Sapper (called No. 1) excavates loose earth sufficient to fill one gabion; when this is done, the roller is pushed on for a distance of two feet, by the other Sappers, so as to allow No. 1 to insert a fresh gabion between the roller and those already placed: this empty gabion is then filled with earth as quickly as possible by No. 1, who keeps himself while doing so under cover of the gabions already filled; loose earth is then prepared in readiness to fill another gabion, which is placed and filled in a similar manner. Following No. 1 Sapper, at a distance of ' 5 ', which is as close as he can work without interfering with him, is a second Sapper (No. 2), who also works on his knees; he widens the trench already formed by No. 1 by 20 inches, making its total width 38 inches. No. 2 Sapper also assists to push on the saproller whenever a fresh gabion has to be placed.

A third Sapper (No. 3) follows 5 feet in rear of No. 2; he deepens the trench formed by No. 2 by 18 inches; the bottom of the trench formed by No. 1 thus becoming the top of a step.

Another Sapper (No. 4), 5 feet behind No. 3, widens the whole trench $10^{\prime \prime}$ : both Nos. 3 and 4 work standing.

## Permanent Fortification.

As the sap advances, one or two rows of fascines, cut into 6 feet lengths, are placed on top of the gahions, to increase the height of the parapet.

To emeh sup-head a brigade of Sappers is told off to earry on the work. It consists of 1 Superintendent and 8 Sappers, tonly of whom work at a time. As soon as No. 1 Sapper has filleil two gabions, und placed a third in position, ho falls to the reur, and becomes No. 1 ; Nos. 2, 3, and d, each tuking the place of the man in frout of him. The four Sappers who are not working band up materials, and the two demi-brigades relieve each other every hour.

A sap-faggot, or a couple of filled sandbags, are placed at each of the junctions of the gabions, to render them musket-proof.

To push on the sap-roller instruments called Sap-forks are provided. At one end they are a combinution of a pitchfork and a boat-hooks at the other they have a hole to allow them to be fastened to the ground by an iron pin, which is attached to them by a small chain.

The trench us thus formed by Sappers (Fig, 399) is widened to its full dimensions by a working party of infantry.
449. The principle of sapping is that one man (No. 1) shall excavate a small trench, and with the earth from it fill gabion after gabion, while other men working behind him shall improve his trench, until there is sufficient cover provided for posting a paity of untrained men to widen the trenoh to its required dimensions. The whole progress of the work depends on the rate at which No. I Sapper can work, for the work of the other Sappers is arranged to allow them to keep up with him. The aotual rate of advance of a sap will depend on the manner in which the musketry fire of the fortress is kept under, and also on the nature of the soil; * but for the purpose of ealenlating the comparative duration of sieges it may be assumed to be about 70 yards in 24 hours, H 5 a gabion can be placed and filled in from 10 to 15 minutes.

Fig. 893 is a prafile of a standica Saf, so called because all the Sappers who form it work


PROILLE. STAFEISG SINGLE 8AY. standing. Each man digs to a depth of ' 3 ', the width of his excayation being $1 \frac{1^{\prime}}{2}$.

This sap may be used when the fire from the fortress is heary, as more cover is afforded to the leading Sapper than in the kneeling sap. As three Sappers work at a time, the brigade would eonsist of six men.

The head of a sap in progress should be protected by rifle pits thrown out in adrance, and also by guards of the trenches, posted as close to the Sappers as the work will allow. 450. At a siege, advantage would be taken of a very dark night, or of a fog, or other favourable circumstances, to push on a sap rapidly. Instead of placing a single gabion, sometimes half a dozen might be placed at once, and then filled by sandbags, or as was done at St. Sebastian in 1813, as related by Sir John Jones:- "The Sappers finding the fire of the place very slack, contrived to push on the appronches more rapidly than usual, by a mixed nature of full and flying sap: that is, the Sappers, adrancing on their hands and knees, placed one empty gation after another until a small row was formed; then two or three Sappers placed themselves behind the empty gabions, at good distances from each other, and, sitting at their work, each formed a simall hole for himself, and with the eacth excavated filled the gabion in his front; after this the Sappers severally worked towards ench other, till the whole row of gabions was filled, and a trench formed along theic rear."

This mode of proceeding would probably much facilitate the reduction of a small detached work the artillery and musketry of which was well kept under, but would not generally be found practicable under a smart fire.
451. (11) The commencement of the formation of the third parallel is a critical period of the attack, as, owing to the proximity of the covered-way, sorties may reach the workmen at any moment vithont previous notice; and until some of the parallel is formed, the Sappers cannot be closely supported; but after the third parallel has been completed, sorties from the front can bardly take place, provided proper precautions are taken by the besiegers, as the whole of the

[^52]glacis is under the close musketry fire of the parallel. Sorties, however, must always be expeeted on the flanks of the attack, from the collateral fronts of the fortress; and to guard against these, the flanks require to be always strongly manned.

45\%. (22) The operation of "Crowning the Covered-way by assault" is a highly hazardous one, and would most likely fail against a determined garrison. It should ouly be attempted against a weak and dispirited garrison, or when it is absolutely necessary to hasten the siege. When this operation is decided on, a sufficient quantity of materials to form the lodgments is collected on the reverse of the third parallel. Portions of the third parallel on both sides of the capital are provided with steps from the bottom of the trench to the top of the parapet, and, if necessary, are widened so as to allow each storming party to advance out of it on a wide front.

The batteries which enfilade the cavered-ways, and those which bear on all works whose fire could retard the operation, keep up their fire until the signal for the assault is given. When everything is ready, the storming parties leave the parallel, rush into the covered-way, and drive away the defenders. They are closely fcllowed by a working party carrying the necessary gabions, with which they trace the lodgments, and also the necessary communications to join them to the third parallel. When sufficient cover is obtained, the storming parties retire into the lodgments, and become their guards. The lodgments need not at first extend further than the first traverses in the covered-way, as that is sufficient to ensure the possession of the latter to the besiegers.
453. (23) The ctrcular portions $(a, a$, Plate 2) are curvilinear trenches formed by two saps breaking out of the third parallel, about 40 yards on each side of the capital, and directed so as to meet 25 or 30 yards in advance. They serve as convenient deposts for the great quantity of materials required for the works in advance, so as to avoid encumbering the third parallel.
454. (24) Double Sap is used when the method of approaching by zigzags cannot be continued, on account of the smallness of the angle they would make with each other, which is the case in advance of the third parallel.

Jebb's direct double sap is that generally used; it has the advantage of not requiring the direction of the sap-rollers to be changed, as is the case in most other methods.

Figs. 394, 395, and 896 represent this sap in progress ; it is carried on by three squads of Sappers (called the right, centre, and left brigades). The two parapets are formed by the right and left squads of Sappers, in the same manner as in single sap. The centre squad work on one side (either side will do) of a centre row of

gabions; their object is to nssist the two other squads to form the traverses, - i.e. the traverses on the left of the sap are formed by the left and centre squads, and those on the right by the centre and right squads.

The leading Sapper in each of the three squads works directly to the front, the traverses being formed by the rear numbers. As the traverses are formed, the centre row of gabions between them are taken down, and the earth inside the sap between the parapets and traverses, which is shaded in Fig. 394, is cleared out to the full depth by a party of infantry.

The sup-head is protected by a line of 4 sap-rollers, usually connected by a spur, which is passed inside and lashed to them.

The double sap may be assumed to advance 40 yards in 24 hours.
Where only a short length of double sap is required, traverses may be unnecessary. When such is the case, two brigades of Sappers will be sufficient to carry on the sap; the gabions of the opposite parapets should have a clear space of 13 feet between them in order to allow a width to the bottom of the trench of $7 \frac{1}{2}$ feet.
455. (25) Treseh Cavatimas are trenches having high parapets sufficiently raised to enable marksmen firing over them (through sandbag loopholes) to see into the salieut places of arms.

When the double sap, in adrance of the circular portion, has reached to within 30 yards of the salient of the covered-way (see Plate 2), it is stopped; a single sap branches out to each side, and is formed in a curve (the salient being the centre) until it arrives on the prolongation of the erest of the glacis; it is then pushed on in a direction perpendicular to the prolongation of the crest of the glacis, for about 15 yards, which is the usual length of the cavalier, when it is terminated by a return, sufficiently long (usually 10 yards) to defilade the cavalier from the reverse fire of the collateral salients. The trench of the cavalier and of its return is then widened, until the parapet is raised to the required height, which, with the ordinary slope of the glacis, will require 3 tiers of gabions. Steps are made leading from the trench to the banquettes, which are formed on top of the second row of gabions, as shown in Fig. 397, which is a profile of a finished trench cavalier.

Fic. 397.-Scale $\frac{1}{\text { To }}$ -


PROFLLE OD A THENCH CAVAGTMR
456. (26) The Crowning of the covered-way of a fortress inangurates a new era in the attack. Hitherto the besiegers have been exposed only to direct or oblique fire from their own front, while they have been enabled to surround or encompass with their own trenches the works attacked. Now that they have to make their lodgments on the crests of the glacis of those works, they, for the first time, have to guard ngainst enfilade and reverse fire, in addition to direct fire, and the real difficulties of a siege may be said to commence. The degree to which their lodgments may be taken in reverse will depend on the saliency of the collateral works.
457. (27) Couster-Batteries on the crest of the glacis are constructed on the prolongations of those ditches and covered-ways that are flanked by the works they are intended to silence; when they are finished, they fire along those ditches into the embrasures of the flanking guns. Having silenced these guns, they may be used as breaching batteries, to breach the escarps of the flanking works, provided those escarps are exposed to their view. Such is the case, for instance, in Vauhan's First System, where a portion of the escarp of the face of the bastion is exposed to the view of the counter-battery at the salient of the covered-way of the ravelin.

In the construction of batteries (either counter or breaching batteries) on the crest of the
glacis, no regular shape can be given to their parapets, as neither shovellers nor rammers can be employed on them. After the lodgment is established, the trench is first widened to the full dimensions for a sunkeu battery, the earth being thrown on top of the parapet; the platforms are then laid; and, lastly, the embrasures would be sapped out in the manner described in the latter part of the next note.
458. (28) A breach ought to be made in the face of a work, and not round its salient. It may commence near the salient, opposite to the angle of the crest of the parapet, and extend thence to the requisite breadth, which has generally been from 40 to 100 feet.

The breaching battery, when practicable, should be opposite the position of the breach to be formed, so as to fire perpendicularly, or nearly so, to the wall to be breached.

The construction of a breaching battery on the crest of the glacis is a work of extreme difficulty, for it is exposed to a plunging fire of musketry from the work to be breached, it is also enfiladed by the works flanking the glacis, and it is taken in reverse by the collateral salients. The exposure to plunging fire necessitates high parapets, while the reverse fire necessitates long and high traverses; the difficulty of forming these traverses will be augmented, if the glacis has a steep slope.

The difficulty of construction is due partly to the great breadth required for the terrepleins of the batteries, partly to the fact that they cannot be made deeper in front than $3^{\prime}$, ou account of the genouillère, and also partly because the platforms must rise towards the rear.

The lodgments are much more easily formed, as their depth may be increased, for the sake of obtaining an increase of cover, and their breadth need not exceed 8 or 10 feet; at the same time they can be made deeper in rear than in front. These are very favourable conditions compared with those of a breaching battery. This, however, is only speaking comparatively, for no formation of any kind by the assailants on the glacis of a fortress is an easy matter.

The embrasures of a breaching battery are sapped out at night, after the parapet is completed, in the following manner:-

A gabion is first removed from the interior slope of the parapet, at the intended position of the neek. A Sapper then gets up into the space so formed, and, working on his knees, he removes sufficient earth to place a gabion in position, to form part of the revetment of one cheek of the embrasure; he then removes the earth from the opposite cheek (filling with it the gabion already placed), and places a gabion on that side. As the sole of the embrasure requires to slope considerably to the front, each gabion must be placed some inches lower than the one in rear of it. A second pair of gabions would then be placed by the Sapper, who would be assisted by a second man, as soon as the space to work in became large enough; and by continuing the work in this manner, the embrasure would be gradually formed and revetted, as the work proceeded. Gabions are the best revetment for this work; they may be crowned with rows of sandbags, to the required height.

The embrasures are not at first cut quite through the parapets of the batteries, but sufficient earth is left in front to mask the opening: this earth is either cleared away just before the battery opens fire, or it may be blown away by the first discharge of the gun.

Fig. 398 * exhibits the profile of a breaching battery, taken through an embrasure, which has been formed in the above-mentioned manner.


The line of fire A is directed in a dry ditch $4^{\prime}$ from the bottom; but in a
wet ditch it is directed to the water level.

* This figure is taken from the "Aide-Mémoire" to the Military Seiences.

459. To make a breach from a battery on the glacis of a work, from 4 to fi pieces of ordnance are required.

A horizontal groove is first cut by the shot in the wall to be brenched, about 4 feet above the bottom of the revetment (if dry), or at the level of the water if the ditch be wet. When this is effected, each gun is ased to cut a vertioal groove in the wall, so as to divide the masonry into rectangular portions, which fall from their own weight, \#s soon as the wall is cut through. A few more rounds would be required to bring down the portions of counterforts that may then remain. The guns used to breach the masomry may now be rephaced by $8^{\prime \prime}$ or $10^{\prime \prime}$ howitzers to fire shells filled with powder into the earth behind, so as to render the surface of the breach miform, and of a slope sufficiently gentle to be accessible.

The quantity of ammunition required to form a breach depends on the sccuracy of the fire of the brenching battery, which is greatly affected,-1st. By the distance at which the battery is constructed; 2ndly, by the fire to which the artillerymen are subjected.

In experiments at Metz in $1854, \mathrm{n}$ breuch 71 feet wide was made practicable with 4 guns, after firing 195 shots, or about 2.8 rounds per foot of breach.

At the siege of the oitadel of Antwerp in 1839 by the French, a battery of 6 guns ( 24 -pounders) on the crest of the glacis mude a breach 80 feet brond, after firing 1,800 younds, thas giving 15 rounds per foot of breach. In this case the French artillerymen were exposed to a close and well sustained fire of musketry from the high ramparts of the citadel; and they also suffered greatly from a heavy vertical fire of shells and stones.

The average of 9 breaches effected daring the Peninsular war gives 103 feet in width, made practicable after firing 10,653 shots, or on an average of about 103 rounds per foot of breach. The average range of the breaching batteries was 550 yards, to which fact is greatly attributable the enomous consumption of ammumition, for the whole surface of the walls had to be battered, as it was impossible at such a range to cut grooves in them,* while the velocity of the shot on striking was so much reduced as to have but little effect on the masonry. The masomry was also partieularly hard.
460. (29) While the counter and breaching butteries are being completed, tur desoend naro the ortch is commenced and carried on, so as to be completed by the time (or before) the brench is practícable.

The descent into the diteh is formed either by a subterranean gallery called a Great Gallery, $7 \frac{1}{\prime}$ wide by $6 \frac{1}{2}$ high in the clear; or by an inclined trench of similor dimensions, covered over with fascines, do., on the top, and called a Blinded Galleyy.

The Blinded Gallery being the most difficult to form, is only used when the great gallery camnot be made: this is the case whenever there would be less than 8 feet of umoved enith over its roof.

The Great Gallery is made as follows:-A shaft or pit 10 feet square, and not less than 10 feet deep, is sumk in the glacis, at such a distance from the ditch as will allow a gallery to be driven from it towards the countersearp, with a slope not steeper than 1 in 1 , but usually between 1 in 6 and 1 in 10. To reach the position of this shaft, a sap will frequently have to be sun out from one of the lodgments.


From the bottom of the shuft the great gallery is commenced, $t$ and is directed towards the counterscarp, through which it breaks at the level of the water (or one foot above it), if the ditch be wet; at the bottom of the diteh, if diy, and the breach is to be assaulted at once; or three feet below the hottom of the ditech, if it is to be sapped across. In the meantime, the side of the bhatt opposite the gallery is sloped into a ramp und blinderl, by means of the frames shown in Fig 399,

[^53]which are placed, as shown in Plate 2, on each side of the trench, sufficiently far apart to allow other frames of the same dimensions to be laid across the top of the blinded gallery, so as to connect, by their projecting ends, two adjacent frames on one side to the two adjacent frames on the opposite side of the trench. In this manner a support is obtained for layers of fascines to form a roof.
461. Another method of descending into a ditch is to drive a gallery from the lodgments on the glacis to the back of the counterscarp, and there lodge a charge of powder to breach it. This is called blowing in the counterscarp. The breach thins formed serves as a ramp leading into the ditch, to which a communication may, if necessary, be made from the lodgments on the glacis.
462. (30) Passage of the Ditoh.-To pass a dry ditch. As soon as the great gallery pierces the counterscarp, filled sandbags, fascines, \&c., are thrown from it into the ditch until sufficient cover is afforded, from the fire from the flank, for a Sapper, who then commences a sap, which is carvied across the ditch in the regular manner. The adverse fire is kept under, from the flanking parts, by the counter-batteries; from the breach in front, by the breaching batteries; and in each case by musketry from every available trench, aided by vertical fire.

Sorties of the garrison in the ditch, with the view of opposing the passage, must be expected from both flanks, and guarded against accordingly. The besiegers, at this stage of the attack, are unable (for want of room) to profit fully by their superior numbers, and consequently the Sappers forming the passage across the ditch are liable to be much interrupted.
463. To pass a wet ditch having no current. This is not a difficult operation, owing to the garrison being unable to interrupt it by sorties, except in boats or rafts, which would be a precarious operation, or to destroy the causeway while making, by floating against it explosive bodies. A causeway of fascines, loaded with stones to make them sink, is constructed across the ditch, the side exposed to fire being provided with a parapet of the same materials. The fascines should be passed from hand to hand by men stationed in the gallery. Much time would be saved by constructing two galleries of descent, as was done by the French at the siege of Antwerp in 1832, and using one of them to build the parapet, and the ather the roadway.
464. To pass a wet ditch having a current of water.-This is a very diffeult operation; and if the stream be deep and rapid, or the garrison have much command of water, so as to be able to empty and fill the ditch at pleasure, the difficulties are almost insurmountable. The passage must be effected either by a floating bridge of some sort, which, however, would require anchoring; or by making a causeway, having openings in it to let the water through. The latter method is generally recommender, and has been proved practicable from an experiment carried on by the late General Sir Charles Pasley, R.E., in the mast pond of Chatham dockyard, where the water runs at the rate of five miles an hour. It was made as follows :-

The ends were taken out of a great number of casks, to allow of water rumning through them; these were joined together in fours, end to end, by means of iron staples and rope-yarn; each set of four casks was brought lengthways through the gallery of descent, launched, hauled by ropes into the direction of the current, and sunk by sandbags; as many sets were arranged side by side as would extend quite across the ditch, thus forming one layer of casks; other layers were formed over the first till the upper casks appeared above the water, when a level flooring was made with fascines and planks.*

Gabions, joined together in sets like the casks, and placed in layers, were tried, and found to be capable of supporting a 24 -pounder, the mass suffering a depression of only 6 inches.

[^54]465. (31) Assault of a Breach. -The difficulties attending this operation are extremely variable, being dependent on the relative position and circumstrnces of the besiegers and defenders; in other words, on whether the siege has been hitherto carried on in an efficient and regular manner, or the reverse. This is well exemplified in the following extract from Note 36 of Sif John Jones' Sieges, headed "Considerations on Stormixg Breaches."
" The defence of breaches made and stormed under any circumstances, whilst the approaches are still distamt, is so very advantageous, that against an intelligent governor and a brave garrison, the chances of success are unfavourable to the assailants; and if, as in this case, ${ }^{*}$ the whole fire of the besieger's batteries has been directed to forming the breaches, aud the garrison in consequence sustain so little loss that the front breached can be fully occupied and men enough remain to form strong reserves, then height of situation, with the difficulty of the ascent over the ruins of the byeached wall, give a great superiority to the defenders. But if, in addition to these advantages of position und force, the brench be well retrenched, and the governor bas adopted the precautions recommendel in every treatise on defence, of covering the approach with chausse-trapes, has prepared small mines at its foot, spread herses oves the ascent, and plated chevaux-de-frise on its surmit; or, as in this case, has preserved a quartity of flank fire, both direct and vertical, to play on the assaulting column, during the struggle, no conceivable smperiority of courage can counterbalance such advantages. . . . The events of the 31st of July, as well as being highly honourable, are traly encouraging to the British soldiery, as they show that in future sieges, when batteries of guns and mortars shall be used exclusively to destroy and harass the garrison, when their labous shall nid their courage by carrying the approaches to the breached wall, and their efforts to assault be duly supported by a close fire from the trenches, no enemy will be found desperate enough to dispute a breach with them. Every advantage of confidence, formation, nud force will then be on their side; and how can a few worn-out and dispirited men, exposed to a murderons fire every time they attempt to stand up, pretend to resist a numerous bods elated with success, and only requiring one effort to crown their labours with a complete triumph?"
466. (32) Forming a Lodgment by Sap on a Brecch.-It was stated in the latter part of the list note, what conditions were necessary to justify assaulting a breach with every prospect of success. These conditions may be shortly stated as (1) By carrying the trenches to the foot of the breuch, to enable the assaulting columns to arrive at the breach in security, and in proper formation; (2) by ruining the defences by means of an overwhelming fire of artillery, both horizontal and vertical ; (3) by bringing a heavy fire on the breach itself.

When these favourable conditions for the besiegers exist, they may obtain possession of a breach, without even risking the loss to be expected in an assault by pursuing the following method, which was repeatedly and always successfully practised by Marshal Vauban, and which is here given in his own words :-
: Preparatory to making the lodgment, a great quantity of materials must be provided, such as gabions, fnscines, and sandbags, and also a number of intrenching tools, which should be carried as far formard as possible, without encumbering the trenches, and be piled on the reverse of them. Care must be taken that all the lodgments, from which it is possible to fire on the part to be attacked, are in a perfect state, and that all the batteries are in readiness to open; and the officers commanding in the batteries and lodgments should have it fully explained to them on the spot, how they are to act according to the signals made. The signal may be by a flag elevated on the lodgment of the covered-way, so that it may be seen from all the batteries and lodgments. Everything being ready, the infantry will place their muskets between the sandbags laid for their protection on the top of the parapets, and every one will await in silence the signal to open his fire by the flag being hcisted, and to cease firing on its being lowered. Thus prepared, two or three Sappers will ascend the breach-not up the centre, but on its right and left, next the end of the broken wall, where cover is usually found between the part of the revetment which remains standing, and that which has been beaten down. The two or three Sappers will lodge themselves in these hollows, throwing the rubbish dawn, but working upwards, and will procure cover for two or three other Suppers, who will be sent to their assistance, the whole being prepared to leave their worle on any advance of the enemy. Should that occur, as soon as the Sappers are off the breach, the signal is made and all the batteries and lodgments instantly open a heavy fire on

[^55]
the enemy, who cannot remain under it, but will quickly disperse. As soon as that is perceived the flag must be lowered, and the Sappers again sent forward, who, resuming their work, will push it forward as much as possible; again abandoning it, however, whenever the enemy make their appearance, which may occur a second, and even a third time. Each time, however, that they do come forward, all the lodgments and batteries, even those of the covered-way, must resume their fire, which cannot fail to drive back the enemy, and give opportunity to establish the lodgment. It will not probably be till the first or second time of returning that the garrison will spring their mines (if there be any), which may be considered an infallible sign that they give up the work. These mines are unlikely to be attended with any great effect, for they may be sprung at a moment when the workmen are not on the breach, or they may have been formed under the ridge, where the Sappers do not work, and at worst can only destroy three or four men. In the meantime the Sappers will have prepared some cover in the excavation, which, when completely ready, and not till then, must be occupied by small detachments; but as soon as the garrison abandon the work, the lodgment must be made openly in the breach, and be well secured along the whole excavation, but not beyond it. Afterwards the work will be extended to the right and left, along the rampart by saps, forming portions of circles which will occupy all the terreplein of its flanked angle; from theuce it will be carried along the two faces of the work, till everything is duly prepared to force the retrenchment at the gorge."
467. (33) Defence of a Breach.- The garrison of a fortress regularly besieged would seldom be in a position to defend the breaches formed in the body of the place; for, from the time when the besieger's batteries first opened their fire, the works breached would have been subjected to a searching fire of artillery, incessantly kept up night and day; and, as the attack progressed, that fire would have increased, aided by musketry, until the work would have become almost untenable. Few troops could be depended on in such a case to withstand an assault, dispirited as they would be from the effects of sheer hard work, and from having observed all their outworks fall one after another into the possession of the besieger, who, having breached the enceinte, would be able to make the final assault with overwhelming numbers of fresh troops.

For these reasons it is usual, as regards a regularly conducted siege, to consider it necessary for the garrison to surrender as soon as the trenches in the enceinte are practicable, unless the works happen to be retrenched; if such is the case, the defence may be prolonged, according to the nature of the retrenchment, for a longer or shorter period.

But if the breach be made under any of the conditions favourable for the defence, mentioned in the former part of note 31, it would be the duty of the garrison to resist the assault, and they would do so in most cases with considerable prospeets of success. When the defence of the breach is resolved upon, the efforts of the garrison should be directed to the following points :-
(1.) To multiply obstacles of every available kind, to impede the advance of the storming party across the ditch and up the breach.
(2.) To concentrate as much fire as possible on the assaulting columns.

For the first purpose, chevaux-de-frise, on similar obstacles, may be chained across the summit of the breach; the ascent may be studded witi harrows, planks with spikes in them, the iron gratings of windows and cellars with the alternate bars turned up and sharpened, crows' feet, \&c. \&c. Mines and fougasses may also be prepared for the defence of the breach. Inflammable and explosive materials of all kinds should be provided, such as fascines and faggots tarred, coils of slow match, \&c., barrels of powder, shells and hand-grenades: some of these should be arranged on the ascent, and at the foot of the breach; others placed in readiness to throw over, so as to set the rest on fire, and afterwards keep up the conflagration.

For the second (latter) purpose, efforts should be made to preserve as much flanking fire as possible, both of artillery and musketry; mortars should be placed in any positions suitable for throwing shells on the breach and into the ditch at its foot; cuts should be made in the parapet to enable infantry to get close to the exterior crest: from these cuts missiles may be thrown, and musketry used with great effect.

To show that no available resource should be neglected, of opposing the advance of the assailants by artificial means, it may be mentioned that hives full of bees have been thrown among an assaulting column, and with such effect as to cause them to retire. This is recorded by Vauban in his "Traité de la Défense des Places," with reference to the siege of Chatté (a small town in Lorraine), carried on by Marshal de la Ferté.

## CHAPTER Y.

## IHE FRESCH MODERN SYSTEM.



 compuxcations deanlied: their advantages and defiects. Conparion of the syatom with Touban's First System, vith referense to the altuck in edtuarce of thired Parallel. Deffecte of the Modern Bystem.
468. This title has been suceessively applied to Vauban's First System, to Cormontaingne's improvement of the same, and to the traees which, varying but little from the latter, have been taught in the French military schools. The aystem about to be deseribed is not exaetly that now taught at the Military College at Metz, but is that usually adopted in England.

The French Modern System exhibits a bastion system in which a considerable degree of perfection of detail has been attained; and presuming that the reader understands the method of attacking fortresses as already described, he will be able to appreciate the advantages that this trace has over the simpler one of Vauban: but not otherwise, for it is not eusy to estimate the full value of a defensive work, without being able to estimate the difficulties that would be experienced in sttacking it.
469. The exterior'side is made from 360 to 400 yards in length; the perpendieular is $\frac{7}{5}$ th* of the exterior side; the faces of the bastions are each frd of the exterior side; the flanks are perpendioular to the lines of defence; the countersearp of the main diteh is rounded at the salients with a radius of 82 yards, and it is directed tangent to the curved part, on to the interior crest of the opposite shoulder angle. By this means the ditch is not made so broad as it would be if the countersearp were directed to the shoulder angle of the magistral line, while the whole fire from the flank can still defend the ditch.
470. The magistral lines of the faces of the ravelins coincide with the sides of an equilateral triangle, whose base is a line joining points on the faces of the bastions 36 yards from the shoulders. The ditch of the ravelin is 21 yards broad throughont, and is rounded at the salient in the usual mamper.
471. The faces of the reduit of the ravelin are parallel to those of the ravelin, and 32 yards from them. The ditch of the rednit is 11 yards broad. The reduit is given flanks in order to bring a reverse fire on that part of the face of the bastion mest likely to be breached, which is the portion between the salient and the prolongation of the face of the ravelin (see the line of fire from the left flank of the right ravelin in Plate 3). The flanks are made long enough to contain three gous each, and are thus traced:-Talse as a centre the middle of that part of the face of the hastion which is liable to be breached, with a radius, extending to a point on the face of the reduit, 19 yards from its intersection with the counterscarp of the main diteh, and deseribe an are from that point to the main counterscarp; the chord of that arc will be the magistral of the Hank of the reduit.

The gorges of the ravelin and its reduit are made parallel to the side of the polygon, and each is a line joining the crests of the works at the points where they cut the counterscarp of the main ditch.
472. The tenaille has a total breadth of 15 yards; its gorge and end walls are parallel to the cartains and flanks, and 11 yards from them. The parapet of the temaille is 15 feet thick, but its crest for the length of 6 yards from the outer extremity of each flank is made perpendicular to a line passing from it to the middle of the junction of the main ditul with that of the ravelin. The fire from these small flanks would oppose any works constructed by the besiegers, to enable them to enter the main ditch from that of the ravelin (see Plate 4).
473. The re-entering places of arms are provided with reduits, which are thus traced: join

[^56]Profile on the Line C.D.
Command of Rove of Place


Profile on the line G.H.

the salients of the bastion and the ravelin, to obtain the counterscarp line of the diteh of the outer face of the reduit; bisect the re-entering angle formed by the main counterscarp and that of the ravelin, to obtain the capital of the reduit, and draw the counterscarp of the inner face of the reduit, at the same nugle with the capital that the outer face makes. The ditch of the reduit is 5 yards broad. In tracing the crest of its parapet, a small flank is given to its inner end, 6 yards in length, for the purpose of bringing a reverse fire on a breach made in the face of the ravelin, and for this reason it is made perpendicular to a line of fire directed on to the salient of the ravelin.

In order to defilade the terreplein of the reduit of the re-entering place of arms from a besieger lodged on the salient places of arms in front of the ravelin, its garge wall on the side of the ravelin is formed by a line drawn from the salient of the ravelin through the end of the crest of the small flank of the parapet of the reduit.
474. The glacis of the re-entering place of arms is made curved as a protection from enfilade. The crest is traced by an aro drawn with the intersection of the counterscarp of the bastion with that of the ravelin as a centre, and a radins, extending to a point on the capital of the reduit of the re-entering place of arms, 20 yards in front of its counterscarp.

The intersections of this arc with the counterscarps of the bastion and ravelin, give the extremities of the crest of the traverses enclosing the re-entering places of arms.

The covered-way has the usual breadth of 11 yards in front of the bastions and ravelins.
475. Each face of the ravelin is provided with a coupure retrenchment, which prevents a besieger lodged on the salient of the ravelin penetrating towards its gorge, and thus seeing the reduit of the re-entering place of arms in reverse.

The countersearp of the ditch of the coupure is usually fixed by a perpendicular to the face of the ravelin, drawn from the intersection of the escarp of the reduit of the re-entering place of arms, with the counterscarp of the ravelin.

The ditch of the coupure is 5 yards broad. The parapet in rear of this coupure has the same dimensions as that of the faces of the ravelin.
476. The counterscarp of the reduit of the ravelin in rear of the parapet of the coupure is in the direction of a line drawn from the flanked angle of the rednit of the ravelin through the point at which the crest of the coupure in the ravelin meets that counterscarp. This is done in order to defilade the interior of the coupure and its staircase from a besieger lodged on the salient of the ravelin.
477. The traverses in the corered-way which enclose the re-entering places of arms, are made 18 feet in thickness, and they occupy the whole breadth of the covered-way. The other traverses are made only 10 feet thick, which is sufficient as a protection from ricochet fire, but allows the artillery of the place to demolish them, when it becomes requisite to deprive a besieger of any cover they might ufford. A pathway 4 feet broad is also left between these traverses and the counterscarp, in order to afford a secure retreat to the defenders during an assault of the covered-way.

In front of the bastions one traverse only is placed on each branch of the covered-way, but in front of the ravelins there is room for four traverses to each branch : one is placed enclosing the re-entering place of arms, that nearest to the salient occupies the prolongation of the face of the ravelin (the magistral line of which produced gives the foot of the exterior slope of the traverse), and the interval between these two traverses is divided into three equal portions to obtain the two intermediate traverses, which in direction are perpendicular to the covered-way.
478. The communications round these traverses are formed en cremaillère, or in single crotchets (as described in Art. 375), which are arranged so as to leave a footpath having a clear width of 6 feet on the ground. The ends of the traverses, and also the interior of the glacis forming the passage round them, are supported by vertical masonry walls, and sometimes a narrow masonry banquette is given to the parapet of the passage, to allow a continuous line of fire being maintained along the whole of the covered-way.

A pan coupe is given to the glacis at the salient place of arms in front of the ravelin, by constructing at the salient a face at right angles to the capital and 10 yards in length: this affords a convenient position from which to obtain a close and grazing fire of musketry on the capital, more likely to be efticient than that from the (comparatively) distant re-entering places of arms.
479. To prevent the escarp of the bastion being breached from the salient of the glacis of the

## Permanent Forlification.

ravelin, a traverse should be constructed in the ditoh of the ravelin, of a height sufficient to cover the escarp of the bastion from a lireaching fire. A height of 15 feet above the ditch of the ravelin may be assumed as sufficient for this purpose. The traverse should slope to the front en glacis, with an inclination allowing it to be grazed by the musketry of the bastion. By placing the crest of the traverse $28^{\prime}$ in front of the line of countersearp of the bastion, room will be allowed for a banquette and a passage in rear $8^{\prime}$ broad, to facilitate the communieation for sorties, \&c. This traverse may join the gorge wall of the reduit of the re-entering place of arms, as shown in Plate 3 , but should be separated from the ravelin by an interval of i yards, to prevent its affording access to that work by zaeans of ladders.
480. A Cwatier Fetrenclement is naually described under the hemd of the Modem System, and one is shown in the centre bastion of Plate 3; but such a work does not form part of any particular system. The cavalier has a command over the bastion (usually) of 9 feet. Its faces and flanks are parallel to those of the bastion, and sufficiently retired from them to afford space for a proper terreplein. The faces of the cavalier have a ditch 10 yards in breadth, the retrenchment being completed by making a coupure across each face of the bastion. The counterscarp of the ditch of the coupure is drawn through the point where the prolongation of the face of the ravelin intersects that of the bastion.

To avoid having dead re-entering angles, the parapet of each coupure is broken, by retiring that portion which oceupies the prolongation of the ditch of the retrenchment, until its magistral line coincides with the crest of the remaining portion. The junction of these portions is in a line directed to the salient of the cavalier. By this means an opening is afforded, whence a view is obtained of any part of the escap of the cavalier, without exposure to an enemy lodged in the salient of the bastion. This advantage is obtained, however, at the cost of cramping the interior space (alveady much cut up by the cavalier) to a most incouvenient degree.

## RELTEFS OF THE MODERN SYSTEM.

481. In arranging the reliefs of a bastioned front, the primary point to determine is the relief of the eneeinte; for on that depends the relief to be given to the reduit of ravelin and the ravelin itself, as the body of the place should have a command of at least $z^{\prime}$ arer the reduit of the ravelin, and this latter a similar command over the ravelin. The relief of the tenaille is also dependent on that of the enceinte.

As explained in Art. 367, page 169, the maximum relief of the enceinte of a bastioned fortress is dependent on the length of the curtain, if the whole of the ditch is to receive muskelry defence from the flanks, as ought to be the case; but if this rule be strietly followed with a curtain of the dimensions here given, a relief to the enceinte of only 34 feet * could be allowed, which is quite insuffieient; for as the escarp ought to be $30^{\prime}$ in height, and the crest of the glacis ought not to be lower than the cordon, there would remain only $4^{\prime}$ as the command of the enceinte over its own glacis, which would not only prevent the proper action of its own fire, but would also prevent the ravelin being given the requisite command over its glacis.

For this reason, while most authors, in describing the Modern System, are nearly agreed as to the trace, they have assumed very different reliefs, and all have necessarily departed more or less from the fundamental rule of thie bastioned trace, which prescribes that the whole of the escarp of the curtain should be defended from the flanks; in fact, it is impossible to combine in one frout,

[^57]having an exterior side of from 360 to 400 yards, the three conditions of a high relief (allowing a good command with a well-covered escarp), a fully flanked ditch, together with capacious and powerful bastions. It is for this reason that the Modern System, while it is nearly complete in trifling details, is deficient in having a portion of its main diteh undefended from the body of the place. This defect may be remedied by the construction of loopholed galleries behind the escarp of the flanks and curtain to defend the (otherwise) dead spaces, but by so doing the flanking works are increased in number.
482. By fixing the relief of the enceinte at 45 feet, and having au escarp $30^{\prime}$ in height, if the crest of the glacis is on a level with the crest of the escarp, the enceinte will have a command of $45^{\prime}-30^{\prime}=15^{\prime}$ over its glacis, which is sufficient to enable the musketry fire of the bastion to defend its own covered-way, and also to allow the ravelin and its reduit to be given a proper command, while, at the same time, they are sufficiently commanded by the enceinte.

By giving to the glacis of the bastions a slope of 1 in 25 , the artillery fire from the faces may be directed parallel to the surface of the glacis and 2 feet above it.

This relief of $45^{\prime}$ to the enceinte would cause the musketry fire from the flanks at a depression of $\frac{1}{8}$ to arrive within $I$ feet of the bottom of the diteh, at a horizontal distance of 72 yards from the magistral line of the flank, and there will be, in consequence, a considerable amount of dead space in front of the curtain.
483. The enceinte is given a command of 3 feet over the reduit of the ravelin, and this latter has also a command of 3 feet over the ravelin, in order to prevent an enemy, when lodged in these several works, from seeing into the next interior work. The ravelin, therefore, has a command of 6 feet less than that of the enceinte: its glacis is made $l^{\prime}$ lower than that of the bastions to enable its artillery to sweep its glacis. The command of the ravelin over its own glacis will therefore be $15-6+1=10$. This command of 10 feet over its own glacis will allow its musketry fire to be directed to a point about $3 \frac{1^{\prime}}{4}$ above the top of its counterscarp, which is sufficient for the defence of the covered-way.

If a shot be fired from an embrasure in the ravelin ( $5^{\prime}$ below the crest) and directed so as to graze the crest of the glacis, it will have a depression of 1 in 24 ; the glacis may therefore be given the same slope, but it is usually made 1 in 25.

The fall of 1 foot between the crests of the glacis of the ravelin and of the bastion takes place at the traverses dividing the re-entering places of arms from the covered-way in front of the ravelins, the passages round these traverses being given a slope of 1 foot in their length.

The bottom of the ditch of the ravelin is made $\gamma^{\prime}$ above that of the main ditch, the junction of the two ditches being formed by a wall $7^{\prime}$ in height. By this means more of the diteh of the ravelin is under the musketry fire of the bastion; and the communication along the main ditch is covered from the view of a besieger lodged on the salients of the glacis of the ravelin.

By keeping the crest of the escarp of the ravelin on a level with the crest of its glacis, a height of 22 feet can be given to it.
484. The bottom of the ditch of the reduit of the ravelin is made 15 feet above that of the main ditch, in order to afford an obstacle against the attack of the ravelin by its gorge.* By so doing, the relief of the work will be $45-(15+3)=27$ feet. Its escarp is made 18 feet in height, and the top of the cordon will therefore be 6 feet below the crest of the ravelin, which is sufficient to prevent such injury as would cause the fall of its parapet, even after the ravelin has been breached.
485. The reduits of the re-entering places of arms are given a command of $4 \frac{1}{\frac{2}{2}}$ feet over the glacis in their front. This command is sufficient to allow the musketry fire from these works to graze the glacis, without being so great as to interfere with the simultaneons fire of the bastions, which will have a command of $10 \frac{1}{2}$ feet over them.

Their ditches are sunk 12 feet below the terreplein of the covered-way, making their relief $24 \frac{1}{2}$. Their escarps are made 18 feet in height, the tops of which will be 2 feet under the crest of the covered-way.
486. The relief of the tenaille should be as great as possible, provided it does not interfere with the fre from the flanks; for the higher it is made, the better it will cover the escarps of the flanks and curtain.

[^58]The crest of the centre part of the tenaille may be made 1 foot* under a line of fire directed from the gun in the flank neurest to the curtain angle, so as to strike the surface of a breach made in the fhoe of the opposite bastion. Such a line of five is shown in Plate 3. It passes over the crest of the tenaille it a horizontal distimee of 68 yards from the crest of the flank, and it reaches the breach at a horizontal distance of 170 yards from the crest of the flauk. Now supposing that the gun is fired 5 feet under the crest of the parapot, and that the surface of the breach is 10 feet above the bottom of the main ditch, it follows that in a distance of 170 yaris the shot will have fallen a height of $a 5-(10+5)=80$ feet. Now the fall of the shot in the distance of 68 yards will evidently be $\frac{68 \times 30}{170}=12$ feet; and the relief of the tenaille, where the line of five crosses it, may therefore be made less tham that of the enceinte by $12^{\prime}+1^{\prime}+5^{\prime}=18^{\prime}$; or, in other words, it may be $45^{\prime}-18^{\prime}=2 \pi^{\prime}$.

The tenaille may either be kept at this relief throughout, and by so doing the guns in the flanks, as they are nearer to the shoulder angles, can see more and more of the ditch; or the tensille may be made higher at the flanks than in the centre, so as to allowv the whole of the guns in the flanks to be depressed only sufficiently to defend the breach made in the face of the opposite bastion. The former method is usually preferred.
487. Having thus established the reliefs and the commands of the several works with respect to each other, it remains to determine their absolute commands, or heights above the plane of site. The rule given in Art. 359, page 168, for this purpose, but adapted for profile only, must be here extended in its application. Taking half the front, the level must be found for a horizontal plane, which would divide it into two parts, so that the solid content of the mampart, glacis, \&o., above the plane, minus the quantity of masonry above it, may be equal to the total quantity of excavation.

In the present case a command of 24 feet above the plane of site for the body of the place will falfil this requirement.
488. The reliefs, commands, \&e., of the various parts of the front, which are based on the foregoing reasoning, are shown in the accompanying table:-

489. The communications of a front are similar in their nature to those already described, but their arrangement is more perfect, inasmuch as the garrison are able to communicate with the several outworks unseen from any lodgments of a besieger in works that may have been captured by him. Thus, after the cupture of the ravelin, the garrison can keep up their communication with the reduit of the ravelin and the coupures in the ravelin, unseen by the enemy lodged in the ravelin.

[^59]490. A postern under the centre of the curtain gives access to the main ditch, its exterior opening being $6^{\prime}$ above the foot of the escarp. Its roadway is necessarily inclined, and this inclination is commenced at such a distance from the entrance as may reduce the slope to 1 in 8 .

A double flight of steps $6^{\prime}$ broad in the gorge of the tenaille gives access to its terreplein. These steps are separated by au interval of 10 feet at the bottom; as the height to be ascended is 19 , the number of steps will be 28, as each step rises $8^{\prime \prime}$, and the length of each flight will be 28 feet, each step having a tread of 12 inches.
A. postern, the floor of which is level with the bottom of the main ditch, leads under the centre of the tenaille to the main ditch in its front. A donble capounière affords a communication across the main ditch, concealed from view from an enemy's lodgments on the glacis of the bastions. The crests of the parapets of the caponnière are 25 feet apart, the banquettes are provided with masonry steps, so as to enable a roadway of 8 feet in breadth (that of the postern) being left between them. The superior slopes should be such that, if produced, they do not pass above the crest of the flank behind them. The caponniere is separated from the gorge wall of the reduit of the ravelin by a pathway $8^{\prime}$ broad, which affords access to the main ditch.

A double flight of steps $\theta^{\prime}$ broad with a space of 10 feet between them, is made in the gorge wall of the reduit of the ravelin, to communicate with its interior. The rise being 21 feet, 31 steps will be required to each flight, which will therefore occupy a length of 31 feet.

A ramp on the capital of the reduit 10 feet broad, and rising 1 in 8 , leads to the terreplein of its rampart.

A postern, slightly inclined, leads under each flank of the reduit of the ravelin into its ditch, elose to the drop between it and the main ditch.

The communication across the ditch of the reduit to the steps in the coupure, is protected by a single eaponniere, separated from the escarp of the reduit by a pathway $8^{\prime}$ broad, which gives access to the front part of the ditch.

A ramp in the rear wall of the ravelin $10^{\prime}$ broad, and rising 1 in 10 , commences at the countersearp of the conpure, and leads to the terreplein of the ravelin. On account of this arrangement of the communications, it is necessary, in order to get either to the ravelin or to its coupures from the enceinte, to pass through the reduit of the ravelin.

The reduits of the re-entering place of arms, have each a double flight of steps leading up from the main ditch; the communication to these steps from the main caponniere is concealed from view from the ravelin or its glacis, by the gorge wall of the reduit of the ravelin, that of the ravelin itself, and also by the wall $7^{\prime}$ high, which separates the bottom of the main diteh from that of the ravelin; but it is not concealed from the salients of the glacis of the bastions, for before an enemy could lodge himself there, the reduits of the re-entering place of arms would have been abandoned.

A postern leads under each face of the reduit of the re-entering place of arms into its ditch, and a ramp opposite each postern leads up the counterscarp to the terrepleins of the re-entering place of arms, whence access to the glacis is afforded by two sally-ports 12 feet broad, and rising 1 in 8 . These sally-ports should be sufficiently curved, to secure them from enfilade.

It is necessary to pass through the reduit of the re-entering place of arms, in order to get to the covered-way, and as the only access to these reduits from the main ditch is by means of masonry steps, cavalry and artillery cannot form in the places of arms for purposes of sorties, \&ce, except on those fronts provided with the gateways and bridges used as communications during time of peace. This is a considerable disadvantage.
491. The revetments of the system are demi-revetments. They may be solid and provided with counterforts, or else counterarched in places either where the escarp is liable to be breached, or, if used in the counterscarp, to serve as a counterscarp gallery, either for the purpose of obtaining a reverse fire of musketry on the ditch, or for purposes of countermines, as in Fig. 433.
492. In comparing the Modern System, as here described, with Vauban's First System, assuming both to be constructed on an actagon, it will be observed that the advantages of the former are nearly entirely due to the increased dimensions of the ravelin, which is large enough to be powerfully retrenched, and sufficiently salient to place the bastions in re-entering positions between the ravelins, thereby forcing a besieger to capture two ravelins before he can attack one bastion. A besieger is also unable to breach the face of the bastion by fring down the diteh of the ravelin, owing to the traverse constructed in the latter, as mentioned in Art. 479.

In attacking both this system, and Vauban's First, on similar polygons, no great difference in the attack would be apparent until after the third parallel is established; it is in advance of that period of the attack that the greater difficulties to be overcome in attacking the Modern System would be experienced. To illustrate these, the successive operations that would have to be executed by a besieger, after the establishment of the third parallel until the fall of the place, are here given in parallel columns (Plates 2 and 4 illustrating the text).
493. Operations in Advanee of the Third Pabaliel to bel performbi in the Attack on

VAUBAN'S FIRST SYSTEM.

1. Donble saps on capitals of two bastions and one ravelin; the construction of treach cavaliers ; and crowning the three salients.
2. Extending the lodgments; formation of breaching and counter-batteries, also galleries of descent.
3. Breaching two bastions and one ravelin ; completing descents into the ditches; passage of the ditches, and lodgment on the breaches.

Place surrenders, if not retrenched.
N.B.-Two bastions and one ravelin being simultaneously breached and captured, the attention of the garrison is much divided, and the defence in consequence must be weakened, particularly as the body of the place is breached in two separate works, while the besiegers are able to profit by their superiority of resources by being able to construct many works at the same time.

THE MODERN SYSTEM,

1. Double saps on capitals of two ravelins; trench cavaliers; and crowning the two salients: formation of the fourth parallel.
2. Extending the lodgments; formation of breaching and counter-batteries; galleries of descent: formation of a fifth parallel.
N.B. The reverse fire of ravelins on each other causes this to be a most difficult operation.
3. Breaching two ravelins; completing descents into their ditches; passage of ditches, and lodgments on breaches of ravelins.
N.B. The body of place being intact, and the ravelins and covered ways having reduits, increase the difficulties of these operations.
4. Extension of lodgments in ravelins, and their conversion into counter-batteries; breaching of escarp of reduits in two ravelins, either by artillery or by mines ; lodgment on reduits of ravelins.
5. Extension of lodgments in reduits of ravelins, lodgments on coupures of ravelins. Double sap on capital of bastion.
6. Lodgment in reduits of re-entering place of arms, crowning of covered-way of bastion.
7. Formation of breaching batteries, coun-ter-batteries, and descents into main ditch.
8. Breaching of two faces of one bastion, passage of ditch and lodgment. on breach.

Place surrenders, if not retrenched.
N.B. The outworlis having to be captured before the enoeinte oan be attacked, allows the defence to be concentrated, firstly to the ravelins, then to their reduits, and afterwards to the enceinte, which is attacked in only one bastion, to retrench and dofend which the whole efforts of the garrison would be directed.

ATTACK ON THE MODERN SYSTEM IN ADVANCE OF

THE THIRD PARALLEL


A:B. The Fiqures in brackiets denote the rights onwhich ine works of A\#tack were exeatred
49.4. Notwithstandiug the advantages over Vauban's First System of the Modern System, the latter has many and grave defects.

The reduit of the ravelin, the ravelin itself, and also its covered-way, form on each face three lines of work which are parallel to one another, and which are completely exposed to enfilade from a single battery. With the artillery of the present day used by a besieger, it is probable that these works would be deprived of much of their offensive power, from the moment when the besieging batteries should first open their fire. No permanent provision is made on the ramparts to secure them from the effects of enfilade or reverse fire, and it would be extremely difficult to extemporize "blindages " sufficiently solid to protect guns from the fire of rifled artillery.

The communications of the system are not well suited to an active defence; besides being intricate, and in many places consisting only of steps, they have the defect of passing through works, the interior of which is thereby practically used as a communication. Thus it is necessary to pass through the reduit of the re-entering place of arms to get to the covered-way, or to pass through the rednit of the ravelin in order to arrive at the ravelin itself.

From the restricted nature of the communications, and the construction of the gorges of the several outworks, it is impracticable to make a sortie in force for the recovery of any outwork which may have been eaptured.

The enceinte has a trace but little different from that of Vauban, and inherits most of the defects of the latter, with the exception that the shoulders of the bastions are better protected from distant fire, and also that the escarps, being concealed from distant view, are better protected from being breached from a distance.

For the further defects of the Bastioned System, the reader is referred to Chapter IX., where a comparison is made between it and the Polygonal System, with reference to the principal requirements of a fortified place. See also Art 404, page 183.

## CHAPTER VI.

## VAULTED WORKS.

Casemates, their nature and various uses. Casemated Barracks. Casemated Batperies for guns; defects of old types, and how remedied in recent constructions: Embrasures of, successive improvements made in them. Casemates with ibon shiedds for sea defences. Mortar Casemates described. Haxo Casemates described. Blindages.
495. A CASEMATE or BOMBPROOF is an arehed chamber, made sufficiently strong to resist the fall of heavy shells; it is usually of a rectangular shape, the walls which form the piers of the arch being from $4^{\prime}$ to $6^{\prime}$ in thickness; the arch which forms the roof is usually $3^{\prime}$ in thickness, and is strengthened above by a covering of earth, which should be at least $6^{\text {r }}$ thick; the object of the earthen covering to a casemate is to protect the masonry of the arch beneath from being injured by the fall of shells; it should always be replaced, as soon as possible, after a shell may have exploded in it, so as to preserve at all times a proper protection to the masonry.

Casemates are largely used in the construction of modern defensive works; the improvements made of late years in artillery have rendered bombproof cover for the gamison, the guns, stores, \&c., of a fortress, more necessary than formerly, and, at the same time, it is requisite that the casemated works should be more strongly constructed, and be in more secure situations than has hitherto been the case.

Casemates are constructed either for the lodgment of troops, and are then termed Casemated Barracks ; or for the purpose of covering guns or mortars, when they receive the name of Casemated Batteries, or else as bombproof magazines, stores, \&c.
496. Casemated Barraces are sometimes separate buildings, but are often placed under the terrepleins of ramparts that are not exposed to reverse fire, for in such positions they are protected in front and above by the mass of the rampart. Figs. 401, 402, represent the casemated barracks that are made in some of the forts protecting the English dockyards. Their breadth of 20 feet is sufficient for a row of beds on each side with a passage in the middle; they are commeeted with one another in rear (on the side towards the front of the parapet), by a gallery of commumication, which facilitates their ventilation, and during a time of siege would be particularly useful, as
affording a covered communication between the different parts of the barracks. These casemates are provided with fireplaces, and are fitted up so as to be used as barracks for 15 or 16 men in time of peace, while, in time of siege, a greater number of men could be lodged in them.

A longitudinal section of these casemates is given in the profile (Fig. 441) of the new English Forts.
497. Casematid oun batreries are composed of a series of casemates, in one or more tiers, each of which has its front wall pierced with an embrusure, through which the gun is fired. The front wall of an ordinary gom casemate is exposed to view**

Casemated batteries are used in positions where it is necessary to protect the guns and gumers from either plunging, enfilade, or reverse fires, or where, as in some sea defences, it is necessary to baild a work in two or more tiers, in order to obtain a sufficient number of casemates, without requiring extensive foundations.

Guas protected by casemates are secure from all fire, except direct fire; the size of the embrasure is therefore a matter of great importance; many contrivances, some of which will be shortly referred to, have been proposed, in order to be able to reduce their opening.

498. The objections furmerly urged against casemates for artillery, were :fired.

2nd The large size and funnel-shape given to the exterior of the embrasures, which rendered the guns very liable to be silenced whenever an acourate fire was brought against them. $\dagger$
499. These two defects exist, to a greater or lesser degree, in old casemates, but are almost entirely remedied in modern constructions. The ventilation has been perfected by leaving the

[^60]rear of the casemates open, by providing doorways of commumication between the several casemates and openings in the roof at the level of the crown of the areh, and at other points, for the exit of smoke. Many experiments lately carried on have demonstrated that no ineonvenience from smoke need be experienced in a properly constructed casemated work.
500. The size of the openings of the embrasures has also been much reduced, but, as the improvements that have been made were successive, a few examples are here given, showing the intermediate stages through which the embrasures of easemates for artillery have passed.

Figs. 403, 404, 405, show a gun casemate in plan, profile and front elevation; they afford a type of such works, as they were construeted up to the beginning of the present centary, and they may be assumed as illustrating the casemates referred to in the foot note to page 220. Here the embrasure is large, the mouth being frequently $6^{\prime}$ or $7^{\prime}$ broad, and about the same in height, and it evidently acted as a funnel, so that every projectile that struck the cheeks would be deflected into the neck and among the gunners. The exposure of the gunners may, in a casemate of this lind, be measured by the size of the large opening (mouth) of the embrasure, the area of which would frequently be 50 square feet. The neek is also very weak to resist the effects of heavy projectiles.

The large size of the mouth of this embrasure (or A, Fig. 406) is due partly to the thickness of the front wall, and partly to the necessity that formerly existed of making the gun traverse horizontally on a point inside the embrasure. In some cases the neck was placed near the middle of the wall in order to allow the mouth to be lessened in size; but the wall was thereby weakened, as it was necessary to cut into its thickness, to allow the muzzle of the gun to project beyond the neek.

501. A great improvement is due to the Americans, who terminated a series of experiments by introducing an embrasure, similar to that shown at B, Fig. 406. Here the throat (or neck) of the embrasure is advanced a little beyond the middle of the wall, which in the experiments was made 5 feet in thickness, the outer opening can thereby be reduced; the cheeks are formed en cremaillere or in offsets, so that the only projectiles that can pass into the casemate are those actually directed towards the neck, since any that may strike the cheeks are not deflected inwards on account of their cremaillère formation. Thus the exposure of the gunners may be measured hy the size of the small opening of the embrasures. The neck of the embrasure is strengthened with iron.
502. A further improvement is due to the introduction of ribbed racers,* by which the traversing platforms, on which the guns work, can be made to traverse horizontally on any chosen point as a centre, by forming the racers in curves which have that point as their centre. This arrangement allows the small opening of the embrasure to be placed on the outside, as shown at C, in Fig. 406, or in Fig. 413 ; with this arrangement, the muzzle of the gun remains practically stationary, while being traversed to the right or loft horizontally. The embrasure requires to be of the height sufficient to allow the proper elevation or depression being given to the gun. The neck of the embrasure is the weakest part of the whole, however, even with this plan, but a vast improvement is effected as compared with old embrasures; for in some new works, embrasures on this plan, having an external opening of $2^{\prime}$ in breadth and $3^{\prime}$ in height, and an area therefore of 6 square feet (of which the gun may be assumed to occupy one) allow to the gun a horizontal range of $60^{\circ}$, au elevation and a depression of about $10^{\circ}$ (see Figs. 412, 418, and 414 ).

[^61]503. The application of wrought irou as a substitute for the masomry of the front wall of casemates has improved and simplified still further the formation of embrasures, on account of the front wall being only (about) 1 foot in thickness, instead of 6 feet. This allows the embrasure to be made as small as possible, both intermally and extermally, and its sides are not such weak parts as they must necessarily be in a masonry wall.

Figs. 405,408 , represent a gun casemate of the latest pattern. The front wall is a shield of wrought iron, firmly supported in rear by powerful struts, and is quite independent of the masonry; the piers of the casemate are strong masonry walls, supporting a masonry arch overhead, above which is the usual covering of earth. The iron shield, which can be made of any desirable thickness, forms practioally an impenetrable and an indestructible parapet wall; the embrasure in it is a small opening, with an area of about 6 square feet. These casemates are fitted up as barracks, so that they may contain at all times the gunners required to work the guns. The type here given is applied to some of the sea defences of Plymouth.
504. It will be observed that in the improved embrasures, as above described, while the width is reduced to 2 feet, the height has to be made 3 or more feet; this is necessary, owing to the gun requiring, while being elevated or depressed, to move on the trunnions as a centre of motion, as shown in either of Figs. 407 or 412.

The only further improve. ment that seems desirable in casemate embrasures is an arrangement by which the gun can be elevated or depressed, so as to allow it to move in an are, which has for its centre the point in which the gun traverses horizontally; for the embrasure could then be made a circular opening, only a few inches larger in diameter than the muzzle of the gun; and since the gun would then nearly fill up the opening, the exposire of the gumners would be reduced to a minimum. This result will, in all protra-
bility, shortly be obtained, for platforms and carriages have already* been proposed of a construction which will enable a gun mounted on them to be elevated and depressed on any required point as a centre of motion.
505. A Mortar Casemate is a work of very simple construction ; it consists, generally, of a bomb-proof roof, formed in the usual mauner, by a strong masonry areh, resting on piers, the arch being covered with earth to the requisite thickness. The casemate has no front wall, and in most cases, is also open in the rear. When two or more mortar casemates are together, openings are provided through the piers to act as commumications.

Owing to the fact that in mortar firing it is not necessary to see the object fired at from the mortar's, mortar casemates have the great advantage of being able to be placed in situations where they can be rendered very safe from an enemy's fire. In Figs. 409, 410, the casemates are represented behind a rampart, the rear of which is supported by a vertical wall. In front of the mortar easemates there is (usually) a diteh, the object of which is to eateh hostile shells, whieh would explode harmlessly there.

A reference to the profile (Fig. 409) will show that it is almost an impossibility for an enemy's shell to strike the mortar, for owing to the high angles at which mortar shells descend, those directed by an enemy against the casemates, which, of course, are invisible to him, would either fall on to the bomb-proof roof, or in the front ditch, or on the terreplein (or other covering mass) in front. Even when mortars are not placed in casemates, their fire is more difficult to silence, owing to their being hidden from an enemy's view, than that of other pieces of ordnance.
506. A Haxo Casemate (Figs. 412, 413, 414) consists of a bomb-proof chamber, constructed for the protection of a gun firing through the embrasure of an earthen parapet. It is usually open to the rear, but is provided with a front wall, through which an embrasure opening is made. The earthen parapet protects the front wall of the casemate to a considerable degree from direct fire. (See Plate 5 for an example of the extensive use of Haxo casemates in recent constructions.)

In order to avoid exposing more of the front wall
 than is necessary, the arch is kept as low as possible in front, as shown in the profile. With this precaution, however, the exposure of the front wall is so serious an evil, that Haxo casemates are only applied, as a rule, to positions where the guns they protect are exposed to vertical or enfilade, but not to direct fire. This is generally the case in the flanks of works.

A Haxo casemate, in addition to the protection it affords to the gun inside it, also acts when used singly as a traverse to the terreplein of the work on which it is constructed, as in Fig. 439.

The exposed portion of the front wall of Haxo casemates will, in all probability, be protected by iron : by this means Haxo casemates will be as applicable to positions exposed to direct, as to any other kind of fire.
507. Casemated Kaponiers are bomb-proof buildings, constructed in the ditches of fortresses for the purpose of flanking them by a fire of artillery and musketry. The casemates in them are in one or more tiers. Further details of these works are given in the description of the Polygonal System of Fortification, Chapter IX.
508. A Blindage is a temporary building, generally of timber, covered overhead for the protection of troops, guns, wells, cisterns, gates, sluices, hospitals, passages across ditehes, \&c. In general it consists either of upright walls of timber with a roof, or of two inclined walls meeting in a ridge at top, and forming two gable ends; the timbers may be $12^{\prime \prime}$ thick, covered with logs,

[^62]planks, \&c, the whole being covered with a sufficient thickness of earth. This is called a torble blindage.

A Leaking Blindage consists of stout beams of timber, twelve or more inches square, planted


Section and elevation on XY.
Fir. 413.-Plan.

A. Recess for shells.

Fig. 414.-Front elevation.


Like Haxa casemates, blindages for guns are suitable for structed. cover are not liable to a direct fire of artillery. If placed on tor positions where the guns they a gun blinded in an efficient manner will bring a reverse fire on to the glacis of the collateral, sulients, and will render the formation of any lodgment there a work of extreme difficulty.

## CHAPTER VII.

OCCASIONAL WORKS.
Citadmls, their uses ant position; esplanade: Cavalier, nature and use. Retrenchments of various kinds. Outworis, Tenaillons, Demi-tenamlons. Counterguards or Couvre-faces. Horn and Crowh Works. Advanced Works. Detached Warks, their objects, conditions to fulfil, etc.
510. In addition to the ordinary works of a Front, which have been already described, other works are, or have been, used in fortresses, which may be divided into four groups, viz. :-

1st. Those used in connection with the Body of the Place.
2nd. " $"$ as Outworks.
3rd. $"$ as Advanced Works.
4th. " " as Detached Works.
511. Occastonal Works in connection with the Body of the Place.

A Citadel (Fig. 487) is a small fortress, usually of 5 or 6 fronts, constructed in the strongest and most inaccessible part of a fortress. Its object is priucipally to provide for a prolonged defence, as it both gives confidence to the garrison, and affords them a refuge after the capture of the town. A citadel also serves to keep in subjection the inhabitants of the town, if hostile to the garrison; and it allows the garrison, if weak, to defend the key of the position, when they would be unable to occupy the entire fortress.

An open space, called the Esplanade, is left between the town and the glacis of the citadel, to prevent an enemy from making his approaches under cover. The fronts of the citadel which face the country should be stronger than those on the side of the town, as otherwise a besieger would at once lay siege to the exterior of the citadel, and would thus avoid having to make two consecutive sieges.
512. A Cavalier is a work situated in, or behind, another, over which it has a command of fire; its usual object is to see into, and defend ground, which eannot be seen from the main work.

A cavalier is sometimes made behind a curtain, where it is usually secure from enfilade, and affords a good position for heavy guns to bear on the besiegers' works, and also on the breaches in the faces of the bastion ; but its more usual position is in a bastion (as in Fig. 415), where, in addition to the extra fire it affords, it has the advantage of protecting the bastion flanks from reverse fire.

Fig. 415.


Fio. 416.


A cavalier in a bastion has the defect of greatly cutting up the interior space of the bastion.
513. A Retrenchment is a work constructed inside another, in such a manner as to isolate a breach made in the latter work from the remainder of the fortress.

Retrenchments of all kinds have the advantage of delaying a siege in a two-fold mamer:1st. They allow the defenders to dispute the possession of the breach, while they cover their

## Permanent Forlification.

retreat: 2nd. They require themselves to be captured, after an enemy has gained possession of the works breached.

The Reduit of the Ravelin, and alse that of the Re-entering Place of Arms, described in the Modern System, are in reality retrenchments of a permanent nature; they, however, are not generally described under that heading.

Retrenchments in the Body of the Place aro sometimes permanent in their nature, but more generally they are left to a time of notual siege, to be constructed by the garrison, as soon as the bastion or point of attack shall become known. Retrenchments vaxy much in their shape, according to circumstances; those generally used are the straight line, the tenaille, and the bastion.
51. In Fig. 416 is a straight line of wouk ( A ) which forms a retrenchment to a bastion, It has the adrantage of not greatly entting up the interior space of the bastion, but as it is withont flank defence, unless provided with kaponiers, it is otherwise very defective.
N.B. In all retrenchments their ditches should be taken tbrough the parapets of the main work, in order to complete the isolation of the salient or other part retrenched.
515. The Tenatlle Retrenomama is shown at B in Fig. 416. It brings a converging fire on to the interior of the bastion, but its flank defence is imperfect. It is used in narrow bastions. If placed at the gorge of the bastion, as shown by the dotted lines, more interior space in the bastion would be available, but at the cost of having the flanks of the bastion in advance of the retrenchment.
516. The Bastor Pemencenemy is shown at A in Fig. 417. It is a suitable work for a

Fio. 417.
 large and roomy bastion. The position of the retrenchment in the bastion is not necessarily that shown in the figure, but it would usually be so, for the reason that while the space in front is not cramped, there remains a portion of the original bastion flanks within the retrenchment, and, consequently, available for deferce until the retrenchment itself is captured.
517. A Catalier Retrenchment
is shown in Plate 3, where it forms part of the permanent defences. This work unites the properties of the Cavalier and the Retrenchment, for it has the command of fire over the bastion possessed by the Cavalier, while it acts as a retrenchment in isolating the salient of the bastion from the body of the place (see Art. 480, page 214):
518. A Coupure Retrenchment is applicable to any work having a narrow terreplein, sueh as a Lavelin, which is provided with a revetted reduit, or an empty bastion. The former is exhribited in the ravelin of the Modern System (Plate 3), and is described in Art. 475, page 218; the latter is shown at B in Fig. 417. In all cases the ditch of the coupure shonld extend across the terreplein and through the parapet of the work retrencled. In the empty bastion shown in Fig. 417 , the rear of the rampart from $a$ to $l$ should be scarped and provided with obstacles to prevent an enemy torning the coupures, and any houses or other buildings from which a fire could be brought to bear on the breaches should be occupied and loopholed for the purpose.

Permanent retrenchments of various kinds have been proposed by Bousmard, Carnot, Dufour, and other writers of repute on Fortification, but a description of them is beyond the province of this work; reference, however, must be made to the retrenchments proposed by Choumara, who songht to correct one great defect of bastioned fortresses, viz., that when one bastion was captured the fall of the place ensued, as the remaining bastions were unprovided with any means of resisting an attack from the interior.

Choumara's design was to provide every bastion with a permanent retrenchment which should face the town, but should be so organized that a slight expenditure of labour would suffiee to reverse it, so as to resist an attack from the exterior. This would only be necessary with the retrenchment of the bastion attacked, nfter the fall of which the garrison could retreat into the remaining bastions, and prolong the defence. Each retrenchment is provided with oasemates for 500 men.

## OCCASTONAL TORTKS USED AS OUTTORES.

519. A Tenamlon a a (Fig. 418), is a work of two faces, one of which is in prolongation of the face of a ravelin, and the other is directed so as to be flanked from the face of the bastion.

Temaillons are to be found in some old fortresses: they were first used in order to remedy the defects arising from the want of salieney of small ravelins, but they do so very imperfectly, while their own defects are very numerous; they complicate the defence, and expose the enceinte to be breached in many places, they mask the fire of a large portion of the faces of the bastions, and their own faces are exposed to enfilade. They are considered to be bad works, the cost of which greatly exceeds the defensive value.

Fres. 418 ,

520. Dent-tenamlons, $b$ b (Fig. 418), differ from Tenaillons in being less salient; one face is flanked by the bastion, the other is directed so as to be flanked from the adjacent face of the ravelin, instead of being in prolongation of the other face. They have the same defects as tenaillons, without the advantage possessed by the latter, of increasing the saliency of the ravelin.
521. A Counterguard or Couvre-face is a work of small command and (usually) narrow terreplein, having two faces parallel, or nearly so, to those of the work in front of which it is construeted.

Its usual object is to conceal the masonry of the escarps of the works in rear from distant view, when this could not be properly effected, owing to the nature of the ground or other causes, by the glacis itself. Counterguards may be used in front of ravelins and bastions, as shown in Fig. 419 ; when so used they should be traced as shown on the right front, in order to avoid exposing the enceinte to be breached from the glacis, as would be the case if they were traced, as shown on the left front.

Fice. 419.


Counterguards are given only a command of observation over the glacis, in order to allow the enceinte to retain a command of fire over them; they also usually are given a narrow terreplein to prevent a besieger being able to construct breaching and counter-batteries on them.

Counterguards have the following defects: owing to their small command, their musketry fire would only feebly oppose the crowning of the glacis, and when placed in front of a bastion, they prevent the ravelin from having any considerable saliency over the covered-way of the bastion counterguard; the flank defence of their ditches is imperfect, and when silenced the ditches afford secure situations for the assembly of powerful storming parties.

The ravelin of the Modern System, with its reduit, resembles in plan a small ravelin with a
counterguard in advance; but there is a great difference between the two, owing to the relative commands of the works. In the Modern System the ravelin is the main work, and has as great a command over its glacis as it can be given, while its reduit is construeted merely to oppose the efforts of a besieger to get possession of the main work, over which it has the least admissible command.

In the other case, the small ravelin would be the principal work, having a command of fire over the counterguard, which latter work would be of secondary importance, being given a command of only $8^{-3}$ or thereabouts over the glacis.
522. A Hornvork (Fig. 420) is a work composed of a front of fortification, joined to other works by two long faces, $b, b$, called branches.

A Hornwork if placed in front of a ravelin (as shown by the dotted outline in Fig. 420,


Frg. 421.

merely in having its front composed of two or more fronts of fo work contains two fronts, a Double Crown work, three fronts, and a Trip

The remarks as to defects, position, dce, stated for hormworks, equally apply to crown works.

OCCASIONAL WORKS AS ADVANCED WORKS.
524. Advanced Works are in some cases necessary, in order to occupy ground that would give a besieger considerable advantage in the attack, or to be able to defend ground which cannot be seen from the fortress, or to give safe access beyond an inundation, or simply to strengthen a weak point by an accumulation of works. They are therefore generally applied to particular parts of a fortress, and not to the entire circumference.

The most usual kind of advanced work is the lunette, constructed on the capitals of the bastions, and receiving flank defence from the ravelins. If placed on the capitals of both ravelins and bastions, as in Fig. 422, they flank one another. Works thus arranged have not the disadvantage of exposing the enceinte to be breached through their ditches, as the glacis of the main works is made to slope down to the bottom of the ditches of the advanced works.

Fig. 422.-Advanced Works.


Advanced Works of all kinds become valuable in proportion as the garrison is strong, and can be maintained in strength. As a rule, advanced works are not applicable to small fortresses, for the garrisons would be too small to be able to spare men for their efficient defence.

OCCASIONAL WORKS AS DETACHED WORKS.
525. Detached Works are much used in fortresses at the present time. As they are constructed too far in advance of the place to be well defended from it, they require to have their own distinct flank defence, and in fact become separate and independent forts.

Detached Works may be constructed for any of the objects for which advanced works are used, but large and important fortresses are now provided with a chain of detached forts, which entirely surround their accessible fronts, and are placed at a considerable distance in their front. The ground between the enceinte and the detached forts is termed an Intrenched Camp, (see Fig. 437) and is destined to afford refuge to an inferior army, which would, owing to the protection of the works, be free for manceuvring purposes, and would thus be able to take an active and powerful part in the defence, by making frequent sorties in force on a besieger engaged in the attack of the detached forts.

Detached Forts of this latter kind are constructed for two main purposes, viz.:-
1st For preventing a distant bombardment by keeping an enemy out of range of the place, until he shall have passed the chain of detached works.

2nd. For increasing the difficulty of a siege. This latter purpose is effected by the difficulty a besieger would experience in carrying on an attack of a detached fort, which, from its position,
cannot be separately iuvested, while it is ulso supported on either side by other works, and can hare its garrison constantly reinforced, or even claanged, from the main work, and may also be supported by powerful sorties made through the intervals, by troops additional to its own gartison.

These advantageous conditions, on the part of the defence, are further angmented by the fact that the besiegers are unuble, owing to the proximity of the collatexal detached forts, to give proper development to their trenches and batteries (as can be dane in the attack of a small fortress, if invested), while they are also obliged to guard their works of attack by a sufficient uumber of troops to repel the sorties of an army, and not merely of a small portion of a garkison.
526. To obtain, fully, these advantages from detached forts, they should fulfil the following conditions:-(See Figs. 438 to 445.)
(1.) They should contain respectable garrisons, and have a powerful offensive urmament.
(8.) They should be sufficiently near to one another to afford mutual support, and prevent an enemy passing between them.
(3.) They should have a profile seeure from assault; escarps of $30^{\prime}$ or more in height, in sddition to a good flank defence, are required to effect this in a dry ditoh.
(4.) Their escarps should be well covered.
(5.) They should have ample bombproof cover.

When detached forts fulfil these conditions, an assailant will have to regularly besiege them, i.e., he will have to make successive parallels and batteries, will have to form lodgments on their glacis, descents in their ditches, and breaching batteries to breach their escarps; all of which operations will huve to be performed under the disadvantageous conditions before mentioned.

It was remarked that large and important fortresses are thus strengthened by an outer line of defences; it might also be added, that such a method of defence is only resorted to when the place fortified is large and important, for then only would the garrison be sufficiently strong to be able to carry out an active defence, -i.e., to be able to properly garrison the necessary works, and still have strong reserves of good troops for offensive purposes. Small places of minor importance, the garrisons of which would be small, and perhaps composed of inferior troops, are better without exterior defences, as the operations of defence are thereby rendered simpler and more concentrated.
527. When very large fortresses are provided with detached forts, such as Paris, Antwerp,* \&c., the garisons of which, if attacked, would be powerful armies, the advantages of defence are so great as to be considered almost insurmountable, for, owing to the great circuanference occupied by the rorls of defence ( 20 to 30 miles), it would be almost impossible to effect a proper investment, without having more troops than any probable enemy could bring into the field, and during the attack of the detached forts, the defensive army can issue in force at any moment, and fight a battle minder advantageous conditions.

In such cases the perfection of defence is reached, for, while under ordiany circumstances a defensive army receives battle only when its adversary chooses to offer $i$, with the fortress the conditions are reversed; for the defensive army, sheltered by their detached forts, are secure from assault, while they may fight a battle at any favourable moment, by making sorties in force through the intervals between the forts, which would afford them efficient support both in advance and in retreat. Finally, should an enemy have succeeded in overcoming the detached forts, the defence of the enceinte is in no way compromised by their fall, but an entirely fresh siege would have to be carried out against it.

These defensive advantages, it should be remembered, are independent, to a great extent, of the system on which the fortifications ave constructed, although they may be affected by it; they result chiefly from the grent size and large garrisons of the place fortified; on this account, the tendency of permanent defence, at the present day, is to construct few fortresses, but to malke those that are constructed of sufficient magnitude to be veally formidable abstucles to large armies.

## CHAPTER VIII.

MILITARX MINING.

Object of a MTVE, excavations required, dimensions for SHarts and Gaileries. Details for sinking shajts and driving galleries
 Mode of preparing mines for simultaneous firing. Tools and worlomsn required jor shafts and galleriss. Charazs eor mines, technical terms. Countrrmaned Sysiens, of what formed; dimensions for galleries, Descriptions of Defourie Countermines, Attack of Counterannes, how carried ons.
528. The object of a Military Mine is to place a eharge of powder under ground, in such a manner as either to destroy by its explosion an enemy's troops or works, or else to render useless any works that may have to be abandoned to an enemy.

The necessary excavations which have to be made to reach the position of a charge, are called Shafts when they are vertical, and Galleries when they are horizontal, or nearly so.

Shafts and Gallexies are lined with timber, when used for temporary purposes, and with masonry, when intended to be permanent.
529. Both Shafts and Galleries are made rectangular in section, when lined with timben, and have usually the following clear dimensions:-

$$
\begin{aligned}
& \text { Bhafts .. .. .. .. .. .. .. .. .. .. } 4 \frac{1}{2} \text { feet high by } 8 \frac{1}{2} \text { feet broad." } \\
& \text { Galleries, Great, used as descents into ditches .. } 6 \frac{1}{2} \text { " ", by } 7 \frac{1}{2} \text { " " }
\end{aligned}
$$

$$
\begin{aligned}
& \text { Galleries, Branch .. .. .. .. .. .. .. } 3 \frac{1}{5} \text { " " by } 2 \frac{1}{2} \text { ". ", }
\end{aligned}
$$

The above dimensions for shafts and common galleries are the most convenient to work in, for if made smaller, the miners would be greatly cramped for room, and if made larger, the excavation would be unnecessarily large, and would progress more slowly.

In mining in chalk or other soil, which does not require artificial support, slafts are made circular or oval in shape, and galleries are given an arched top.

Shafts and Galleries are lined with timber in two different manners, viz., by "Cases " or by "Frames and Sheeting :" the former method is that generally used, as it has many advantages over the method of frames and sheeting.
530. Mining with Cases. A mining Case (Fig. 423) is composed of four pieces of plank, viz, 2 stanchions (or side pieces) $\delta, s$, and 2 end pieces, E, E, (in a gallery these latter are termed the ground-sill and cap-sill). The stanchions $s, s$, have a tenon $a^{\prime \prime}$ broad at each end, of a length equal to the thickness of the plank; these tenons fit into corresponding martices cut at each end of the pieces E, E. Fig. 423 shows one stanchion and one end piece of a mining case laid flat on the ground, and also the plan of a finished case.


Case tor a Commox Galuiery or Shaft.-Scale $\frac{1}{r^{2}}$.
The planks are usually $11^{\prime \prime}$ broad, and are found to occupy an average of 1 foot in the excavations; their thickness is $2^{\prime \prime}$, except when used for Great Galleries, which require greater

- They are $4^{\prime} \times 3^{\prime}$ when lined with frames.


## Permanent Fortification.

strength, and are given cases which have their ground-sills $3^{\prime \prime}$, stanchions $4^{\prime \prime}$, and cap-sills $5^{\prime \prime}$ thick.
531. To Sisk a shaft, from the wotcom of whech a galteny is to be driven, a rectangle of the dimensions of the outside of the case is first marked on the ground, care being taken to have its centre line coinciding with the direction of the intended gallery. The excavation is then carried to the depth of 1 foot, and the first case is placed. The excavation is again carried on for another foot in depth, and a second case is then fixed. The other cases are placed in succession vertically under one another, until the required depth is effected. Each case is fixed before the exeavation is carried below it, and in fixing any one case the miner does not actually sink the excavation by one foot over the whole area at once, but excavates for, and places separately, each piece of the case. In shafts, it is of no consequence in what order the pieces of a case are fixed,
592. To drive a ganery prom the bottom of a shaft it is necessary to set up a fixed frame (Fig. 421, 425), baving projecting ends, on that side of the shaft from which the gallery has to be driven. The outside wiath of the frame must be exactly equal to the clear width of the shaft. This frame is sunk until the upper surface of its sill is level with the floor of the iutended gallery. The end pieces of the shaft should be removed to the proper height for the gallery; the side pieces, on stanchions, being prevented from falling inwards by the fixed frame, the olject of which is to support the stanchions when the end pieces are removed.

In Fig. 125, which is a transverse section of a shaft, the fixed fiame and the entrance to the gallery are shown in elevation; and in Fig. 424, which is a longitudinal section of a shaft, the gallery is shown in progress, three complete cases having been fixed, and the ground-sill of a nerा case having been just laid.

In fixing a case in a gallery the ground-sill is first laid, the stanchions next, and the cap-sill lact. The cap-sill is first fitted to one stanchion, and it is then necessary, in order to fit it to the other stanchion, either to raise one end of the cap-sill, or push out the head of the stanchion 2 inches (the thickness of the plank) beyond its proper place, before the mortice and tenon can be adjusted to one another ; the latter method is preferable as it does not disturb the earth of the roof. Whichever method is used, no more earth must be cut away than is absolutely necessary.
588. In farourable soil, partial casing only is necessary; in shafts, the cases would be placed at intervals, without any planking between them; in galleries, the cases would be laid at central intervals of $3^{\prime}$ and $4 \frac{1}{2}$ nilternately, in order to be able to use the planks of other cases to roof the intervals. The cases are then said to be at "Open order."
534. When driving galleries at a slope either ascending or descending, the cases are placed perpendicular to the slope.


In churging from a descending gallery to a level one (as in Fig. 426 ) the cap-sill of the first ease of the level part should touch the last cap-sill of the descending part; the same is done if a change fram a level to an ascending gallery be required; the triangular spaces between the stanchions at the angle thus formed are filled up, if necessary, by pieces of wood being pushed behind them (us seon in Fig. 426).

When changing from a level to a descending gallery, it will be necessary to make the ground-
sills of the cases at the point where the change occurs touch one another, while the cap-sills are separated; the interval between the cap-sills (which varies according to the degree of the change of direction) is roofed over by pieces of plank.

In changing the direction of a gallery horizontally, the change should be made gradually (as in Fig. 427), by placing two or more cases, each changing the direction slightly. The open spaces are filled up with planking, if necessary.
535. Mining with Frames and Sheetivg.-This method would be followed only when unable to obtain planks suitable for making cases.

A Shaft Frame is a rectangle composed of 4 pieces of wood, measuring $3^{\prime} \times 4^{\prime}$ in the clear ; the first, or top frame, has the ends of its long sides projecting 1 foot (as in Fig. 428); the other frames form simple rectangles, 3 feet broad and 4 feet long in the clear. The wood used in their formation is $3^{\prime \prime} \times 4 \frac{1}{2}^{\prime \prime}$ in section,

A Gallery Frame has no ground-sill, except in bad soil; when in position, the ends of the stanchions are sunk about 3 inches below the floor of the gallery.

Shecting Planks are thin planks, driven by means of mauls, between the frames and the earth, so as to form a lining for the sides and roof; they are bevelled off at the front ends to facilitate the operation of driving them.

A Gablery Changing Direction Horizontally.


Mining with Frambs and Sheetivg.-Scale $\frac{1}{7^{2}}$.


Fig. 428. Plan of a Shaft.

Fic. 429.
Section of a Shaft in Progress.
536. To stink a shaft with frames and sheeting. - The frames are placed at equal intervals of from 3 to 4 feet, the actual interval being determined by dividing the depth of the shaft minus 1 foot, into divisions of from 3 to 4 feet; thus, if a shaft is required to be sunk to a depth of 16 feet, the intervals of the frames wonld be $\frac{16-1}{4}=8^{\prime} 9^{\prime \prime}$.

The top frame is first laid on the gromnd with its long sides pointing in the direction of the intended gallery, and sunk until its upper surface is flush with the ground. The top frame should be carefully levelled.

The excavation for the shaft, which has to be made larger than the frame, in order to allow room for the sheeting planks, as shown in Figs. 428, 429 , is then carried on to a depth of $4^{\prime}$ (or whatever interval is required), and the first common shaft frame is then fixed. Each fresh frame must be made level, and also vertically under the one above it.

After placing each frame, it has to be supported in its place, by nailing battens of wood to secure it to the frame above; or rope is used for the same purpose.

The sheeting planks are then pushed or driven down, !letting the top of the planks rest against

and the (then) bottom frame. The ohject of the wedges is to allow room for the next set of sheeting planks.

The excavation of the shaft is then sunk to the position of the next frame, which is placed, levelled, and connected with battens to the next upper frame. The sheeting planks are then fixed by removing the wedges and inserting the planks in their plages; these are then driven until their bevelled ends reach the bottom frame, wheu they are wedged out as before.

Fig. 429 is a longitudinal section of a shaft, the second common frame of which has just been fixed, and the sheeting planks secured in their places. The connecting battens are omitted for the snke of clenrness. The wedges are shown between the bottom frame and the sheeting planks. In this manner the shaft is sunk, until the last frame is fixed $9^{\prime \prime}$ or 1 foot above the position of the capsill of the first gallery frame. The excavation of the shaft is then continued until the level of the bottom of the intended gallery is reached, when a frame is there placed and sheeting driven all round it, except at the end where the gallery is to cormmence.
597. In driving a galiery with frames and segeting from the botton of a shaft, the first frame is carefully placed at right angles to the direction of the gallery, the excavation is then earried forward for if feet, driving the sheeting planks forward, if neeessary, at the same time, when a second frame is placed. Sheeting in galleries is only required for the roof, unless the soil is unfavourable.

The excavation is carried on in this manner frame by frame, for the required distance.
538. If the soil is loose great difficulty is experienced in mining with frames and sheeting. It becomes necessary to use close shecting (i.e. the sheeting planks must touch each other), and to drive them on inch by inch, as the excavation proceeds; it frequently happens, however, that the earth is made more loose by the vibration caused by driving the sheeting.

In very unfravourable soil it is necessary to support the ends of the sheeting planks while being driven forward in galleries by a false (or temporary) frame; this frame is removed as soon as the next regular gallery frame is fixed, in advance of which it would be again used for a similar purpose.
539. The following are among the advantages gained by mining with Cases instead of Frames and Sheeting :-
(1.) Much less excavation is required for a shaft or gallery having the same clear opening in either case.
(2.) The work is much more rapid and regular.
(3.) No wedging out or driving forward the sheeting planks is required, thereby avoiding shaking the earth and making a noise.
(4.) Work can be carried on in soil so unfavourable that it would be impossible to advance at all with frames and sheeting.

In mining with cases great galleries and shafts advance about 1 foot per hour, galleries 11 feet per hour. With frames and sheeting about one-half the above rate would be obtained.
540. Previons to lodging the charge, which may be either at the bottom of a shaft or at the end of a gallery a Chamber has to be made for its reception. The chamber is a cubical recess made clear of the direct line of the shaft or gallery, so as to prevent the effect of the explosion taking place in the direction of the exeavation.

The powder may be phaced in the chamber in bags, if the soil be dry and the mine is to be fired immediately, but if the soil be wet, or if the charge is required to be under ground any sonsiderable time, the powder should be placed in one or more boxes, which require to be made watertight. A single box is sufficient for ordinary charges; it is taken empty to the chamber and there filled after being placed in position. When large charges are used, several boxes may he required to hold it, each being made of dimensions which will allow of its being passed down the shaft and along the galleries.

The size of a box to contain a given charge of powder is obtained by knowing that 1 lb . of powder occupies 30 cabic inches.
511. Before mines are fired they require to be tamped, i.e., the excavations near the charge nre filled up, in order to prevent the effect taking place in the direction of the excavations. When charges are to be fired at the ends of galleries, it is usual to tamp for a length one-half greater than the line of leust resistance ; but in the case of $u$ charge at the bottom of a shaft, the whole
shaft is tamped. In badly tamped mines the tamping is frequently blown out by the explosion, the useful effect of which is lost, either wholly or in part.

When time does not permit a mine to be tamped, the required effect will be produced by doubling the charge.
542. In preparing a mine for explosion (where it is not to be effected by electricity) it is necessary to lay a train of gunpowder or other inflammable matter, from the charge to any convenient point beyond the tamping. The train is either a powder hose or Bickford's Fuze. The former is a tube of linen, either 1 inch or $\frac{1}{2}$ inch in diameter, filled with gunpowder; the latter is a thin flexible waterproof tube containing gunpowder.

The powder hose is enclosed in a wooden trough, which is led along one side of the floor of the gallery, and, if necessary, up an angle of the shaft. The hose is fired by means of a fuze (of a sufficient length to allow the man who fires it to escape before the explosion takes place) inserted into the end of the hose, care being taken to cover the junction of the hose aud the fuze with wet clay, to prevent fire accidentally reaching the hose.
543. When different mines are required to be exploded simultaneously, the powder hoses are arranged so as to lead to one point, called the focus, or point of ignition, in such a manner that there are equal lengths of hose from each charge to the focus. Fig. 430 shows this arrangement applied to fourteen different charges; it is evident that if fire be applied to the focus, it will spread along the various hoses and reach the fourteen charges simultaneously. In this manner considerable numbers of charges have frequently been exploded.

Fic. 430 .

a. Focus.
544. Tools required.-In ordinary shafts and galleries it is necessary to use pickaxes and shovels, with short handles,-these are termed "Miner's Picks and Shovels." The corners of the excavations are picked out by an instrument called a "Pushpick," which is a sharp piece of iron, having a wooden handle about $2^{\prime}$ in length. The earth is lifted out of the shafts in canvas buckets, each of which contains about a cubic foot of earth. The bucket has two rope handles, by which two men at the top of the shaft lift it to the surface; and it also has a loop underneath by which to turn it up so as to empty it. In common galleries the earth is removed in a miner's truck, which is a small box fixed on four low wheels: it measures two feet in mean length, one foot mean breadth, and is one foot in height.

To supply fresh air to the miners in the galleries, which is necessary, after they have advanced some distance, a miner's bellows is used; the air is led from the bellows to the head of the gallery by means of tin tubes $\overline{5}$ feet in length and $1 \frac{1}{2}$ inches in diameter, which fit into each other, and so can be continually prolonged as the excavation advances. Flexible joints are provided to use wherever the pipes are required to bend at an angle.

The miner's bellows is cylindrical in shape, the top and bottom are made of wood, the sides are of leather. It is 13 inches in diameter, and holds about a cubic foot of air. One man works it standing, by means of a staff which fits into a socket at the top: he steadies the bellows by standing on the projecting end of a cross-bar fixed on the bottom. The air enters by means of a valve in the bottom of the bellows, and issues through a short pipe fixed on the side of the bellows at the bottom.
545. The number of workmen required depends on the length of the excavations. In commencing a shaft one man only is required, as the earth can be thrown out by him for the first 4 or 5 feet in depth; after that two men are required to lift it by means of the bucket. In
driving a gallery from the bottom of the shaft six men are required, who are this employed: one man digs, a second fills the truck, which is wheeled to the bottom of the slait by a third; the bucket is filled by a fourth, hauled up to the top

Fra. 231.

A. The elarge of powder.

AB. Line of least resistance (L L R),
BC. Rariins of the crater.
AC. Radius of explosion.
A E. Radins of horizontal rupture.
A D. Radius of vertical rupture, of the shaft by the fifth and sixth, who spread the earth about.

To this number must be added, when necessary, two men, one to blow the bellows, the other in long galleries to wheel the truck half the length of the gallery.
546. Charges of Mines.- The effect produced by a mine depends on the depth the charge is placed, the quantity of powder used, and on the nature of the soil.

If the charge is so small as to produce no visible effect on the surface, it causes merely a compression of the earth round it to an equal distance in every direction; but when the charge is sufficiently strong, the explosion raises the earth above, and forms a hollow circular opening, called the crater, in addition to compressing and disturbing the earth for a certain distance in every direction, sufficiently to destroy shafts and galleries. The distance to which this compression extends AE, A D (Fig. 481) are termed Radii of Rupture; the radius B C of the opening is called the Radius of the Crater; the line A C drawn from the charge to the edge of the crater is the Radius of Explosion, and the distance AB from the charge to the nearest surface is the Line of Least Resistance, usually expressed thus, L L R.

Onc-lined, two-lined, three-lined, de., Craters, are those whose diameters are equal to once, twice, thrice, do., the L L R. Common mines are those which have two-lined craters. Undercharyed and overcharged mines, or globes of compression, are those which have craters less or greater than common mines.

With a common mine (two-lined crater) the crater is generally assumed to be the frustrum of a cone, whose height is the LLR, the zadius of the large end (crater) is equal to the LLR, and the radius of the smaller end half that line: the solid content of this is equal to $\frac{11}{6} \mathrm{LLR} \mathrm{R}^{3}$ : the radius of rupture is considered to be equal to $\frac{7}{4}$ LLR horizontally, and $\frac{4}{3}$ L LR vertically.

The charges of powder for mines with similar craters but different L L R's are in proportion to the oubes of the respective L L R, because the quantity of earth to be moved varies in proportion to the cubes of these lines. Up to three-lined craters the charges are fixed with sufficient accuracy for practical purposes, but with larger craters great discrepancy exists between the statements of different authorities. The following are the rules fixed from actual experiments earried on at Chatham, for ordinary soils, the L L R being expressed in feet.


A Camouftet is a small mine usually employed by defensive miners to destroy the besiegers mines. It consists of a charge of 10 or 12 lbs . of powder, placed in a hole, about 6 inches in diameter, bored in the direction of the attacking miner. When exploded, it bursts in the enemy's gallery and suffocates the miners.

## COUNTEEMENED SYSTEMS.

517. The defensive mines, or countermines, of a fortress, which me usually constructed at the same time ne the place, consist of galleries lined with masonry extending inder the ground ou
which an enemy would require to which an eneuy would require to construct bis works of attack; they afford the garrison the
power of blowing up any part of the ground above them, and they thus force the besieger to destroy them, by mining against them, before he can advance his trenches above ground.

The siege of Schneidnitz, in 1762 , affords a good instance of the increase of strength given to a fortress by a system of countermines, for out of 63 days which the siege lasted, 49 days were occupied in mining operations.

A system of countermines consists generally of a magistral gallery, usually a countersearp gallery, from which branch off various branch and listening galleries. In some systems an envelope gallery is used, which is a gallery parallel to the magistral, and at a variable distance in front of it.

The magistral gallery serves as the basis of the system of mines, and as a depot for the stores required for the service of the mines.

Branch galleries are usually $6^{\prime}$, and listening galleries $4^{\prime \prime}$ in height, the breadth of both being $3^{\prime}$.
548. The following rules are general, and are applicable to all systems of countermines.
(1.) The chambers should be in one plane, situated at a depth below the surface of from 12 to 18 fect. The besieged do not, as a rule, use charges larger than those for common mines,-viz., 2 -lined craters ; these will destroy galleries directly under them at distances equal to the LL R; the besiegers cannot, therefore, pass safely under them without descending to a depth of more than from 24 to 36 feet.
(2.) Galleries should present their ends rather than their sides to the besieger. They are thus less liable to be destroyed by the besieger's mines, and uninjured portious are available for further use.*
(3.) Galleries which are intended to be preserved, when common mines in their neighbourhood are exploded, should be at a distance from them of double their LL $R$. This is necessary, since the horizontal radius of rupture of a common mine is, as before mentioned, equal to $\frac{7}{4} \mathrm{LL} \mathrm{R}$.
(4.) Galleries should not be so far apart, as to admit of a besieger passing between them without being heard from one side or the other.

The noise made by miners has been heard from ather galleries, at distances of from 40 to 50 feet.
(5). Galleries should be crossed by other galleries at intervals of 40 or 45 yards, to facilitate their ventilation.

Many systems of countermines, some of them very complicated, have been proposed by engineers of celebrity; that of General Dufour is described here as it is generally considered to be the best, since it would afford as much resistance to a besieger as the others, while it is far simpler in construction.
549. Dufour's System of Countermines. These mines are applied to the French Modern System, and owing to the fact that the besiegers are unable to crown the glacis of the bastions until after all the outworks are in his posession, no mines are placed under the glacis of the bastions, because the defenders would only be able to communicate with them, when required to be used, by means of a subterranean gallery, which is considered objectionable. The portions of a front that are mined in this system are, the glacis of the ravelin, the salient of the ravelin, and the faces of the bastions, at the parts liable to be breached. The details of construction are as follows. See Fig. 432.

Glacis of Ravelin.-The "pan coupe" of the salient place of arms, is made 9 yards in length; the lines $p q, q r$, and $r s$, are drawn parallel to, and 60 yards from, the crest of the glacis, to mark the ends of the galleries : parallel to $q r$, and 72 yards from it, the gallery $t v$, is drawn, extending 20 yards on either side of the capital. The ends of this gallery are joined to the points $q$ and $r$, by two galleries $q t$, and $r v$, which are produced to the counterscarp gallery. These are connected by a transverse gallery situated half way between the lines $q r$, and $t v$, and parallel to them. A gallery on the capital extends from $q r$, to the counterscarp gallery, and half way between it and those terminating at $q$ and $r$, are two others, extending only as far as the outer transverse one.

The positions of the galleries on either side are determined by placing their ends ut equal

* Euvelope galleries are uot usually recommended, as they break this rule, for they present their sides, oud mot theinends, to a besieger.
distanees of 26 yards apart, commencing from the points $q$ and $r$. The first galleries on either side are directed to the points $t$ and $v$, and the remainder are parallel to them. The positions of the other galleries will be evident from the plan.

550. In this system, the galleries und the chambers of the mines are situated in two different planes. The galleries have their floors, as shown in Fig. 433, in a slope rising from the floor of the counterscarp gallery to a point 15 feet under the glacis at their own extremities. This facilitates their drainage. The chambers are situated in a plane sloping in the contrary direction to that of the galleries. It commences at $y$, the extremities of the galleries, and rises towards the counterscarp, until it intersects at $x$, an imaginary plane inclined at $45^{\circ}$, drawn from a line on the glacis, parallel to, and 8 yards in front of the crest. The intersection of the plane of the chambers with this imaginary plane is 18 feet below the surface of the glacis, and it fixes the positions of the mines nearest to the crest, which will thus be so far from the covered-way as not to injure the latter by their explosion.

The galleries are just close enough together to prevent a besieger passing between them without being heard, but they are too far apart to ensure his (the besieger) being destroyed by the explosion of common mines fired in them. It is, therefore, necessary to form the chambers for the mines, at the extremities of short branches constructed for the purpose, and to facilitate this operation, openings $a a$, are left in the walls of the galleries of a sufficient size from which to commence the branches when required.

Durour's System of Countermines,-Scale solvo.
Fig. 432.

551. The Sallent of Raveliny and Faces of Bastions.-A double row of chambers are provided for these works, one row being in front of the escarp and situated under the ditch, the other being behind the middle of the escarp and 18 feet from its face. Those for the bastions are thus traced, see Figs. 432 and 434.

The escarp gallery is 20 yards behind the escarp, and parallel to it. Its floor is situated 6
feet above the bottom of the ditch, in order to equalize the slopes of the galleries leading to the two sets of mines. The front row of chambers are 10 feet in front of the escarp, and 6 feet under the bottom of the ditch; every pair of chambers is connected by a branch, from the centre o which a gallery at right angles communicates with the escarp gallery. A great gallery on the capital, communicating with the interior, and another across it to the end of the escarp gallery, complete the arrangement as shown in the plan.


Fig. 434.


Mines under faces of the Bastion.-Scale $\frac{1}{600}$.
The mines under the ditch are intended to destroy a storming party when commencing the ascent of the breach, and also to clear away the rubbish from the foot of the escarp, so as to render the breach impracticable. The inner line of mines are intended to destroy the besieger when forming his lodgments on the summit of the breach.
552. Where two or more galleries meet, small circular or square rooms are made, which afford space in central positions in which to deposit tools and materials, without impeding the communication through the galleries; sometimes air-holes for ventilation are made, extending from the tops of these rooms to the surface of the ground, as in Fig. 483. To shut out portions of a gallery, for the purpose of defence against a besieger, in case of his penetrating into it, or to exelude foul air, doors are constructed; grooves are also formed in the side walls to facilitate the construction of retrenchments by fixing beams in thero, which may also be useful in tamping. When the plane of the galleries cannot be inclined towards the ditch so as to drain them, this object may be effeeted by sinking cess-pools, as required, in the floors of the several galleries.
553. Attack of Counternines. In attacking a system of countermines the besieger will use overcharged mines for the purpose of destroying galleries to as great a distance as possible. The garrison have, however, to confine themselves, as a rule, to the use of common mines, both for the purpose of economising powder and to avoid destroying more of their own galleries than is necessary. This is one advantage on the part of the attack; another is that the explosion of any mine, whether by besiegers or by the garrison, destroys a portion of the surrounding galleries, and allows the besieger to occupy its crater by a flying sap, from behind which he can proceed to mine against the remaining galleries.

From the uncertain nature of subterranean warfare, it is impossible to give more than an outline of the mode of attack, which would be usually as follows:-The third parallel is constructed about 50 yards from the nearest defensive mines; from this parallel one or two galleries, about 35 yards in length, are driven towards the place, and at their extremities overcharged mines will be fired. The craters of these mines, when fired, are crowned by the besiegers by a flying sap, and connected by trenches to the third parallel.

From these craters fresh galleries are driven towards the place, in order to lodge charges for fiesh overcharged mines. The garrison, who will discover the advance of the besiegers, by hearing his mines at work, will prooeed to lodge charges to cut them off. It then becomes a race ns to which side will be beforehand with its ndversary in the explosion of its mine, and it may be presumed that either side will at times obtain the advantage, but, as remarked, every explosion brings the besieger nearer to the place. By a repetition of these operations,-wiz, by Ariving galleries, firing mines at their extremities, and forming lodgments on the craters, the besiegers will ultimately reach the counterscarp; but only after very lengthened operations. In faut, it hans been calculated that after completing his third parallel the besieger conld not make his descent into the ditch in less than 40 days. From this statement it will be evident that a good system of countermines, with a proper number of trained miners, forms a ready resource for ndding to the strength of fortified places.

## CHAPTER IX.

## THE POLYGONAL STSTEM.

Recognised defects of the Bastioned System. Gradual wise of the Polygonal (or German) System. Improvements made of late years in new exorks, applicable to any System. Comparison of the Bastioned with the Potygonal Trace on the following points:(1.) Efficiency of flank defencf. (2.) Sedurty of Enceinte from znfliade. (3.) Concentration of Fibe os the "Field of Atpaces," (4.) Lencurh of the Exterior Sides.
 for which constructed, general description of the works of defence: detailed deseription of the works of one of the fromts of the enceinde. Defonsive powers of the ploce, illustrated iny an outtine description of the difficulties of besieging it. 2nd. To detached Forifs. Principles upon which the detached Forts in Angland have been designed as regords (1) their distance in adeancs of the place; (2) their distance apant; (3) their trace; (4) their profile; (5) their Monk dejence. Description of the Kaponiers; thair secturity from fire. The Feeps of the Forts, their object, posilion, shape, profle, foc.

554, The defects of the Bastioned Trace have Jong been felt and acknowledged. They are so grave in their nature, and are also so numerous, that of late years the Bastioned System has ween renounced in constructing new fortresses,* and gradually a new system of defence has arisen, which was originally termed the German System, from its having been first adopted in Germany, but to which more lately the term "Polygonal" has been applied, on account of the outline of the works of the enceinte approximating to a polygon.

The difference between the Bastioned and the Polygonal Systems arises from the different methods prusued in the two systems for obtaining a flank defence for the ditches of the enceinte; for while in the former a flank defence is obtained from the uncovered flanks of bastions, it is obtained in the latter by means of powerful casemated works termed Kaponiers, $\dagger$ which are construeted across the ditches, and from which a flanking fire of artillery and musketry can be directed along the ditohes.
555. The method of flanking by means of kaponiers, instead of bastion flanks, has led to many advantages in the new system, which will be duly explained. These advantages belong to it as a system, and cannot be obtained in the Bastioned System; but other innovations have been carried ont in most new fortresses, which while they are great improvements on old constructions, etill do not form part of any system, being equally applicable to the Bastioned as they are to the Polygonal, or any other system. These improvements are, -
(1.) The independence of the lines of rampart and parapet, with respect to those of the ditches. $\ddagger$

[^63](2.) Increased use of casemates, as cover for troops and also for artillery, both for horizontal and vertical fire.*
(3.) Increased use of countermines.
(土.) Simplification of the communications.
Of these it is only necessary here to observe, that the independence of the parapets and ditches is a principle of great importance, as it permits the ditches to be traced in the most favourable directions for flanking and other defensive purposes, while the parapets and ramparts can be arranged either so as to obtain the most efficient fire on the country, or so as to be secure from enfilade fire. Instances of the actual independence of the lines of ditch and rampart are afforded in Fig. 438, C, and in the plan of Plate 5.
556. The principles of the Polygonal System will now be illustrated by a comparison of it with the Bastioned System; but, in comparing the two together, it is preferable to consider them with reference to the principal conditions that ought to be fulfilled in every fortified place, rather than with reference to a particular type of each system. One of the advantages of the Polygonal System is the ease with which it can be adapted to varieties of ground, but this very circumstance renders it a difficult matter to decide upon any fixed type for a front, out of so many varieties of form in actual use.

The following are the principal desiderata in a permanent system of defence:-
(1.) There should be a powerful and efficient flank defence.
(2.) The enceinte should be secure from enfilade.
(3.) The exterior sides should be either long or short, acoording to the requirements of the case.
(4.) The works should permit a powerful direct fire of artillery to be concentrated on every part of the field of attack.

The two systems will now be compared with reference to these important points.
557. Flank Defence.-The flanking guns in a fortress should be able to be preserved until the moment when they are required to act; their number should be in proportion to the length of line to be flanked, and they should be able at all times to fire the most destructive projectiles, without detriment to the defenders of the parts flanked.

In a bastioned fortress the flanks are exposed to almost every kind of fire, and experience shems that they are usually silenced by a besieger from a distance long before he (the besieger) arrives at the crest of the glacis, which is the period when the flanking guns begin to come into play.

The guns in an ordinary (not casemated) bastion flank, such as C E, Fig. 435, are exposed to vertical fire, because they are not protected by a roof; they are liable to be silenced by enfilade fire from a distance, becanse an enemy can always occupy the prolongations of the terrepleins of the flanks; they are exposed to reverse fire, whenever the adjacent face of the bastion (as A, C, Fig. 435) is enfiladed; they are also exposed to a direct fire from a distance, whenever the faces of the opposite bastion can be enfiladed; and, lastly, should the effect of these fires, either singly or combined, be insufficient to silence them in the early parts of the attack, the besieger is able, after he has effected the crowning of the covered-way, to form a counter-battery ( $x$, Fig. 435) sufficiently powerful to reduce them to silence.

In the Polygonal System, where the flanking work is casemated and runs across the ditch, the flanking guns are concealed from view beyond the crest of the glacis; they are secure from vertical fire by being placed in a bombproof building, which also secures them from reverse fire, and they can only be reached from a distance when an enemy can occupy the prolongation of the ditch with a battery, for the purpose of striking the concealed kaponier with pitching fire, the effects of which must be uncertain. This latter case will seldom occur, owing to the great security of the enceinte from enfilade, as will be pointed out further on; but when it does happen, the kaponiers can be secured from the effects of pitching fire by casemating them à la Haxo, as shown in Plate 5,t or by providing them with iron shields similar to that shown in Figs. 407, 408, or els?

[^64]by placing the kaponiers at that end of the ditoh to be flanked by them which is nearest to the evemy, as in Fig. 439.
558. The number, of guns in a flank is dependent on the length of the flank, and also on whether it is provided with one or more tiers of guns.

In a bastioned front the advantage of a long flank can only be obtained by tracing the front with a long perpendicular, which creates the defect of reducing the size of the flanked angles of the bastions, thereby rendering the faces more liable to enfilade, besiles curtailing the space inside the bastions.

Fig. 43


Fre. 436,


If an increase in the number of guns in a bastion flank is obtained by placing casemates under the parapets of the flank, the tenaille must be suppressed, and then the escarps of the flanks and ourtain are liable to be breached.

In the Polygonal System, a powerful flanking fire can be obtained, without attendant defeets, either by increasing the length of the kaponier, as shown by the dotted lines in Fig. 436, or by providing it with two tiers of casemates, as in Fig. 444, or else by both methods combined. In this manner a greater number of guns can be used for flanking than a besieger can by any possibility place in battery on the crest of the glacis to oppose them. These flanking guns being protected from distant fire would remain effective until the moment they are required to act, viz., when the covered-way is being crowned, and during the further operations of the attack.
559. Lastly, as regards the efficiency of the flanking fire, it may be observed that the guns in a bastion flank camnot with safety use case-shot or grape-shot for the defence of the face of the collateral bastion, on account of the danger to the defenders of that bastion from the shot spyeading, whereas with a kaponier, the fire of the two sides (or flanks) of which is directed outwreds and proceeds from guns situated near the bottom of the ditch, there is no danger to the defenders of the enceinte from the projectiles that may be used for flanking purposes. Also, sinee the kaponiers act as casemated barracks to the artillerymen who are required to serve the guns, there is no danger of the flanking guns not being properly manned in the event of an attempted surprise. Moreover, the fire of a casemated work in the ditch may be kept up on the rear of an assaulting
column after its head may have entered the place, and for this reason an attack may fail against a place flanked by kaponiers, when there would be every probability of its success if the flanking fire proceeded from an ordinary bastion flank, as this latter could be reached by the assailants as soon as a footing had been obtained by them in the enceinte.
560. Security of the Enceinte thom Enfilade.-Whatever system of defence is follaned, there will always be greater security from enfilade in fortresses with many sides than in those with few sides, for the angles of the polygon will be larger, and, therefore, the prolongations of the main lines of work will be more difficult to be oceupied by a besieger, being more immediately under the fire of the collateral fronts. But in order to compare two systems together, as regards liability to enfilade, it is necessary to take a front of each system on similar polygons. This is done in the sketches shown in Figs. 435 and 436, where the angles ABH, are equal to one another, being the angles of a regular octagon. In the bastion outline, the prolongation of D B, the face of the bastion can evidently be occupied by a besieger with much less exposure to fire from other works, than is the case with reference to the prolongation of A B, the main line of work in the polygonal outline, because the prolongation of the former (D B) falls much further off the other works of defence than does that of the latter.

This may be illustrated in another way : for instance, the prolongations of the faces of the bastions in the Modern System will fall on the ravelins in polygons of 24 sides and upwards, while in a Polygonal fortress, having equal exterior sides and ravelins of equal saliency, with a flanked angle of $60^{\circ}$, the prolongations of the body of the place will be intercepted by the ravelins in polygons of 12 sides and upwards.
561. It is impossible to overrate the advantages secured to the defence by protecting the main lines of work from enfilade fire.

When a line of work is exposed to such fire it is necessary to provide substantial traverses, at least at the rate of one traverse to every two guns; frequently the traverses would require to be as numerous as the guns. If we allow the former rate of a traverse to every two guns, also that a gun requires 6 yards of parapet, and that a traverse accupies a length of terreplein (or base) of 7 yards, which is the least that would suffice, it will be found that the face of a bastion having 120 yards of parapet could only mount, at most, about 13 guns with 6 traverses. The fire of these 18 guns could be silenced with ease by an enfilading battery of 6 pieces, whereas, if the face of the bastion were not liable to be enfiladed, and the substantial traverses were replaced with others merely splinter-proof, 18 guns could be mounted, to silence which, by direct fire, would require on the part of the besiegers a counter-battery of from 20 to 30 pieces. In addition to this material advantage arising fiom the security of a work from enfilade fire, the morale of the defenders should be taken into consideration; in the one case, the defenders are placed on an equality with the besiegers, if not at a superiority; for they have on their side the advantages of being covered by well-constructed parapets, of having guns of a calibre superior to those used in the attack, and they have the option either of replying to the besieger's fire, or of masking their orn embrasures, and retiring their guns behind the merlons, until a favourable opportunity shall arise for their use, * whereas, in an enfiladed line, every part is searched out by a destructive fire, which proceeds from guns to which the defenders of the enfiladed line cannot reply.
562. Length of exterior sides. - In any system of Fortification, the maximum length of the exterior sides is dependent on the maximum length that can be given to the lines of defence, in other words, on the greatest distance at which guns for flanking purposes may be placed from the furthest part of the line to be defended by their fire.

In the Polygonal System the greatest possible length ean be obtained for the exterior sides, (as shown in Fig. 436) where A F, or E B, is assumed as the maximum admissible length for the lines of defence. The exterior side A B, will here have a length equal to twice the line of defence, plus the breadth of the Kaponier, or, 2 A F + F E.

In the Bastioned Front sketched in Fig. 435, where the line of defence A F or E B , is equal to that used in the polygonal front, the length of the exterior side is equal to (approximately) twice the length of the line of defence minus the length of the curtain, or, 2 A F - E F.

[^65]563. It follows from this, that with two bastioned fronts, which have each the same length of line of defence, that which has the shorter curtain will have the longer exterior side, and will also have longer faces to its bastions, and consequently larger bastions. But if, in order to obtaín these adrantages, a short curfuin is used, it cannot be done mithout attendant defects, for either the relief must be reduced in order to allow the short curtain to be defended from the flanks, or, if a high relief be used, theve will be a considerable amount of undefended ground in the ditch in front of the curtain. It is one of the defects of the Bastioned Trace that the relief of a front, the dimensions of its curtnin, and consequently of its flanks and faces are mutually depenient and inseparably comected; and for this reason, when arranging the proportions of a front, the Engineer has to consider each part, not merely as regards the best dimensions for such part, but also as to the manner in which such dimensions affect the other portions of the fiont. In fact, the most desirable dimensions for any particular portion of a front can seldom be allotted to it, on account of the defects to the other portions that would be the result.

564 . It is a great advantage of the Polygonal System, that the trace, or outline, is altogether independent of the relief given to the works. This permits the use of exterior sides having any desirable shortness (as in Fig. 439), where ditches of about 100 yards in length are used, while a very strong profile is retained, as will be evident from a reference to Fig. 441.

The Polygonal System thus allows the use of very long, and also of very short exterior sides, whenever such may be required, while it also permits the use of exterior sides of any intermediate length to suit partioulur requirements. In either case, the profile of the works may be arranged so as to afford the maximum strength requirel, without being in any way affected by the outline given to the front.
565. It is difficult, if not impossible, to fix to an exact number of yards, a minimum length for the exterior side of a bastioned front; the following defects, however, arise when the exterior sides are much reduced, viz., -the faces of the bastions get too short to afford a sufficiently powerful fire; the bastions themselves beoome small and cramped in their interior space, the effects of an enemy's fire, particularly of shells, being thereby rendered more hurtful; the flanks become too short to contain a proper armament; and the curtain also becomes so short that its ditch cannot be defended from the flanks, should the latter have a good relief. It is for these reasons that Vanban fixed the minimum length of his exterior sides at about 320 yards. Thus it is evident that the Bastioned System does not permit the use of short exterior sides, a good flank defence being at the same time retained.
566. Long exterior sides are advantageous for the enceintes of fortresses, because few sides then surround the space to be fortified, thereby giving few fronts, and consequently few points of attack. The number of flanking works is also kept to a minimum, and the defence altogether becomes more simple, and in consequence more effective.

Short exterior sides are generally required in detached forts, which are usually made of so small a size as to render the Bastioned Trace inapplicable to them : the Polygonal System, which permits any desirable shortness being given to the line to be flanked, without interfering with the profile of the work, is peculiarly applicable to such forts.
567. Dibeot fibe on the Country. - The offensive power of a fortress is, to a great extent, measnred by the number of guns which can be mounted on its ramparts so as to bear on any particular point of the surrounding ground, provided that such guns are not liable to be silenced by enfilade fire. The number of guns so able to be brought to bear on the exterior ground will, in any particular system, depend on the number and size of the sides in the polygon of the fortress; polygons with many sides being in this respect superior to those having ferv sides. But to compare the two systems under consideration on this bead, a reference to Figs. 435 and 438 (which represent works constructed on similar polygons) will show that, because the flanked angle EBH of the enceinte in Fig. 436, is so much larger than the flanked angle DBG in Fig. 485, the guns in the former have a more direct action on the exterior ground than have those in the latter; and for this reason, more lines of work will be able, in the former case, to concentrate their fire on a given point, than in the latter. Long exterior sides will of course permit of move guns being mounted on each front than conld be done with short exterior sides.

Owing to the large size of the flanked angles of a polygonal fortress compared with those of $a$ bastioned fortress in similar polygons, it is more practicable to obtain, in the former, a direct
fire on the capitals, than is the case with the latter. This will be clear from an inspection of Fig. 436, where D B G is the angle of the bastion ; very oblique embrasures in DB or B G would be required to obtain from them a fire on the capital of the bastion, while in Fig. 485, where ABH is the angle of the work, embrasures only slightly oblique would suffice for the purpose.
568. The principal features of the Polygonal System having been thus detailed, illustrations will now be given of actual applications of the system, to the enceinte of a great fortress, and also to detached forts. The subjects taken for illustration, viz., the enceinte of the new fortress of Antwerp, and the detached forts which have been constructed round Portsmouth and other English dockyards, possess considerable interest, as they are works of very recent construction, and practically illusirate the changes in many details which have been rendered necessary by late improvements in artillery, and its increased use in the defence of fortresses.

ANTWERP.
569. The Fortress of Antwerp (Fig. 497) is situated on the right bauk of the Scheldt, and has been constructed for the purpose of enabling the defence of the kingdom of Belgium being



IN.B. Projected works are marked thus *.
based, in case of invasion, on the ability of the Belgian army to hold against an invader one large fortress which is favourably situated for receiving assistance from other nations. The garrison of Antwerp when attacked, may, therefore, be assumed as consisting practically of the
entire Felginu army. To place this large force in the most favormable condition for carrying on an active defence against rery superior forces is the principal object of the works of defence.

The ground in the vicinity of Antwerp may bo ussumed as affording practically a level site, and for this reason the works that have been constructed may be taken as a type of a system to a much grenter extent than is generally the case with existing fortresses.

The works of Antwerp may be divided into two parts.
(1.) The great enccinte.
(2.) The detached forts.
350. The enceinte consists of ten fronts, each of which hans an exterior side of about 1,100 metres in length. At each extremity of the enceinte is $n$ citadel; that on the sonth side is the citadel of the old fortifications, and is connected with the main fronts of the enceinte by a line of rampart and wet ditch which it flanks. Each citadel is unattacknble until after the fall of the enceinte.

The four fronts which adjoin the new citndel can be protected by inuudations, and are therefore made weaker than the others; their flank defence is less powerful, and they are unprovided with ravelius. They ure, however, given a covered-way.

The remnining fronts, six in number, are made strong in every way, and are shown in detail in Plate 5; four of them are traced on a line which is nearly straight, and so nlso are the two southern fronts; these two lines of fronts form together an angle which is sufficiently small to render it the least strong part of the works, and in order to restore the equilibrium of defence, the front on either side of this angle has been strengthened with an advanced ravelin, which occupies the prolongation of the enceinte of the adjoining front, which it thus protects from enfilide. The entire enceinte is about 9 miles in length.
571. The detached forts are eight in number, and occupy a line which is a little aver 4,000 yards in advance of the enceinte. They are placed at regular intervals of about 2,000 metres ( $1 \frac{1}{6}$ miles) from centre to centre; and they give a front of 9 miles to the Intrenched Camp.

The forts are all on the same plan. They have uurevetted earthen ramparts with a command of 0 metres ( 29 feet), a wet ditchr from to to 50 metres ( 44 to 55 yards) broad, a covered-way on the flanks and gorge only, with a glacis entirely surrounding them. Each fort has bombproof nccommodntion for 1,200 men, magazines, stores, ic., together with a large masonry keep, which affords (in addition to its own independent stores, \&o.) accommodation for 200 men. The ditches are flauled by kaponiers.

No further details will be given here of these forts, ns those constructed in Eugland will be more folly described. The reader is referred to Art. 527 for a statement of the advautages to the defence of the above arrangement of detached works, which form, in combination with the enceinte, an "Intrenched Camp" of the most formidable description.
572. Destgastrons of the Worrs of a Fhont, as in Ph. 5.-The Body of the Place consists of a Defensible Baryack, of two Curtains, tivo First Flanks, whioh bear on the ditch of the Kaponicr, two Second Flanks, which bear on the Terreplein in rear of the Kaponier, Two Faces, and Two Orillons; the open space in rear of each orillon is called the Place of Assembly.

The Kaponier is composed of two Flanhis, of a Head and of two Wings. The lower flauks are cosemated à la Haxo, the upper flanks are uneovered (à oicl ouvert).

The Couvre-face is composed of two Branches, and of a loopholed gallery in its counterscarp, from which branch out galleries of mines. At the foot of the convre-face there is either a palisade or a revetment of 3.50 metres ( 12 feet) in height, the foundations of which are taken below the level of the water.

The Ravelin is composed of two Branches, each of which consists of two Crotchets and of a hattery for reverse fire, in which is prorided cover for the guard of the ravelin.

The Great Tracerses in the body of the place, and in the ravelin, are provided with open vanlts to cover light guns and their gumners.
573. Construction of a front of the enceinte of Antuerp, see Pl. 5.-The exterior side AB varies between 900 and 1,100 metres. The rampart of the enceinte either coincides with the exterior cile, us in the plate, in which ease the adjoining front is beat back so as to allow the line of fire (shown on the plan) which passes through the point A from the outernost gun in the flunk
of the kaponier, to clear the kaponier of the collateral front; or else it is brismred inwards sufficiently to effect the same purpose; this latter mode is resorted to when two adjacent fronts are in one straight line.

Bisect A B by a perpendicular, on which make $\mathrm{CD}=95$ metres and $\mathrm{C} \mathrm{P}=65$ metres, through P draw a line parallel to AB , and extending 115 metres on each side of the perpendicular, to obtain the line of the curtain, join D Q, perpendicular to which line draw $Q \mathrm{R}=31.50$ metres, in order to obtain room for the six Haxo casemates in the 1st flank, draw R S, the line of the 2nd flank, parallel to the perpendicular CP, and 11 metres in length, this line when produced will fix the point G .
574. The head of the defensible barrack is obtained by making $\mathrm{P} \mathrm{U}=55$ metres; the wing $\mathrm{U}^{\prime}=75$ metres, and the length of gorge $=135$ metres. The gorge is occupied by a low casemated building, the front of which (the side facing the town) is given a bastioned outline. This building is connected with the wings of the barrack by a wall.

The roof of the head and wings of the barraek is provided with a parapet and terreplein for artillery, the former has a command of $2 \frac{1}{2}$ metres ( 8 feet) over the enceinte. The barrack itself is a loopholed casemated building of two stories, and is capable of accommodating $1,200 \mathrm{men}$, and is very serviceable for interior defence. The guns on the flanks of the barrack sweep the interior of the enceinte by their fire, as is also the case with the loopholes of the casemates below, which latter also protect the approach to the main gateways.

575 . The line $\mathrm{OO}^{\prime}$, the termination of the wing of the kaponiex, is thus obtained. From Q set along Q P , a length of 25 metres, and from the point thus obtained erect a perpendicular to QP; this perpendicular will fix the point $O$ where it intersects a line drawn from the middle of RS (the 2nd flank) parallel to the exterior side, and $O^{\prime}$ where it intersects D Q.

To trace the wing of the kaponier make $C C^{\prime}=20$ metres, and $G^{\prime \prime} G^{\prime}=\frac{1}{5} G G^{\prime \prime}$, and join $C^{\prime} G^{\prime \prime}$.
The Court of the Kaponicr extends inwards 20 metres, and outwards 70 metres from the exterior side, and its breadth is respectively 16 and 10 metres at its inner and outer extremities. The dimensions, slopes, \&e., of the kaponier are shown in detail in the profile in Pl . 5 .

The kaponier is provided with a double tier of guns; the lower tier is composed on each side of 14* Haxo casemates, which also serve as barracks ; the upper tier is formed of an open (uncovered) parapet, which is provided on each flank with embrasures for 6 guns, and is traversed as a protection from enfilade. Guns are not permanently mounted in the upper tier, but would be placed there only when required. The casemates open in rear on the court of the kaponier; they can be used, if required, as mortar casemates to fire to the rear, as well as gun casemates to fire to the front, that is, the casemates for the guns of the left flank will serve for mortars to fire to the right.

The head of the kaponier is provided on each side with an arched communication, which leads under it from the count to a bridge across the ditch in front; with this exception, the head of the kaponier is a solid mass, made difficult to breach by having its escarp strongly counterarched.

The wings of the kaponier serve as a protection to the masonry wall of the defensible barrack in rear, and they also cover the texreplein in rear of the kaponier, which affords a convenient place of assembly.

The ditch of the kaponier is flanked from the first flanks of the enceinte by a double tier of guns; the lower tier is in Haxo casemates, $t$ and is concealed from view beyond the couvre-face; the upper tier is on the terreplein of the enceinte. Both tiers bear also on the terreplein of the couvre-face.
576. The trace of the courre-face of the kaponier is obtained by fixing its salient E at 165 metres from C, and by drawing its faces to points H at 175 metres from C. The couvre-face is principally intended as a protection to the masonry of the kaponier, and therefore its faces are not broken into crotchets, as is the case with those of the ravelin, as a protection from enfilade, but its salient affords a good position for guns, and is occupied with seven embrasures.

The exterior slope of the couvre-face is carried downwards to the bottom of the dry ditch in its front; it is provided at the foot of the slope either with a palisade (as shown in PL. 5), or with

[^66]a revetment of $3: 50$ metres ( 12 feet) in height. The dry ditch of the courre-face greatly facilitates any attempts of the garrison to retake the ravelin.

The sulient of the convre-face is provided with galleries of mines, which radiate from a counterarched revetment in its gorge wall.

The flouk defence of the dry ditech of the courre-face is derived from the main rampurts.
577. The salient F of the ravelin is fixed at 270 metres from C , and its faces are drawn to points I at 925 metres from C . Its wet ditch is made 60 metres broad at the salient, which diminishes to 50 metres at fhe magistral line of the low battery.

In order to avoid enfilade, the parapets of the ravelin are broken into crotehets, as recommended by Choumara; embrasures und barbettes are provided in positions most suitable for each. The rear of the rampart of the ravelin, and also of the couvre-fnce, is terminated by au carthen slope, in which broad ramps are construeted.

At the salient of the ravelin is a Haxo Casemated Battery (batterie de revers) the object of which is to bring a reverse fire of artillery, extremely diffienlt to silence, on to the glacis of the enceinte and of the collateral ravelin. The head of this reverse battery is protected by a large bonnette, which is formed by carrying up the exterior slopes of the faces of the ravelin at the salient to the required height.

The ditah of the ravelin receives flamk defence from a double tier of guns, those of the upper fier are in the enceinte, the whole of which, from the orillon to the cavalier, may bring guns to bear upon it; the loirer tier is formed by a low Haxo battery for 6 guns, which erosses the ditch of the ravelin close to the main ditch.* This battery is constructed at as low a level as possible, in order that it may be concealed from the country; and, also, that the artillery of the enceinte may be able to bear on as great a portion as possible of the ditch of the ravelin.

Another reason for lreeping this, and similar batteries (such as the lower tier of the Eaponier, \&c.). which flank wet ditches at as low a level as possible is, that when a besieger commences a passage across the ditch, he will mask the fire of his own counter-battery by the leight necessarily given to the epaulment of his floating bridge or embarikment, and thus would be unable to effectually silence the low flanking battery. When a ditch is thus flanked by a low casemated work, and also by a second line, which has a great command, and ean therefore bring a plonging fire on to a besieger's lodgments, \&on, on the glacis, its strength is materially increased.

The magistral line of the low battery of the xavelin forms an angle of $115^{\circ}$ or $120^{\circ}$ with that of the ravelin, instead of the usual angle of $90^{\circ}$, which nould, in the present case, expose it to enfilade. The cuter flank of the work is protected by an epaulment, behind which is a magazine aud a guardhouse, under which latter the moveable portion of the bridge of communication with the covered-way can be rolled horizontaliy. The rear of the low battery is enclosed by a loopholed wall, which renders the entire work a Reduit of the Re-entering Place of Arms.
578. The covered-way has a breadth of 20 metres in front of the enceinte, and of 10 metres in front of the ravelin. The ordinary traverses are suppressed, as being more hurtful than useful to the defence. The covered-way of the enceinte is secure from enfilade, but that of the ravelin is not so, and is protected by having its glacis indented (as shown in the plan) with five crotehets, the flanks of which are 10 metres in length, thereby increasing the breadth of the coverect-way at those parts to 20 metres. In this manner the corered-way is quite open for communications, and it also permits the use of field artillery in it, to any desirable extent, while its entive surface is exposed to the fire of the artillery of the enceinte. A large traverse is constructed across the re-entering place of arms, with the vier of protecting the roadway of commuication from the enceinte to the comiry.

At the salient Place of Arms of the ravelin is a large bonnette, which rises $1 \frac{1}{2}$ metres ( 5 feet)

[^67]above the crest of the glacis, and serves to cover the salient portions of the covered-way, as far as the first crotohet, from enfilade, and also masks a blockhouse ( $w$, Plate 5 ) which would be constructed in time of siege to act as a rednit to the Place of Arms. A similar blockhouse would be constructed, in time of siege, behind the traverse already described as runniag across the re-entering place of arms.
579. At the salients of the polygon of the enceinte is an earthen cavalier, having a shape similar to a lunette, to which is given a command of 5 metres ( $16 \frac{1}{3}$ feet) over the enceinte. The faces of the cavalier are calculated for 3 guns each, and the flauks for 4 guas, which take the glacis of the ravelin in reverse. The terreplein of the cavalier is provided with three large casemated traverses, one of which is on the capital and one at each shoulder.

The great command ( 49 feet) given to the cavalier causes its artillery to have considerable action on the field of attack, and would render the plunging fire which it can bring on to the glaeis most effective against the lodgments and batteries constructed there by a besieger.
580. On the Profile of the Woris.-Many considerable changes from the usual dimensions of works have been made in the fortifications of Antwerp, with the view of increasing their offensive powers, and of facilitating the communications so as to allow of the rapid movements of large bodies of troops of all arms. As these changes are innovations, differences of opinion will exist as to their actual value.

The command of the enceinte has been increased from its ordinary height of 23 or 24 feet to 10 metres ( 33 feet), while that of the ravelin has been reduced to 4 metres ( 13 feet); by this means the artillery of the enceinte can act on the field of attack over the ravelin, while the latter has still sufficient command for its artillery to defend its glacis.
581. Another alteration in the profile of the Antwerp works is the greatly increased use of barbettes for artillery.

The well-known defects of the ordinary embrasure of earthen parapets, which weaken the parapets (and the more so when they are very thick), and limit the range of the guns, while they fix the position of the latter, require constant repairs, which can be ouly done at night to the suppression of their own fire, and which cannot be placed, when behind a thick parapet, at less intervals than 25 feet, are considered sufficient to cause their use to be confined to flanking batteries, or to situations where large guns, with necessarily heavy platforms, are used. Allowance being made for these situations, it will be seen (in Plate 5) that about one-half of the rampart of the enceinte is provided with long continuous barbettes, on which a considerable number of guns can be served. The parapets of the barbettes are provided, at intervals, with substantial bonnettes, which afford to the barbettes a general protection from oblique fire, and also serve to cover guns placed behind them in readiness to be used as required.

The advantages claimed for the fire en barbette, over that from embrasures, are, - (1.) wide range; (2.) choice of position for the guns, which can be constantly varied; (3.) great concentration of fire, if required for any special purpose, as the small space occupied by each gun allows many guns to be massed together; (4.) less damage to parapets, and, therefore, fewer repairs required; (5.) greater facility for night firing; (6.) increased command given to the guns, together with (7.) greater security from fire to the terreplein in rear.

The defect of the increased exposure to the gunners would be lessened, by providing a musket-proof sereen of filled gabions or sandbags on the crest of the parapets, in which gaps would be made wherever a gun was required to fire. It is to be understood that the guns would be withdrawn from the barbettes, when not required to be in action, and placed under cover of the bonnettes or in the vaults of the great traverses, or else simply on the terrepleins of the ramparts.
582. A further change in the profile is the great width ( 20 metres or 66 feet) given to the terreplein of the rampart of the enceinte. This permits a width of 8 metres (nearly 27 feet) being given to the terrepleins of the barbettes clear of all slopes, and of 8 metres to the terreplein for communication in rear.

The exterior slopes of the various works are made at an inclination of $\frac{3}{4}$, those of escarps and counterscarps at $\frac{2}{2}$; these latter are paved, in order to resist the action of the ripple to be expected in the broad wet ditches.

The bern, which is 5 metres brond fon the enceinte and 2 metres for the ravelin, affords great facilities for the repuir of the purapets.
588. The Conduncentons or a Frons. - The communications are arranged in conformity with the general design of the works, so 45 to facilitate the rapid movements of large bodies of troops of all arms, they are both simple and convenient.

On each front there are two roadways (practically level) which lead from the body of the place to the foot of the glacis. These roads are 8 metres ( $26 \sqrt{2}$ feet) in breadth at their narrowest parts-the bridges; and their position and general arrangement possess the merit of passing along ground which is under the concentrated fire of many works, while they do not interfere with the proper defence of any work.

A large and handsome gateway ( 8 metres in clear breadth) leads under the midalle of the curtain on each side of the defewsible barrack to the main diteh, and affords access to a bridge which communicates with a permment pier, or causeway, which adjoins the wings of the kuyonier. ${ }^{*}$

In continuation of this pier is another bridge leading to a cinseway which crosses the original breadth of the main ditch. The surface of this causeway is only $\frac{1}{4}$ metre ( $1^{\prime} 8^{\prime \prime}$ ) above the level of the water, and it is therefore no impediment to the fire of the lsaponier, which latter, however, is a great protection to it. After thus crossing the main ditch, the roadway leads along the rear of the couvre-face, of the ravelin and of the reduit of the re-entering place of arms (the low battery) to a bridge over the junction of the ditch of the ravelin with that of the main ditch, thus affording access to the covered-way. The dry ditch of the courre-face, the terreplein of its rampart, and also that of the ravelin, are in direct communication with this road.

A roadway in continuation, out through the glacis, communicates with the country.
$58 \pm$. These two main roads are the principal communications of a front; there are others, which are supplementary to them, made in the following positions:-Along the exterior of each wing of the defensible barrack is an open road, which sepurates the curtnin from the barrack, and leuds, by means of a bridge across the ditch of the curtain, to the terreplein in rear of the kaponier. Steps in the gorge-wall of the kaponier lead to the terreplein on its roof. A passage through the gorge of the work affords access to the court of the kaponier, and to the casemates, which open on to it; two passages made, as before mentioned, under the head of the kaponier, lead to bridges across its ditch, and thus afford an independent communication to the couvre-face, which would be available for sorties, de., in case of damuge to the principal roads.

Wherever a bridge is carried across a wet ditel, a portion of it is made as a rolling bridge, which is moveable horizontally, so as to be able to be withdrawn to one side and placed under bormb-proof cover when not actually required. The bridges are placed in situations of great security from fire, as will be evident from an inspection of the plan, Plate 5.

The tumparts are renched in the usual manner by means of ramps, which differ from ordinury ones only in being mich broader: the breadth of those in the enceinte being 8 metres, in the coupre-face 7 metres, and in the ravelin 6 metres.
585. Remaris on the defensive powers of a frome--In analysing the works of a front, according to the type in Plate 5, as regards their power of resisting attack, it is impossible to avoid the conclusion that they are exceedingly strong.

One principal cause of the success of regular sieges, is the ability of the besieger, with an ordinary siege train, to keep under the artillery fire of the place sufficiently to enable the works of attack to be pushed forward, if not with rapidity, at least with compaxative certainty. But, in the cuse in point, instead of "one gun in the attack being superior to many in the place," it is rather the reverse, for, owing to the immunity of the enceinte from enfilade, and to its great development and approximation to a straight line, also to the pecnliar and novel orgamisation of its ramparte, it is difficult to see in what manner a besieger could establish a superiority of artillery fire. It may, therefore, be fainly assumed that every work of attack would have to be constructed by the besieger, in the face of a powerful artillery, the result of which fact alone would be to render a siege a most tedious and uncertain operation. But to this must be added the

[^68]THE

## CAVALIER 250


\%

A

Sale for Profites $\frac{1}{s 90}$, or 75 Wietres to I Inch
Srate for Phan $3 \frac{1}{50}$,or 80 Metres to 1 hinch.

power of the garrison to make the most formidable sorties, for, owing to the extreme simplicity of the communications, strong bodies of troops may, after parading in the body of the place, march to the glacis without being hindered by going up or down slopes, or by passing through any defensive work; or, if more convenient, the troops may form, prior to making sorties, in the covered-way of the enceinte which is secure from enfilade.

Assuming that, in spite of these great and ever-present difficulties, the besieger has been enabled to pass through the early operations of the attack, and to establish and perfect his 3 rd Parallel, he would then have to crown the covered-way. This operation, confessedly almost the most difficult of a regular siege, would have to be performed not only in the face of that portion of the artillery remaining unsilenced which bears on the distant attack, but also of that of the lower casemated flanking works and of the reverse batteries of the collateral ravelins, both of which now become visible to the besieger for the first time.*

Supposing the lodgments to have been formed, the next step on the part of the attack would be the construction of the neressary batteries in them. At this period the great command of the enceinte would make itself felt in the plunging nature of its fire. This, joined to the reverse fire from portions of the works, and to the direct fire of the flanking guns (which being in two tiers are more numerous than those of the counter-batteries) will serve to illustrate the difficulties of the undertaking.

The passage of the broad wet ditch of the ravelin, the operation next in order, would have to be effected in the face of an unsubdued artillery, both of the flanking guns and of others which take the ditches in reverse; towards its completion it would be exposed to the sorties of the garrison, who could assemble in considerable numbers close to the passage.

Allowing that the passage of the ditch is effected, and the besieger established on the ravelin, he would be still under the fire of a porverful artillery, and exposed to the attacks of the garrison.

Assuming him to have pushed on his works and to have gained possession of the couvre-face, he there nnmasks the casemates of the 1st flanks, 12 in number, bearing on the terreplein of the salient, which spat is a focus for the concentration of the fire of the orillons, the curtains, the 1st flanks, and the head and wings of the kaponier, and which moreover (as it is permanently undermined) could be blown up.

Granting that these difficulties of situation have been overcome, that the kaponier has been breached, its ditch passed, and the work taken possession of, it may then be assumed that the flanking fire of the main ditch has been silenced, $\uparrow$ and it would be for the besieger to decide on the spot most convenient for him to effect an entrance into the enceinte. Either, he would push on from the kaponier and endeavour to breach the curtain, in spite of the double tier of guns in the two 2nd flanks which bear on the terreplein in rear of the kaponier, or he would attempt the passage of the main ditch.

But either of these methods would be a difficnit task, and would, if effected, be but the preliminary operation to the assault of a place defended by an army, which would have the advantage of being able to move in masses, while the besiegers could only advance on a narrow front, the breadth of which wonld be determined by that of the work forming the passage of the ditch.

[^69]
## DETACHED FORTS TOOUN THE ENGFFSI DOCKYARDS.

596. The principal dockyards in England, viz., Portsmouth, Plymouth, Chatham, \&c., are protected from an attack by land by means of a chain of detached forts, which are constructed sufficiently in advance of the place to prevent the possibility of its being bombarded until after the chain of forts shall have been forced by an assailant. Owing to the great range and accuracy of fire of rifled artillery, a bombardment of a dockyard (or other object which covers a large space of ground) is considered practicable at a distance of five miles, provided that at that distance a clear view of it can be obtained. For this reason the forts have been constructed about 8,000 yards in advance of the places fortified, in cases when the ground is open; this distance has been reduced whenever the formation of the ground permitted a less advanced position to be occupied so as to concenl the place from view.

Fre. 438.-Scale 900 yards to 1 inch.


The distance apart of the forts varies considerably according to the nature of the groand; but in cases when the ground is open, or where it can be swept by the front and flank fire of the forts, these latter have been placed (as in Fig. 438) at intervals of about one mile from centre to centre. This distance permits the intervals between the forts to be well defended by the fire of the adjacent works, and also of the ground in front of each fort being commanded by the artillery of the collateral works,
587. The forts are required to fulfil the following conditions, viz. :-
(1.) To be able to bring a powerful (offensive) fire of artillery to the front and flanks.
(2.) To be secure from a coup-de-main, by having a strong profile, together with a good Alank defence.
(3.) To have sufficient bombproof cover to be able to withstand a severe bombardment.
(4.) To be provided with a keep or reduit, to increase the defensive powers of the fort.

The general shape of the works is that of a lunette, the salient angle of which is sufficiently large to allow both faces to fire on the capital of the work. This is the case with the fort marked B, in Fig. 438, which is an outline of the fort shown in detail in Fig. 439, in plan, and in the accompanying profiles, Figs. $440, * 441$.

[^70]When the angle is not sufficiently obtuse for this purpose, an additional face is added to fire on the eapital as in Fort C, in Fig. 438. The flanks of the forts are traced on a principle similar to those of field lunettes, viz., so that their fire may defend the intervals and cross on the capitals of the collateral works.

Fig. 439.-Scale $\frac{1}{\text { suon }}$


From these considerations it seldom happens that the same outline is given to two separate works.

The length of the faces and flanks, and also the size of each fort are regulated according to the fire required from it, and to the peculiar conditions to be fulfilled by the work.
588. The command of the works is regulated so as to allow the covered-way and ground in


Seotion on the line AB, Fig. 439, through the centre of the Keep,
front to be swept by the fire from the ramparts, and also, where necessary, to afford sufficient height for cascmates to be placed, as in Fig. 441, under the terrepleins of the ramparts. The faces of the works are usually provided with ousemates, as they are there better protected from fire than if placed in any other part of the works. A command of 30 feet is required for the ramparts which are thus provided with casemates, as in Fig. 441. The flanks of the works (Fig. 142) are not given casemates under their terrepleins: a command of about 23 feet is


Profile on C D, Fig. 439, Scale in or


Profile on E F, Fig. 439, Seale $\frac{1}{\text { com }}$
assigned to them as being sufficient to afford a proper fire on the exterior. The ramparts of the faces and flanks are provided with traverses, which are built hollow so as to utilize space; those on the terrepleins of the faces are used as expense magazines, or as rooms for artillery stores, \&c., while those on the terrepleins of the flanks are usually made as Haxo casemates, which thus afford bombproof cover to the guns placed inside them, in addition to protecting others by acting as traverses.
589. The depth and width of the ditches are regulated so as to afford sufficient earth for the formation of the ramparts and glacis, and also to allow the escarp ( 30 feet or more in height) to be well covered from distant fire. A depth of 30 feet below the ground level and a breadth of 50 feet are the dimensions most usually assigned. Compared with the ditches of former works these dimensions exhibit an increase of depth and a decrease of width, each of which tends to improve the protection of the esearp from artillery fire. They, however, necessitate an increased command being given to the glacis in order to allow it to be swept by the artillery fire of the work; this lends also to the covered-way (when there is one) being raised above the ground level.

A glacis and corered-way are provided in front of the faces and flanks of the works; there are no traverses in the covered-way, which is communicated with only from the gorge of the works.

The escaups are provided with a chemin-des-rondes, as in Figs. 441, 449, the wall of which increuses their height by 6 or 7 feet, while the berm, which is 12 feet broad, facilitates the repairs of the parapets. The berm is flanked by means of musketry kaponiers whieh run aeross it, and to which access is afforded by means of a communication from the casemates under the ramparts.

In Fig. 441 the top of the parapet wall of the chemin-des-rondes is $5 \frac{1}{2}$ feet below the level of the crest of the glacis, and the berm is consequently 12 feet below that level. By this arrangement a shot falling with an inclination of $\frac{1}{7}$, and just clearing the crest of the glacis, would strike the escarp only 2 feet under the level of the berm.

Both the escarps and counterscarps are built with counterarches, which diminish the cost of construction, and can be used as flanking galleries from which to defend kaponiers, \&c., at the same time that they increase the difficulty of forming a breach by artillery when in escarps, and serve as a basis to mining operations when in counterscarps, as in Fig. 433, page 239. Whenever counterscarp-galleries are made use of, a communication is made to them under the ditch.
590. The flank defence of the forts is derived from masonry kaponiers, which are connected with the escarps, and are constructed for two tiers of fire. In some cases two tiers of artillery are used in the kaponiers, while in others guns are used only in the lower tier, the upper one being reserved for musketry. In this latter case a balcony is provided for the riflemen in the upper tier, thus avoiding the necessity of constructing a floor (as is required when a double tier of guns is used) and thereby giving more space and ventilation in the kaponiers.

Figs. $443,444,445$, are a plan, side elevation, and profile respectively, of the kaponier shown at the salient in Fig. 439, which is thus provided with a row of loopholes and a balcony, which serves

Kaponier at the salient of the Fort, Fig. 439, Scale $\frac{1}{760 \cdot}$


## Permanent Forlification-

ns a banquette to them above the embrasures. A species of machicoulis is also formed above each embrasure, ns seen in Fig. 445, which allows a musketry fire to be directed downwards, so as to defend the exterior of the embrasures,

The ordoance used in the kaponiers are short smooth-bore pieces of large calibre, such as the $8^{\prime \prime}$ or $10^{\prime \prime}$ howitzers, or the $8^{\prime \prime}$ shell gun, which combine lightness with the power of throwing 2 large wharge of case-shot along the ditchas. It is probable that a short breech-loading smoothbare piece may be designed for the special purpose of arming these flawking works.

Owing to the great depth and narrow breadth of the ditches, the kaponiers can be placed in sitantions where they are secure from fire which may enfilade the ditches which they flank. In cases where the ditches cannot be enfiladed, as in Fig. 498, Fort A, a kaponier is placed at an angle so us to flank two lines of diteh, but when a line of ditch is exposed to enfilade, a kaponier is constructed to flank the single line, and it is then placed at that end of the line to be flanked which is nearest to the enemy's position, as it is there covered from distant fire by the glacis in front. This is the case with the kaponiers which defend the ditches of the flanks of Forts B and C in Fig. thy.

The kaponiers are flanked by mosketry from the escarp and comterscarp galleries, and in some cases by the fire of collateral kaponiers. They can be oceupied as barracks for the artillerymen who are to serve their guns.

The commmications to the kaponiers are underground galleries, which usually lead from the diteh of the keep, and have no connection with the main fort. Thus the kaponiers and the keeps can be held after an enemy may have penetrated into the main work.
591. The keeps are construeted with the object of increasing the defensive powers of each fort, which they effect by enabling a fire of artillery and of musketry to be brought to bear over the whole of the interior of the fort, and they also enable a fort to be held by a small body of men in the event of a sodden attack. The keeps are casemated works, either circular, polygonal, or horse-shoe shape in plan, and have a cont-yard in the interior. The front portion of the keeps are provided with an earthen parapet and rampart, as in Fig. 440, to which is given a command of observation only over the faces of the fort. This command is, however, sufficient to enable an artilley fire to be brought to bear from the keeps over the intervals between the forts, since the leep has a command of $10^{\prime}$ or $12^{\prime}$ over the flanks of the fort. The rear portions of the keeps are kept considerably under the level of the front portions, so as to protect them from projectiles which masy pass over the front parapet of the keep.

A dith surrounds the keep and commanicates with that of the gorge of the work, which latter is flanked by the keep. The gorge of the keep flanks its own diteh; in Fig. 489 the remaining partion of the diteh of the keep is Hanked by musketry kaponiers, which cross the ditch, and also by a counterscarp-gallery, with which they commumioate. From this latter branch off the galleries of communication with the main kaponiers.

In order to cover the escarp of the keep as much as pussible from a pitching fire, the embrasures in the casemates of its escarp are placed on a level with the terreplein of the fort. By this means the cordon of its escarp, which is 30 feet in height, can be lsept i2 feet under the level of the crest of the faces of the fort, as shown in Figs. 440, 441.

Fig. 440 is a section through the centre line of the keep of the fort, Fig. 439, and illustrates in detail the above general description; two thers of casemates are shown under the parapet of its front, the upper one of which is used as barracks, and opens on to a balcony in rear; the lowev tier of casemates run completely through the work, and is used for a double purpose, as the front portions are provided with embraswes and loopholes from which to fire on to the interior of the fort, the remainder being used only as barracks.

The line of ditch of the gorge of the fort is traced so that its prolongation shall fall on to the glacis of the collateral fort. By this means the atillery of the rear portions of the keep not only flank their own ditch, but can, from concealed positions, bring a fire on to the glacis of the collateral works, which would be extremely difficult, if not impossible, to be silenced by an enemy.

## INDEX.







## SECTION III,-FIELD FORTIFICATION.




Index.








6

$$
\begin{aligned}
& \Rightarrow \quad A R=123 \mathrm{Hat} \\
& \frac{6+x+4+x}{2} \times 12=123 \\
& \frac{10+2 x}{2} \times 12=123 \\
& (5.5+x) \times 18:=123 \\
& 60+12 x=120 \\
& 120=12 \nu-60 \\
& 12=-63 \\
& n-\quad=\frac{1}{4} \frac{d x t}{\operatorname{cosec} 2} d x
\end{aligned}
$$




[^0]:    - A certain proportion of steel shot are issued to men-of-war for service against iron-plated ships,

[^1]:    * The shell from the Armstrong 12-pounder gun rotates abont 125 times in a second.
    + In some riffed guns windage is allowed for convenience in muzzle-loading, lut still the coincidence of the axes of the bore and projectile is retained, while the latter moves along the bore.
    $\ddagger$ The position of the axis of an elongated rifle projectile throughout its flight cannot be accurately determined. It should be, if possible, always tangent to the trajectory, so that at any rauge its head shonld first strike the object. This, however, is not the case, for its rotation tends to keep its axis in parallel directions; while the effect of the resistance of the air, the length of the projectile, the position of its centre of gravity and other causes, is to bring its head downwards, and tends to make its axis more nearly a tangent to the trajectory. Consequently, throughout its flight, the axis of the projectile may be assumed as being in a direction somewhere between a tangent to the trajectory and a line parallel to the line of fire.

    This defect is not of much importance at short ranges, but it is so at long ones, where, owing to the size of the angle of descent, the projectile will strike with its axis considerably deviating from the trajectory. The force of the blow and the penetration of the projectile are thereby much reduced.

[^2]:    * It will most probably be shortly converted into a breech-louler.

[^3]:    * In the Berares, the given lines are "Hhin and contimwis;" the lines of construction, i.e those used to abtain the resulte, "Ohin toultel," aud the resulting lioes "Ulick and continuous, A Aiven point is shown by a circle described about it as a eentre y and, generally, thone lines whimb are only required for proof are omitteit.

[^4]:    A T. Rase of slope of banquette.
    TS. Ditto of the banquette.
    SR. Ditto of interior slope.
    RQ. Ditto of superior slope ; also thickness of the parapet.
    Q F. Ditto of exterior slope.
    FG. The berm.
    G P. Base of the escarp.
    PO. Width of bottom of ditch.
    OK. Base of counterscarp.
    K N , Ditto of reverse slope of glacis.

[^5]:    * This triangle will be the same in any parapet, the interior slope of which is 1 .

[^6]:    - A perpendienlar of tha the exterior aide must be used for any exterior angle leas thau $108^{\circ}$; the when the augle is retween $108^{\circ}$ and $120^{\circ}$; and jth when $120^{\circ}$ or larger.

[^7]:    - In the Danioh redoubts at Duppel, the interior blockhouses nut being screened from distant view, served as targets for the Promiun urtillery, which asuu reduced theoo to rains. Owing to this error of construction, the blockhouses were grurne thenit uockes, as the splintery from them whea struck by shot rendered the main works untenable.

[^8]:    - The most commanding point of a height in not necessarily the bighest point; but it is that which has the greartar angle of devation with reference to the site of the work; or, in other words, which appearg highest when viewed from the work.

[^9]:    ground, ia couetimes termed "Defilading by the trace." of work, so that their prolongationa do uot fill on commanding

[^10]:    *Sir John Jones, in his Memorzmin on the Lines of Torres Vedras, vol, ïi, [. 78, says:- "To ensure an efficient cystem of draimage should always be a principal ounsideration with an cuficer on commencing a work. Some redonbta deeply excavated, with a view to sereen the defenters, particularly Nos. 101 and 102 at Oegras, from ueglect of this precantion literally filled with water, in September 1810, and the labour of forming draius to keep their interior dry was little leas than that of coostruetiug the redoults."

[^11]:    * From Sir John Jones's "Lines of Torres Vedras."

[^12]:    * The pouition, however, may in some cases be a had oue for forming the bridge itself, and the choice may often be between a yood atructure and a bad defence, or vice verad.

[^13]:    * In Sir Howanl Donglas' "Military Brilges," p. 21: "The author has frequently found rivers fovdable io this fonled the Dala in the campaign of perpendicilarly at any point. The Spanish army, with which the author gecyed, eame manoer he forded the Duero, near Lamora, and several other formillable advers." 1812 , withe of this circumstance; and in the

[^14]:    * Advanced rentries in presence of an enemy should be composed of a file (couple) of men, and not of single men, io order to increase the difficulty of an enemy surpising them, by creeping up and bayonetting them, or by making them priaonera without ogise.
    $t$ The Russians at Sebastopol, and the Turks at Silistria and Kars, during the late war, mounted the superior slopes of the parapets of the works in this manner, at the several assaults.

    7 At the asault of the lonetto S. R. Roque, at Badajoz, by the British, in 1812, the defenders of the prapapets were so pocupied with their own duty, that they were unawarc of the work heing entered at the gorge until too late to prevent the iob of the work. Such an oceurrenee shows in a forcible mamer the advantage of having a reserve of defenders to a work
    of defence, in addition to the men manning the parapets.

[^15]:    * At the Battle of Waterloo the advanced post of La Haye Sainte was lost from neglect of the simple precaution of blocking up the entrance gate at the side, and forming an opening throngh the rear enclosure will; which would have admitted of the ammunition of the defenders being renewed, and their casualties replaced,

[^16]:    * Fig 279 is Laken from smoue instriotions issoeil by the Erenoh Imperial Mimater of Wran in 1814
    f Thin was the cae in the attack by the Prussians ou the Danish tied poritiou at Duppel, in 1864

[^17]:    * This refers to regular parapets only, for goed musketry cover can be provided for infantry to defend a slope, however steep it may be, provided that it is not precipitous, as shown in Fig. 281, by the dotted profile.

[^18]:    - A clear width of 9 feet between the ribbands is sufficient in a military bridge to allow troops to pass over, because lufantry in fours occupy a width of Do. with supernumerary rank ...
    ...
    Artillery Cavalry in two ranks, about $\quad . .6$

[^19]:    * Variable, depending on the depth of the river.
    + For methods of calculating the strength of beams, see the end of the chapter.
    $\pm$ In the construction of the trestle bridges over the Beresina, by which the wreck of the French army crossed in their in the water throughout the whole of the operations, which were carried on during a severe frost.

[^20]:    *This interval is termed the opeu order. The baulks are, however, provided with pin holes, so as to allow the pontoons to be brought closer together, if required. The bridge can be made with either of three intervale, viz::-
    $\begin{array}{lllllll}\text { Open order } & \ldots . & \ldots . & \ldots & 12^{\prime} & 6^{\prime \prime} & \text { For cavalry, infantry, and field artillery. } \\ \text { Intermediate } & . . & \ldots & \ldots & 10^{\prime} & 5^{\prime \prime} & \text { For medium artillery. } \\ \text { Fing, }\end{array}$
    $\begin{array}{lcccccc}\text { Intermediate } & \ldots & \ldots . & \ldots & 10^{\prime} & 5^{\prime \prime} & \text { For medium artillery. } \\ \text { Close } & \ldots & \ldots & \ldots & \ldots & 8^{\prime} & 4^{\prime \prime} \\ \text { For heavy artillery. }\end{array}$

[^21]:    *These men are provided with long water-tight boots

    + At Chatham the bridge is frequently boomed out at the rate of 1 pontoon per minute, everything being in readiness for the work.
    $\ddagger$ Although every raft (ar wagon load) carries one anchor, yet when formed in bridge every alternate raft is usually given two anchors, as shown in the plan, aud is then terued a mooring raft; the mooring raits are numbered $1,3,5,7$, de, the even pumbers being termed reserve rafts. To suit special circumstances of wind and current, more anchors may be laid on one side of the bridge than the other.

[^22]:    －It has been done at Chatham in less than three minutes，

[^23]:    * This lowever, requires doublethe mimber of wen that are naed for matomoving the bridger
    + A emall ollowager alowde he viale for leakage with poubsous ano bake.
     zuake hules in the oides of the gontoony of the other.

[^24]:    *Tu prevent thie as moch as possible, the eude of the timber should be tarred,

[^25]:    * They should on no account be allowed to keep step while on a bridge, as by so doing the bridge is strained to a dangerous degree.
    + They will seldom march in such clase order, but as they can, it is necessary to assume that they do so, to allow for aceidental crowding on the bridge, which may happen from a variety of causes, but which should lie carefully guarded agaiust.

[^26]:    *The leogth of a beam, as regards ita atrength, is the clear distance between its points of support.

[^27]:    * This breadth is measured irom the font of the interior slope of the parapet.

[^28]:    - A naw of palisailes in this position may aypear to be a very slight obstacle, but it will frequeutly haprien that an whetacle very slightit io iteelf nay loe the cause of considerable delay to a body of troops, topecially if they are ailvancing at might.

    Colowel Lamare the Commandinis French Engineer in the defence of Badajoz in 1812, attributes the success of the Englieb esealade to be greatly owimg to the absence of palisades.

[^29]:    * This dimension is obtained by zubtracting the height of the genouillere for a guu on a garrisou earriage ( $\Omega^{\prime} 3^{\prime \prime}$ ) irou 7 ' 6 ', the height of the parapet above the terreplein of the rampart.

[^30]:    - In 1814 the Britiab surprised Bergen-op-Zoom, defenied by the French, and entered the place in some parts, by crossing the frozen ditches and reariug ladders on the ice against the escarps. Although they were afterwards driven ont, it wis owing to the brillinat defence made inside the towa by the French, and not to any assistance the lafter derived
    frow their fortifications.
    + These remarks apply unly to the ditebes of old fortresses ; the defects mentioned do not esist in the works shown in Plate 5. See Clapter IX.
    \& A lodgment is in trench and parapet formed to enable troops to hold ground gained from an orpoucut.

[^31]:    * The cordon has a small groove, or throating, cut on its under surface in advance of the face of the wall: this prevent water running on to the wall from the cordon.
    $\dagger$ Vauban only used counterforts to his escarps.

[^32]:    * So named, as it affords a pathway along which officers ean go their rounds, and obseme the ditch of a worls, withont being exposed.
    + Ealled by the French the mur des rondes.
    f Thu dinudvandage is partienlarly felt in hastioned fortresses, so by breaching the parapot at the shoulders, the flanks van Le entiladed through the opening so formed, and the flowking gues silenced from a diatance.

[^33]:    - The back wath of the counterarched revetment shown in Fig. 347 is sometimes built in the form of vertical archea, as
    oluwn in the plan by the dotted curved lines.

[^34]:    * If $b c$ is required by calculation, it will be thus found, $b c=\left\{\left(R-4^{*}\right) \times 6\right\}-d b$ : where $R$ is the known relief, and $d b$ is the sum of the bases of the superior and exterior slopes.

[^35]:    ${ }^{2}$ This presumes that CD is required to be AB ; for by similar triangleg $\mathrm{Ge}:=\mathrm{D}:=\mathrm{BG}: \mathrm{CD}$. AA in Field Fortification, a perpendicular of 引th and the is used when the polygon of the work is a negular pentagon, or a equare.
    t At Hilsen Lincs (fart of the Portamonth defencee), the lines of defenee are 500 yds. At Autwerp they are atill
     at whort ramyen, such au the dituches of vetachel forts, are the diost dextructive projectiles for llanking purporch. Clase-shub. however, canout be osed with safety from the open flant of a Bastioned Fort.

[^36]:    * Because H b: He: : BF: FC-by similar triangles.
    + As before mentioned, this is the usual proportion, but it varies : it is sometimes two-sevenths of the exterior sides, as in Plate 1.

[^37]:    * For the calonlations necessary to find the relief of a temille, aee Art. 486, Modera Systam.

[^38]:    * Some authors make the salients of the bastion the centres of these arcs; this is a better construction than the one given above, which is, however, that stated by most authors, and among them by Bonsmavi.
    + Vanban is said to have invented the tenaille, which has all the advantages of the ancient fausselraie, as it provides the double tier of fire, while it has none of the defects mentioned in Art. 363 : from its position also, the tenaille is secure from enfilade.

[^39]:    OPERATIGESS OF A REGULAR STEGE LELUSTRATED BY AN ATTACK ON A FORTRESS CONSTRUCIED ON VAUBAN'S FIRST SYSTEM. Troops and Artillery for the Defence and Attaol:
    308. The Garrison of a Fontuess varies with its size and its particular circumstances of situation: it is usual to consider it under two heads, viz. :-
    (1.) That which is necessary for the immediate security of the place.
    (3.) That which is required for the defence of the place, if besieged.

[^40]:    * The umolrars iu gracenthoses in this Chapter refer to explanatory notes whiols are at the end of the Chapter.

[^41]:    * The above estimate for the strength of a besieging army is given by the late General of Engineers, Sir John Jones, Bart, an officer of great experience in sieges, and who served with anmies invariably far weaker in number than those he recommends; nevertheless, the propriety of having the above proportions has been proved by expericnce, to avoin the otherwise fearful loss of men by fatigue and sickness. It is to be understood that these numbers are ill addition to the troops keeping up the investment,

[^42]:    * Batteries are so named, when their object is to silence guns by direct fire.

    | + Now replaced by the $32-\mathrm{pr}$. of 50 ewt., and the $\mathrm{S}^{\prime \prime}$ shell-gan of 52 cwt . smooth-bore gans ; or by the 40 -pr. Armstroag |
    | :--- |
    | 5 ewt. | rifled gun of 35 ewt.

    A Prerrier is a mortar dealigned for the Inupose of throwing stones at short ranges. There is no regular pattern in the
    Ither service. Britinh service.

[^43]:    * It is considered that none of these defensive disadvantages exist in the Fortress of Antwerp, which is described in Chapter IX.

[^44]:    - See Ohapter VII., on Occasional Worke.

[^45]:    －The parallel being of eonsiderahle length，the gronnd it is to occhpy is divided into several portions of 300 or 400 yard，to each of which a traciug Engineer and a working party are ullotted，that the uperation may he executed rapidty．

[^46]:    * That there may be light enough to enable the parties to be instructed in their dnaies.

[^47]:    - The frogqa are anmetimes ported with the reserves in rear of the workmen, and the piequets only in frout-

[^48]:    - This is a necessary exception to what in otherwioe a rule,-viz, to make the rear of all trenches deeper than the front, as hy as doing more cover $1 s$ obtained, and drainage is muoh facilitated.
    + A gum or mortar portion in a baltery is the length of parapet ( $18^{\prime}$ for guns, $15^{\prime}$ for mortars) required for the service of the picce; its centre agresa with the centre line of the embrasure or plafform. It is equal to, although not coincident witt, the central interval between two adjacent embrasures or platiorms.

    I An extra half-merlon is the levgth required to be added to the last gon portion of a bstitery, in order to make the jarapet at the flank as solid an it is between two embrasures. (See Fig. 372.)

[^49]:    - So called from its ahape in profile; not from its shape in plan, which is also rectangular.
    $\dagger$ Those ubed at the siege of Selastopol were rectangular.

[^50]:    * It is almost romeecestary to remarle that in enfilading at line of work by rieochat finc, the gous, \&o., fired at are not vieilite from the buttery.

    1 The housee aud other buildinge in the liue of fire of a connter-hattery are thus noon deatroyed.

[^51]:    * Thie torn implies the most advanced points of the attacks that happen to be executed at any particular time.

[^52]:    $\rightarrow$ The ronts of trees are a most serious impediment to sapping. For this reasou plantations of small trees are unale ou the gliwin of wany fortresses ; when a siege io threateued, these would be this down and used in the defence, leaving the roota
    in the ground.

[^53]:    2. Thit could, at the prusent time, he offeered with rifled ordnance, owing to tho great seeoracy of theio firc, avil to the pery slight loa of velocity in therir projectiten, at raogen of 1,000 yarda and upwarde

    + Ror detaila sed Chapter VIIL. "Mining."

[^54]:    * Bousmard, in his edition of the "Mémorial pour l'Attaque des Places," observes, that Cormontaingue has in that work proved the passage of ditches full of water, on floating bridges of fascines, to be far from a chimerical operation; and we find, at p. 181 of the "Memorial" itself, ample details giveu for the construction of such a bridge, which the anthor employed with entire success at the siege of Pbilipsburg. The points of most importance appear to be:-1. To place the fasciues in suecessive layers, crossing each other at right angles alternately, with hurdles interposed at intervals. 2. At every three layers to drive pickets into the fascines, and to load them with sandbags sufficient to siak the loridge to the level of the water, so that the besieged may be unable to set fire to it. 3. To lay each suecessive course of fascines within the preceding one, in order that the bridge may not turn over when ladeu with its epaulment. 4. To build the epaulment itself considerably within the edge of the bridge, and to place the gabions which compose it on a double row of fascines of the same breadth as itself, in ovder to increase the buoyancy of that side of the bridge where the greatest depression must take place, owing to the weight of the epaulment. 5. To cover the whole with raw hides, to prevent its being burnt,

    Philipsburg being seated in a marshy country, it is doubtful whether there was a very rapid current thoongh the ditches; but an engineer is compelled to vary his methods, and devise experients, according to the emergency of each particular ease.

[^55]:    + Assault of St. Sehastian, 31st July, 1813.

[^56]:    * The syitem here described would nat be spplied (if actnally eanatmuted) to polyguma of fever sitles thau ois ; conscyountly the 1 -rjendicular of a front will nerer he lefs than one zixth of the exterion bide.

[^57]:    * This relief of 34 feet is thus obtained (see Fig. 400)-

    $$
    \text { Nuw } \mathrm{AD}^{2}+\mathrm{D} \mathrm{~B}^{2}=\mathrm{A} \mathrm{~B}^{2}
    $$

    $$
    \text { and } D B=\frac{A D}{3} \text { for } A D: D B: A B: B C
    $$

    $$
    \therefore A D^{2}+\frac{A D^{2}}{9}=52^{\circ}=2704
    $$

    $$
    { }_{9}^{10} \mathrm{AD}^{3}=2704
    $$

    
    
     $\therefore$ Felfef $=\frac{148+30}{6}+4=\frac{178}{6}+4=3 t^{\prime}$ nearly.

[^58]:    * This comstruction has the defect of preventing the garrison making a powerful effort to recover the raveliu, after an enemy is lodged in it. The same may be said of its reduit and of the outworks generally.

[^59]:    bastiou whas breached.

[^60]:    - The masonry walls of casemates must he concealed from distant view from land, as otherwise they conld be breached from a distonee: it is not so necessary to conceal them from view from the sea, as the fire from a ship uever cau be so sccurate as crow in land battery, even ill calm weather:
    Castle of Scyllm, in Calabria, in 1805:- "On examining the reference to the effect of the British fire on the casemates of the etill copying out fair, and comsequently before steps could be takens of these casemates, whilst the terms of surrender were to observe the misehief which hail been produced by shot which to clear or purify the castle, it was altogether surprising entered the casemates. To judge from the indentations on the walls, dellected from the cheeks of the embrasures, and everywhere presented themselyce, a direct fire into a casemated embrasure of the marks of slanghter and destruction which bitteries untenable; indeed, at this attack, the French losed embrasure of the usunl construction must render casemated nassed through the rear of the casemates."

[^61]:    - Irou rails on which the trucks of the traversing platforms run.

[^62]:    * By Captain Inglis, R.E.
    $\dagger$ So named from its inventor, General Haxo, of the Erench Engineers.

[^63]:    - Bastinued lines having powerful casemated Alanks have heen recently construeted at Filses, near Portsmonth. allord a goond example of the suitahility of the bostioned trace for partical cor purneted at Filises, near Portomnuth. They the fares of the haxtions are secure from enfliade while the fire particolar jurposes; for, from the nature of the position, the bistions, Lat also to aweep the channel which mums past the front of the times is required not only to protcet the faces of flamks coudd be oprosed in front only by the fire of gua pobats.
    tion in the Erench Bantioned Systems,
    i Finst aivnocuted, it ia lielieveri,
    the Belgian Engoper Brialmont, is recommended to the attention of any, whose Treatise on Fortifieation, as well as that by zubject.

[^64]:    * Brialmont states, in his Etudes sur. la Defence dee Evuts et sur la Fortincution, that in the new Russian fortress of Modlin, on the Vistula, there is easemated accommodation for a corps darmee of 30,000 men, inclading the horses for the cavalry and also those for the field batteries.
    + It is not meant to be implied that the enceinte of Plate V . is liable to be enfiladed, for such is not the case.

[^65]:    * At the siege of Sebastopol, where many of the Russiau works had to be opposed by counter-batteries, which wewe obliged to cease firmg at nightfall, the Russian gunners frequently withdrew theix guns from the embrasures during the day, and at dusk requcerl them, so as to be in readiness to repel an assault.

[^66]:    * Through inadvertence 15 cascmates have been shown in Plate $V$., instead of 14. . ; thase in the secozi flank are at + In Plate V , the floor of the low batteries of the first flank is at the level of ( 9 -50) (11-50).

[^67]:    - This battery is exposed to be struck by pitching fire with full charges, because the prolongatiun of the ditch of the raselin cas be occupied by a besieger. The effect of auch lire would not probally be great, owiog to the small size of the olject (the buttery), the greater portion of which is protected by an earthen parapet, aod the whale of which is concealed from view beyond the glacis, Experiments have shown that distant nitching fire is mucertain, even under the favourable conditions of the exact range being lonown, the effect of each round reported to the experimenting battery, and of the latter out being itvelf exposed to lire.

    In eases where thesy low flanking batteries axe much exposed, their frout walls would be provided with irou shields, of be composed enticely uf irom.

[^68]:    * Temparary treatle-bridges would be placed when regaired between this piex and the torrpiein in vear of the kuponiter, sud ateo the place of anvembly in rear of the orillon.

[^69]:    * The Siege of Sebastopol is the only siege that has been carried on against a place hearing any resemblance in defensive powers to Antwerp. Sebastopol, although an extemporised fortress, resembled Antwerp so far that its extent was cousillerable, its resources in men and artillery great, and it was not invested (it is not probable that Antwerp if attacked conld be iovested), but it was infexior in having only a weak profile, which rendered it opea to assand, anderecessitaked the works being always strongly guarded, one principal chuse of the enormous losses sustained by the defenders, further there were no goon ontworks (at the heginaing of the siege there were not any and uo covered-way, neither were thers the proper facilities for the garrison making sorties of a force in proportion to theiv strength. But, notwriastanding these nissivantages to the defence, the hesiegers had, at the termination of this remarkable attack, in no place advanced as far as the period of the crowning of the covered-way ; in fact the siege terminated at a time when in the attack of a permanent fortress the real difficulties wonld have commenced.

    Marshal Niel, in his relation of the siege, remarks that if the Russians had made powerful sorties at day-break, the siege would have become an impossibility, as the guards of the trenches would bave heen overwhelmed, and the batteries destroyed befnre sufficient troops to repel the sortic conld have been assembled and marched to the spots Also the following :- "If the enceinte had heen provided with well revetted escarps, if it had been necessary to make a hreach therein, in order to penetrate by difficult approsches, and hehind which the heads of our colmmos would bave lieen met by an army, Sebastopol would have heen impregnahle. In fact, on the Sth September, the day of the fival assault, we had ouly execnted, after the greatest efforts, those approaches which are preparatory to the crowning of the covered-way; we had, therefore, not yet engaged in those works which are the most difficult and dangerous in a siege."

    + It does not seem practicable on the part of a besieger to silence the kaponier in any other way than by eaptining it.

[^70]:    - Fig, 440 requires some explanation. Commencing from the left of the drawing, the section is first taken through the rump descendiog to the bridge of conmumication ; it then pasees acruss the ditch and through the centre of the gurge of the teeep, the rewainder of the gurge being shown in elevation (but withunt the details, sueli as embrasures and loopholes) ; the court of the keep is next shown with the curved portion in elevation, but with the details of windows, sce, omitted ; the jrofile of the curved face of the lecep is next given, together with that of jte ditch and counterscarp gallery. In the dith the countercarp is ehown in elevation with the loopholes of the gallery behind it.

