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PREFACE.

The Editor has much pleasure in presenting the Corps with Volume XII. of the R.E. Professional Papers, *Occasional Paper Series*, which brings the publication up to date.

Volume XII. of this series contains two historial papers, one on the Defences of Dover, by the late Major-General C. S. Akers; the other the Coast Defences of England, by Walter Tregellas, Esq. These sketches are particularly suitable to the Volume published in 1887, as there has been much discussion about the centenary of the Corps, but these papers show that the Military Engineer in this country dates back to remote antiquity, long before the Corps of Engineers existed. The centenary comemmorated this year is, however, only the 100th anniversary of the date of the warrant altering the name of the Corps of Engineers to that of the Corps of Royal Engineers.

To those interested in the art of photo-lithography, or to officers who may have to reproduce coloured maps or plans in outline, *Plate* V. of the sketch of the Defences of Dover will be of interest, as it is an outline photo-lithograph from a coloured plan, reproduced by the following simple process. The negative is taken in the usual way, but when the transfer print is made on the gelatinised paper, instead of exposing the paper to the direct action of the light through the negative, a sheet of thick white paper is introduced between the glass of the printing frame and the negative, and the gelatine paper then exposed in the usual way, but in good diffused light, not in sunlight, when, instead of a transfer with patches to show each coloured portion of the drawing, an outline plan is produced.

The subject of fever and malaria is one of particular interest to the Corps who have charge of the sanitary arrangements in all parts of the world where H.M. troops are located, and the paper on this subject will therefore not need any recommendation. We must, however, give a cordial welcome to Lieut. Clauson's paper, as it is not often that an officer contributes to the *Corps Papers* during the first two years of his service.

Major G. S. Clarke, C.M.G., has our thanks for his valuable summary of the Lydd Experiments for 1886; from his digest the officers of the Corps are, by the perusal of a few pages, able to gather all the important facts demonstrated by these experiments, without having to work through long reports and lists of tables and figures.

Captain F. Rainsford-Hannay contributes an account of the Milford Haven Submarine Mining Operations, which will be received with much interest by the Corps. The account was compiled for a lecture delivered at the R.E. Institute during the winter session of 1886-87. We are also able to supply our readers with an account, by Lieut. J. Pring, R.E., of the blowing-up of the wreck "Gondola," which will be of use to officers having to undertake similar operations.

During the last few years the use of Steel has been coming largely to the front, and its properties have received much attention from engineers and scientists. The subject has been brought before the Corps by Mr Ewing Matheson, C.E., in a course of lectures delivered at the R.E. Institute in the winter session of 1886-87, which we reproduce for the benefit of our readers. In these lectures we have introduced a full description of the Siemens gas producer and open hearth furnace, from Percy's *Metallurgy*, for the benefit of officers who may not be quartered near one of the R.E. Corps libraries, or in a station where they can refer to Dr. Percy's valuable work.

We have been requested to state that Paper IV., in Volume XI.—"The Demolition of Ruins of Poor House at Halifax, N.S.," was compiled by the Secretary of the R.E. Institute from a report by Captain J. C. Middlemass, which was supplied from the office of the Inspector-General of Fortifications and Engineers for this purpose.

FRANCIS J. DAY, MAJOR, R.E.
Secretary, R.E. Institute, and Editor.

November, 1887.

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PAPER I.

HISTORICAL SKETCH OF

THE FORTIFICATIONS OF DOVER.

BY MAJOR-GENERAL C. S. AKERS, R.E.

THE Military History of Dover may be held to commence with the appearance before it of a Roman fleet and army, under Julius Cæsar, in the year 55 B.C.

It is conjectured, that at that time, and for some centuries later, the harbour extended, more or less, up the Charlton and Buckland Valley, with a direct outlet between the Castle Hill and the Western Heights, occupying, in fact, a great part of the site of the modern town.*

Anchors, timber of vessels, and other articles found in excavations along the course of the valley, bear out the probability of this conjecture, which agrees also with the account given by Cæsar of the part of the coast to which he first brought his fleet.

Such a harbour, no doubt, offered an inviting opening for the approach of Cæsar's transports, and for the disembarkation of his troops in still water.† But the steep heights, rising rapidly from the

* See "Kent, by Robert Morden;" "Barton's Commentaries on Antoninus," "Leland's Itinerary." See also "Robert Talbot's Annotations on Antoninus," quoted by Leland.

† The deterioration and alteration of direction which afterwards occurred here, as in so many other ancient harbours, was probably due in some measure to the reclaiming of land along the course of the river Dour, which forms its backwater.

A part of the valley where Charlton and Buckland now stand was probably, in ancient times, covered by the sea at high tides.

The scour caused by the ebb and flow of so large a body of water would have kept the mouth of the harbour open, but in proportion as the water area was diminished by the reclamation of the land, the scour would become less, and be at last insufficient to clear away the beach. Falls of cliff to the eastward arresting the travel of the shingle would also have helped to close the mouth of the harbour.

water's edge on either side, were covered with armed and determined warriors, prepared to take full advantage of their commanding position to dispute the entrance of the fleet and the landing of the troops.

In view of these hostile preparations, Cæsar decided to seek some other landing place, which, although offering less natural facilities for the approach of his vessels and less shelter from the weather, might at the same time be less open to interference on the part of the enemy.

Professor Airey has suggested an ingenious theory, based on the state of the tides on the supposed day of landing, that the disembarkation was effected some miles to the westward of Dover, at or about Hythe; but the balance of evidence goes, I think, to prove that the landing was actually effected somewhere between Walmer and Sandwich.*

No record exists that Julius Cæsar ever set foot in Dover itself.

With regard to the founding or first construction of Dover Castle, Lambarde, in his History of Kent, refers it to one Arviragus,† King of the Britons, and quotes Juvenal, as saying to the Emperor Nero, "*Regem aliquem capies, aut de temone Britanno excidet Arviragus*"; which he translates—

"Some king thou shalt a captive take, orels from British wayne shall Arviragus tumble down." He continues—"whosoever were the authour of this Castell, Mathew Parise writeth that it was accounted in his time (which was under the reign of King Henry III.) *Claris et repagulum totius Regni*, the verie locke and key of the whole Realm of England."

Lyon considers that the first portion of Dover Castle was built by Publius Ostonius Scapula, about 49 A.D. This work, he says, was in an oval form, surrounded by a deep ditch and high rampart.

The oval form of the original fort, however,‡ which is still sufficiently marked, appears to point to British rather than to Roman

* The arguments as to Cæsar's landing place are fully worked out in Mr. Cardwell's paper in Vol. III., *Archæologia Cantiana*, where, I think, he successfully refutes the theory of the landing being effected west of Dover. Both papers agree that Dover was the place where Cæsar first brought his fleet.

† John Rosse, who died in 1491, speaks of this Arviragus, who, he says, married a daughter of the Emperor Claudius, and afterwards rebelled against Vespasian. He strengthened the works of Dover Castle and of the "portum Rutupium" with a view of keeping out the Romans. Shakespeare adopts him as the son of Cymbeline.

‡ *Fig.* 1, *Plate* I., represents the original (so-called) Roman work, copied from Lyon's *History of Dover Castle*.

work. The almost universal shape of the Roman work was a square, or oblong.

It seems likely, therefore, that in this, as in many other cases, the Romans simply utilized an existing British work.

In the reign of Constantine a 'præporitus,' with a detachment of Tungrians, formed the garrison of Dover.

At Rutupice (afterwards Richborough), near Sandwich, was a strong Roman fort, garrisoned by a cohort of the Augustan Legion.

At Lemanis, or Lympue, near Hythe, was another large work, occupied by a 'præporitus' and a company of men from Tournai.

The principal object of maintaining these military posts, after the complete subjection of the country, appears to have been to secure the coast from piratical incursions.

'Anderida' is spoken of as another Roman post, either in Kent or Sussex.

In the reign of Theodorius, father of Theodorius the Great, the 1st cohort of the 2nd Augustan Legion was quartered at Dover. About this time a Roman bath was built in the valley, fragments of which remained as late as 1813. It extended over the present site of the west end of St. Mary's Church.*

Hasted, in his *History of Kent*, says that according to "Pancirollus, who wrote his 'Notitia' somewhat later than the times of the Emperors Arcadius and Honorius, viz.: before the middle of the 5th century, a Roman officer, called 'Comes Littoris Saxonici, or Count of the Saxon Shore,' kept guard over this coast from the depredations of the Saxon pirates, and had among the troops under his command a company of soldiers under their chief, called Præporitus Militum Tungricanorum, stationed within the fortress of Dover.

Few records are to be found of the state of the Castle after the Romans left the country until the period of the Norman invasion. It is certain, however, that the Saxons occupied and strengthened it. The outer vallum and fosse round the space in which the Norman keep was afterwards built is considered to have been originally Saxon work†.

* Lyon, writing in 1813, says he has himself seen many parts of this bath "with much labor demolished" at different times, for the purpose of interring the dead.

† *Fig.* 2, *Plate* I., from Lyon's *History of Dover*, represents the Castle in the state in which he supposes it to have been in early Saxon times; *Fig.* 3, *Plate* I., its state at the time of the Norman Conquest. Lyon describes various works executed in Saxon times, but quotes no authorities.

Various modifications and additions are attributed to Earl Godwyn, who, in the reign of Edward the Confessor, was Governor of the Castle.

During Godwyn's tenure of office, Eustace, Earl of Boulogne, coming over to see his brother-in-law, King Edward, landed at Dover. A quarrel occurred between his men and the townspeople, in which one of the latter was killed. The rest of the townsmen flew to arms, attacked the Earl of Boulogne, and killed 18 of his men. Godwyn took the part of the townspeople, and demanded that the King should deliver up Eustace to him. His conduct was so arrogant that he was banished the realm, but he caused so much trouble while in banishment, that the King re-called him and restored him to his former rank and dignities.

It was about this time that Harold fell into the hands of William of Normandy. Harold's oath to William, before the latter would allow him to depart, is said to have included a promise to deliver up to William, Dover Castle and the well within it.

Immediately after the battle of Senlac, or Hastings, which was actually fought near Pevensy, William marched on Dover and took the Castle after a short resistance. He put its governor, Bertram de Ashburnham, to death, and appointed his own half-brother, Odo, Bishop of Baieux, constable.

Soon after the arrival of William a great fire occurred, in which the whole town of Dover, except 29 houses, was destroyed.

Odo, afterwards Regent of the Kingdom in the absence of the Conqueror, oppressed the country so much, that the Kentish people rose in rebellion, and, with the assistance of the Earl of Boulogne, attempted to seize Dover Castle. They were, however, discovered, and repulsed with great loss.

On his return from the Continent, William greatly added to, and strengthened, the Castle works, and gave them in charge, for life, to a trusty relative, John de Fienes.

To him also he gave large estates to cover the charges of the erection of new works, and of the maintenance and defence of the whole.

De Fienes associated with himself eight other knights, to assist him in the Castle-guard, and divided among them shares of the above estates.

The number of men each knight was to supply, and the portions of the works they were to build, maintain, and defend, were regulated by himself, as constable.

The names of the knights were as follows :—

(1.) William de Albraucis—Lord of Folkestone.
(2.) Hulbert de Dover—Lord of Chilham.
(3.) William de Arsick—Lord of Lexbourne and Boxley.
(4.*) William Peverell—Lord of Urmsted.
(5.†) William de Magminot—Lord of Deptford.
(6.) Robert de Porth—Lord of Bellshanger.
(7.‡) Robert Crèvequeur—Lord of Leeds Castle.
(8.) Adam Fitz-William—Lord Downe and Graveney.

The garrison, in time of war, was to consist of 1000 foot and 100 horse, in addition to the constable, his knights, and their military tenants.

The general plan of the works having been decided, John de Fienes and his associated knights each undertook to build a tower in the lines of works.

The work undertaken by de Fienes himself was the re-construction of the principal (or constable's) gateway, and the apartment over it.

The main features of this building remain to the present day, but the old doors and windows have long ago been removed, and more modern ones inserted, quite out of keeping with the massive grandeur of the building.

The brick arch and covered gallery on the north-west front are said to have been added in the time of Charles I.

The arched passage through this work formed the main entrance of the Castle until the year 1798, when a new entrance was formed, in connection with the new road of approach completed in that year. This new entrance was made by the enlargement and re-construction of an ancient passage, known as the Canon's gate, so called from the fact of its adjoining the quarters allotted to the priests or canons appointed to serve the old church of St. Mary, within the Castle, which then, as now, was partly a parish, and partly a military church.

Opposite the old gateway in the constable's tower, in the inner ditch, is the entrance to a souterrain, cut in the solid chalk through the Saxon vallum into the exterior ditch under the present draw-bridge. During the French war, at the end of the 18th century, the caponier, as now existing, was made at this point for the flank defence of the exterior ditch.

* In Lambarde's, called "Gulfride Peverille."

† Lambarde called him William Maynemouth.

‡ Called in the Latin Records "De Crepito Corde," or, as Lambarde translates it, "Crackthart."

It was the duty of the constable to see that the military tenants supplied a certain prescribed number of men for service, either in the field or in garrison. Those retained in garrison kept guard over such of the most important points as it was not considered safe to entrust to the care of ordinary soldiers. They were liable to be visited by one of the eight knights, who took duty in turn.

According to ancient rule it does not appear that the constable, as such, had any legal jurisdiction beyond the limits of the Castle, and the properties immediately pertaining to it. It is, however, certain that successive constables, who, with few exceptions, were also Lords Warden of the Cinque Ports, assumed considerable power over the adjacent country, and it was not until the reign of Henry VIII. that their power was materially curtailed. From that time the constable's power, even within the limits of the Castle and its properties, gradually decreased, until in the last (18th) century it became merely nominal, and in the present (19th) century the title of constable finally lapsed.

The power still remaining in their hands in the time of Elizabeth is curiously illustrated by an order issued by Thos. Fane, Esq., Lieutenant of Dover Castle, dated 26th February, 1590,* to the Mayors, Bailiffs, Jurats, etc., of the Cinque Ports, prohibiting the killing or selling of meat during Lent without special license from the Lord Warden.

The officer next in rank to the constable was the marshal. To him was confided, among other duties, the keeping of the prison.

In the reigns of the early Norman kings the town of Dover was surrounded by a wall, with flanking towers, some portions of which remained till the end of the 17th century.† The present Town Wall Street marks the line of a part of the old town wall. Various Roman implements, coins, and ornaments, have been found in excavations made along this street, as well as in other parts of Dover.

In the wall were 10 gates, viz. :—Eastbrook Gate, St. Helen's Gate, The Postern or Fisher's Gate, Butchery Gate, Severus's Gate, Snare or Pier Gate, Adrian's or Upwall Gate, Coumeon or Cow Gate, St. Martin's or Monk's Gate, Biggin Gate.

* State Papers, Foreign and Domestic, "Brewer."

† Lyon says the wall was built towards the end of the reign of William the Conqueror. The Snar, or "Snare" Gate, probably remained until 1685. An inscription of that date, still existing on the plinth of a house in Snargate Street, records its position. The word "Snare" meant a sluice, and the "Snare," or Sluice Gate, was probably over or close to a sluice used for flushing out the harbour. A plan of the town, taken in the reign of Queen Elizabeth, shows the situation of the gates.—See *Archæologia Britannica.*

The following description of the various towers erected in and about the Castle works, is taken almost entirely from Lyon's *History of Dover*. He unfortunately quotes no authorities.

Earl Godwyn is said to have removed the ramparts of the so-called Roman work on the north-west side, and to have made a sally-port and tower (marked 4 on *Fig.* III., *Plate* I., and 4 and 5 on *Plate* II.) at its north-east angle. After the Norman Conquest apartments were built for the King's suite over the passage to this sally-port.

Three towers were built as outworks on the exterior bank (or counterscarp) of the Roman ditch, prior to the building of the existing line of walls and towers, which were mostly added towards the close of William the Conqueror's reign.

Of these three towers, that known as Clinton's (marked 16 on *Plate* II.) was on the north-east side of the Roman fortress, near the vallum made by Earl Godwyn across the ditch.

Valence Tower (marked 17 on *Plate* II.) was built on the south-east side of the Roman fortress. After it ceased to be occupied as a place of defence, it was utilized as a mill for grinding corn for the garrison, and was known as the Mill-tower. Lyon says: "It was destroyed in the American War, upon a plan of economy, by the Ordnance Board, but the materials never paid the expense of pulling it down."

Mortimer's Tower (marked 18 on *Plate* II.) was a quadrangular work defending the entrance at Colton Gate. The basement story in this building was sunk several feet in the solid rock, and part of the walls are yet, according to Lyon, remaining underground.

Colton Gate. (No. 19, *Plate* II.).

"This gate and square tower were built over the original entrance into the Saxon ground-works." It was probably much altered after the Norman Conquest. In the reign of Edward III., Lord Burghash held the command of it, and his arms remain engraved on its front.

Lyon says: "The wall round the Roman rampart was connected with Colton Gate, but the part of the wall to the angle was taken down in 1772, and one man was killed, and several hurt, by its fall.

Harcourt Tower was built near the angle of the quadrangle, on the south-west, and over a passage inclosed by the parallel walls leading from Peverell's Tower.

In this caponier, or concealment, the archers, through the slips in the walls, could command the vallum before the Governor's apartments, and an enemy would have been exposed to their arrows while ascending the hill, or the side next the tower, and near the cliff.

In the wall on the right side, going up this caponier, was a door (*e* on *Plan* II.), which opened into the quadrangle.

The two sides of Harcourt Tower, built over the passage, were supported by arches, to open a way to the souterrain gate, where there was a considerable ascent, by a flight of stone steps, to the area before the gate at the Duke of Suffolk's Tower.

This caponier has been destroyed at different times; but in the year 1797, the demolishing hand of modern engineers put the finishing stroke to the connecting parts of the Saxon masonry and Harcourt Tower on this side the Keep, and the end of the interior ditch at this place is filled up to make a way for carriages from the vallum, across the quadrangle, to the new well.* The ancient plan of the Castle at this part of the keep cannot any longer be traced by a stranger.

Well-Tower and Gate. (No. 12*a* on *Plate* II.).†

This tower derived its name from the well in it.

The well is about 380 feet deep, but when it was dug is uncertain; as it is not within the Roman fortress, it cannot claim a Roman origin. They had a well within their fortifications; about 200 feet of it have been filled up. The top is now arched over. There is a third well near Colton Gate, which is most in use by the garrison.

About the year 1800 a bomb-proof work was erected over this well, and the labourers, in clearing away for a foundation, came to one of the caves in the rock which had been designed for lodging the Saxon soldiers or depositing their stores.

The Armourer's Tower (No. 14 on *Plate* II.).

The wall which enclosed the area between the Saxon and Roman fortress connected the well with the Armourer's Tower. The last remains of this tower were erased from the foundation in the alterations made in 1795–6.

King Arthur's, or North Gate. (No. 15 on *Plate* II.).

This gate leads from the area before Palace Gate, into the Roman fortress, and there was a passage between two parallel walls to the Roman works and Earl Godwyn's sally-port.

All the masonry of this work is dug up from the foundation.

* Now disused and supplanted by a still newer well, 400 feet deep, from which, by a powerful engine, water is supplied to all parts of the Castle and to Fort Burgoyne.

† No trace of this tower is now left.

DUKE OF SUFFOLK'S TOWER, OR PALACE GATE.
(Nos. 1 & 2, *Plate* II.).

The entrance into the Saxon keep at this gate was once secured with a portcullis,* and the grooves in the stonework are still remaining.

"After entering the gate there is a tower which was originally only a defence, but it has been enclosed, and apartments fitted up for those who commanded in the tower.

Edward IV. expended a considerable sum in repairing and decorating this building for the accommodation of the Duke of Suffolk, who had married his sister."

THE OLD ARSENAL. (No. 3, *Plate* II.).

An old tower in the curtain converted into an arsenal.

The building, fitted of late years as a stable, but now used as a barrack store, covers the site of this tower. (The tower itself is gone).

The King's kitchen and offices filled the remainder of the space between the so-called 'Arsenal' and the eastern angle of the Saxon keep.

In 1745 barracks were built upon the site of these offices. Lyon considers that the old buildings were either removed or cased over.

ARTHUR'S HALL. (No. 5, 6, 6, *Plate* II.).

Lyon says: "The space on the north-east side of the keep, which is now occupied by a mess-room,† kitchen and barracks, was anciently the site of a large room, called King Arthur's Hall, built in front of the three towers. In the wall, on the back part of the present buildings, there are four towers."

The King's Gate and Bridge is at the north-west angle of the Saxon Keep.

MAGNIMOT'S TOWER. (Nos. 8_1 8_1 8_1 *Plate* II.).‡

Gilbert de Magnimot was a favourite of William I., and was appointed Marshal of Dover Castle when enrolled as one of the associated knights.

* Now replaced by a drawbridge ; probably constructed in the end of last century.

† The buildings occupied as an officers' mess establishment, in Lyon's time, are now converted into a sergeants' mess and adult school.

‡ The plan, which is an exact copy of Lyon's, does not agree with his description.

"The tower erected by Magnimot was a considerable building . . . . in the bending of the curtain, towards the south-east, and the front of it, next the ditch, consisted of two circular parts, joined by a sharp angular projection, and at a small distance a third circular part, which had a communication with the rest of the building by the parapet on the wall.

When the alterations were made . . . . in this place in 1798 . . . . it appeared by the old foundations that Magnimot's Tower had been a large one, and formed the principal guard-room for the night.

Gore's Tower. (No. 10 on *Plate* II.).

Built in the reign of Henry VIII.

Lyon says: "All the towers in the interior wall were for the defence of the vallum, in case the enemy had made a breach in the exterior works; but there were no lands given for keeping ward in them.

Arthur's lesser Hall, or Guamobour's Tower, was attached to Gore's Tower.

The Keep.

In the Chronicle of Benedict of Peterborough it is stated that a very strong tower (*turris fortissima*) was built at Dover about 1187, by order of the King.*

It appears probable that the tower referred to was the keep. It was most likely commenced some years earlier, but completed in 1187. Lyon says the foundations were laid in 1153. Puckle, however, considers the keep was built earlier.

In 1160 various repairs were executed upon the Castle.†

Extensive repairs were also executed a little later, under one Mauricius (Eugeniator), at an expenditure in

		£	s.	d.	
A.D. 1180	of	165	13	4	
,, 1183	,,	129	16	11	
,, 1184	,,	171	8	10	
,, 1185	,,	299	2	1	on 'turris' alone
,, 1186	,,	207	9	0	on the keep and cingulum
Total		£973	10	2	

exclusive of architect's fees.

* *Chronicles and Memorials of Great Britain and Ireland*, British Museum. *Chronicles Henry II. and Richard I.*, Vol. II., p. 5.

† Pipe rolls, 1160. Lt. Emmerson Peck's *Notes on Keeps, etc.*

As a means of comparison of cost, it may be observed that Orford Castle was built in 1163, at a total cost of £323.

Clopton Tower (No. 30 on *Plate* II.) is in the outer rampart, next to the Constable's Tower, on the north side. The constable gave the manor of Clopton, in Norfolk, for its maintenance and repair. A person named Clopton held it by service of Castle-guard.

Edward IV., finding this tower in ruins, re-built it at his own expense.

It had been appropriated for the use of the treasurer by Stephen de Pencestre, and the records of the Castle were preserved in it till the reign of Edward VI. The place, being afterwards neglected, was plundered by a man named Levenste, who took the books and parchments from the shelves, and burned them in front of the building.

He is said to have done this out of jealousy at finding another man preferred to him for the office of Lieutenant-Governor.

GODSFOE TOWER. (No. 31 on *Plate* II.).

Stands next to Clopton Tower, on the north.

CRÉVEQUER'S TOWER. (No. 32 on *Plate* II.).

Built by Robert Crévequer, one of the confederate knights, son of Hamo Crévequer, who came over with the Conqueror. Lyon says he was involved in the faction raised by Simon de Montfort, Earl of Leicester, and his estates were seized by the King. But here Lyon seems to have forgotten his history, for Simon de Montfort's rebellion was in 1258, 200 years after the Conquest.

The five towers along the salient (marked 33 on *Plate* II.) are attributed to the same Magnimot who built towers 8_1 8_1 8_1 in the inner line.

No. 34, *Plate* II., is St. John's Tower, built by a knight of that name, in connection with a souterrain leading to the work figured 35, which was thrown up by Hubert de Burgh after the repulse of the French in the reign of King John. The site of this work is now occupied by the spur ravelin and redoubt, constructed during the French war in the end of the last century.

FITZWILLIAM'S TOWER. (No. 39 on *Plate* II.).

Was on the north-east side of the Castle, similar to Magnimot's Tower, but on a smaller scale.

At this tower there was a souterrain (No. 40, *Plate* II.), the entrance of which was in the interior ditch in the side of the Saxon vallum. A caponier (No. 41, *Plate* II.) was carried across the exterior ditch, and a passage from it continued through the bank, opening into the present North Fall meadows.

The Watch Towers. (No. 42, *Plate* II.).

Lyon considers that these may have been part of the old Saxon works. They do not appear to have had any knights appointed to them, nor any land given for their support.

Albraucis, or Aberauche's Tower. (No. 43, *Plate* II.).

This was one of the most important of the series. Its foundations were laid "below the bottom of the deep ditch, on the north-east side, and the wall was carried up about 10 feet thick, to a level with the Saxon vallum." The archers could command a considerable length of the ditch, on the north-west and south-east sides of the tower, and also the approach to Earl Godwyn's Tower.

Neville, or Pencestre's Tower. (*b*, *Plate* II.)

Was in the angle of the wall between Aberauche's and Godwyn's Towers. Lynn makes the following remarks about it :—

"Stephen de Pencestre commanded in the tower after he had conducted the 400 men into the Castle, while it was besieged by the Dauphin.

"Several bomb-proof casemates have been made on this side of the Castle, in the bank between Fitzwilliam's and Pencestre's Towers, which open on the Saxon vallum.

"In making these alterations and additions, the vaulted gallery and the room under the platform at Albraucis Tower have been enclosed by a high bank of earth; but a passage has been left to them from one of the casemates. The old idea of the necessity of a covered way between the Roman and Saxon fortresses has been adopted by the engineer, and a large arch has been turned at a considerable expense, through the Saxon vallum, which was made when they extended the fortifications on the hill.

"A great change has been made in the appearance of the Castle, between Pencestre's and Earl Godwyn's Gateway, by casting up works which have entirely covered all the ancient ground plans, and the connecting parts between the Roman and Saxon fortifications.

The vallum made by Earl Godwyn across the Roman ditch, the souterrain, the sally-port, and the turrets of towers in the exterior wall, are all hid from the eye of the antiquary."

ASHFORD TOWERS. (No. 47, *Plate* II.).

These were three square towers between Earl Godwyn's Gateway and the edge of the cliff. The lordship of Ashford, from whence they derive their name, was given for their support.

Of the remaining towers I can find no records. They bear the names that tradition has handed down as those of their founders.

In the reign of King Stephen, the possession of Dover Castle was looked on as of great importance by the contending parties in the civil war.

Lambarde says: "For King Stephen, in the contentions that arose between him and Maude the Empresse about the title of the Crowne, thought that no one thing stoode him more in hand than to get possession of Dover Castell; and therefore he never ceased to sollicite Walkelm (that then had the custodie thereof) till he had obtained it."

This account is probably taken from the chronicle of Mathew Paris, who says it was surrendered to Stephen's Queen by 'Walkelimes,' in 1138.

In 1189 Richard I. embarked at Dover, on his way to the Holy Land.

In the year 1213 (May 15th), King John made his submission to the Papal Legate Pandulph, in the house of the Knights Templars, near Dover; and he then put in the Legate's hands a charta recording the act,* which is dated "*Apud dornum Militum Templi juxta Doveram......xv. die Maii anno regni nostri decimo quarto.*"

The historian, John Stow (who lived in the 16th century), refers to this in his annals. The same transaction is referred to by Lambarde in his *Perambulations of Kent.* He says the Templar's house at Dover was erected after the time of the Conquest, and was suppressed, with other houses of that order, in the reign of Edward II. (A.D. 1312). "There standeth yet," says Lambarde in his notes to his book, not published till after his death, "upon the high cliffe between the town and the peere (as it were), not far from that which was the house of the Templars, some remain of a tower now called Bredenstone, which had been a 'pharos,' for the comfort of saylors and also a watch-house for defence of the inhabitants."

* Mathew Paris. Edited by Watts, Vol. I., p. 197.

Although the order was suppressed by the Pope, and its possessions given to the Knights Hospitallers of St. John in the reign of Edward II., it does not follow that the house was then pulled down; and, indeed, it would seem to have been standing in the reign of Henry VIII., for in a view of Dover taken at that period, and preserved in the British Museum among the Cotton manuscripts,* a large house then standing on the Western Heights is described as the *Domus Militum Templi.*

It stood at some distance west from the Bredenstone, and almost in a north-south line with Archcliffe Chapel, which was near the site of the present Archcliffe Fort.

In the year 1216, Dover Castle was besieged by the Dauphin of France, assisted by some of the rebel barons who had taken arms against King John, but held out successfully under the great Hubert de Burgh.

Lyon thinks the Dauphin made his approaches on the west side of the Castle, from the town towards the entrance at the Constable's Tower.

While the Dauphin was at work here, Stephen de Pencestre, with 400 horse and warlike stores, entered the Castle undiscovered, on the east side, by the sally-port under Earl Godwyn's Tower.

In the chronicle of Thomas Redburn, quoted by Darell, it is stated that Hubert de Burgh introduced this reinforcement by a postern in Clinton's Tower. He speaks of this relief as considerable, and consisting chiefly of bowmen with cross-bows and other engines for annoying the enemy.

The following account of the siege is translated from the Latin chronicle of Mathew Paris.

King John, lying at Dover with an army composed chiefly of foreign mercenaries, received news of the embarkation, at Calais, of the Dauphin Louis, with his army, in a fleet composed of 680 vessels. John, fearing that should he await the landing of Louis many of his men would desert him and join their own countrymen, retired from Dover, leaving the Castle in the hands of a trusted knight, Hubert de Burgh.

Louis then landed, without opposition, at Sandwich, and soon gained possession of the whole county of Kent, except Dover Castle. He then marched to London (Rochester Castle throwing open its gates to him on the way) and was received with great joy by all the Barons.

* A tracing from a carefully reduced copy of this drawing accompanies these papers. See *Plate* III.

He afterwards laid waste the eastern provinces, and took Norwich, where he made prisoner Thomas de Burgh, brother of Hubert. Louis now hoped by this means to induce Hubert to surrender Dover. But, says the chronicler, he little knew the firmness and loyalty of Hubert.

Louis, reproved by his father for showing ignorance of the art of war in having made his way into the interior without first securing Dover Castle, returned to Dover with a large force, and laid siege to the Castle on the 24th of June. To assist him in the siege, the King of France sent over a very large and carefully made "petraria," an engine for discharging heavy masses of stone. This implement, with many others, was erected before the Castle walls, and was kept at work day and night.

The French, also, poured a perfect hail of darts into the place at frequent intervals. Hubert, however held the Castle with a garrison of 140 men-at-arms and a number of retainers, and conducted the defence with equal vigilance and fortitude. He replied so vigorously to the enemy's attacks, discharging at them showers of darts in reply to their darts, and rocks for their rocks, that after suffering much loss the French were at length forced to withdraw their tents and their machines farther from the walls. Louis was so enraged at this that he swore a mighty oath that he would never leave the place till he had taken the Castle and hanged every man within it.

During the progress of the siege news was received of the death of King John. This was on the 19th October.

At the receipt of this intelligence, Louis and the rebel Barons in the camp before Dover were much elated, and Louis, thinking now to undermine the allegiance of Hubert, and to tempt him by bribes, proposed a parley.

On Hubert signifying his consent, Louis sent messengers to meet him at a certain convenient postern. With them was the Earl of Salisbury, William Longsword, a bastard brother of King John's, who took with him, to ensure his own safety, but bound in chains, Thomas de Burgh, brother of Hubert, who had been made prisoner at Norwich. A count of Niverne and three other Frenchmen of high rank, also accompanied him.

Hubert came to the postern, attended by five cross-bowmen, with their bows bent and arrows fitted, ready for use in case of need.

The Earl of Salisbury addressed Hubert thus :—

"O Hubert, it is, I think, no secret to you that King John is dead, and that our master, Louis, has made a most solemn oath, that on taking this Castle by storm he will hang every man he finds within its walls. Consult then both your own safety and your honor. You cannot for ever, nor yet for long, hold and guard this Castle, which at least famine will drive you to surrender.

"The power of our master, Louis, increases daily, while his enemy's forces have now lost their leader and are manifestly proving weaker.

"All hope of succour from without must now have left you. Then deliver up the Castle without further useless delay, and no question can arise of any breach of loyalty on your part in doing so, when it is no longer possible for you to hold it. You see that the whole country is now rendering its allegiance to our master."

Thomas de Burgh, who stood, bound and fettered, by the side of the Earl, cried out to Hubert with mingled tears and sobs: O dearest brother, have pity on me and on all our family, and yield to this appeal; for by so doing you will save us all from the greatest misfortunes. Should you refuse, Louis has sworn that I shall be ignominiously hanged before your very eyes, to the eternal disgrace of our race."

And William Longsword added, "Your brother, O Hubert, has spoken truly, but, my friend, only submit to our advice and to the rule of our master, and he will give thee Norfolk and Suffolk in hereditary right, and you shall be first among his friends and councillors."

To this appeal Hubert replied as follows: "O Earl, thou most shameful traitor, although the King, our lord and your brother, be dead, he has made his son, your nephew, his heir, to be succeeded by any sons or daughters that may be born to him.

"Let not Louis conceive a hope that I will surrender the Castle. As long as I draw breath, never will I resign to French aliens this Castle, which is the very key and gate and barrier of England. And were there no rightful heir to the young king, thou, his uncle, should'st in no case supplant him.

"And does not the innocent boy deserve our allegiance. Has he not been crowned, as we know well, and joyfully proclaimed king in England? So will he, under God's protection, reign over us with splendour.

"But thou, O Earl, withdraw thyself from the excommunicated Louis, and from the proud French strangers, who in the end will trample you under their feet. You have an honorable plea to leave them, that you may give due allegiance to your innocent nephew."

And when the Earl and his companions showed their anger at these words, Hubert looked back sternly on them and on his own brother, saying, "Be off, miserable wretches! For by God's thunderbolt if another word escapes from your mouths your hearts shall be pierced by arrows in an instant, nor think that I will spare my weak brother Thomas."

The Earl and his party, seeing instant death threatening them, for the bowmen were merely waiting for a sign from Hubert to discharge their already fitted arrows, retired rapidly and in some dismay.

When what had occurred at the parley was reported to Louis and the French nobles, they, although both pierced and angered, could not but admire the fortitude, fidelity, and energy displayed by Hubert.

The garrison of the Castle taking fresh heart, urged on the defence with greater alacrity than ever, and succeeded in laying low many of their opponents. Louis, at length, after holding a council of war, decided that it would be wiser to relinquish the siege for the present, and before undertaking it afresh to reduce to submission such of the lesser castles throughout the kingdom as still held out against him, so that the smaller places being subdued they might collect in greater safety for the attack of the more important ones.

This decision being carried out, the siege was ingloriously abandoned, and the enemy retired on London.

As soon as they were gone, the garrison of the Castle sallied out and burned the huts and buildings which had been erected, in great numbers, about Louis' camp, as at a fair or market. His people, foraging about the country in all directions, like bees seeking stores for their hive, had supplied the camp abundantly with all manner of provisions.

In the course of the following year, after meeting with serious reverses, especially at Lincoln, and after many of the English Barons had deserted his cause, Louis applied to his father to send him assistance from France. In answer to this appeal, a strong force was equipped, and set sail for London in a fleet commanded by one Eustace, an ex-monk, and a man of notoriously bad character.

The French troops embarked on the 24th of August, and were carried rapidly towards England by a strong and favourable gale.

They were altogether ignorant of the preparations which were being made to receive them.

Their fleet consisted, however, of 80 large ships, besides many smaller vessels and galleys, while the English had barely 40 vessels, furnished by the Cinque Ports, to oppose them, but all well manned.

When Hubert de Burgh, looking down from his Castle on the cliff, was informed of the approach of this formidable force, he took counsel with the Bishop of Winchester, the Marshal, and other magnates who were with him, as to what action should be taken.

Hubert argued as follows: "If the people be allowed to enter England with impunity, the King will be overcome and the Kingdom lost."

"It is, therefore, most important that they should be attacked at sea and kept away from our ports."

"For the very flower and heart of the French soldiery is coming over, and will certainly fight most desperately to relieve their master in his present difficulties. If they arrive safely in port, it will be a hard matter to resist them, but at sea we shall find them out of their element, and with little stomach for fight. Nor let us fear their number or strength, for God is with us, while they are excommunicated. God, who has begun to help us, will not desert us. Come then and follow me, showing thus your loyalty to your King and country."

When, however, it came to the Marshal's turn to speak, he made excuses, saying, "I am not a sea soldier, but a land one."

The knights and barons present also spoke to the same effect, saying that being neither fishermen nor pirates they were not accustomed either to being tossed about in a tempest or to naval warfare.

Hubert, grieving at these cowardly answers to his appeal, retired from the Council, secretly called his chaplain and confessor, made a full confession of his sins, and submitted to the most severe penance —then, all bruised and bleeding, he received the holy viaticum.

Endued now with the boldness of a lion, he called together the leaders of the garrison, and said to them:—

"I call you to witness through the blood of Jesus Christ, that if by chance I am taken captive, you may permit me to be hanged and all my family to be put to death, even should I myself come to your gates and cry for mercy, rather than give up this Castle into the hands of any Frenchman. For it is the very key and bar of England."

They, weeping, mournfully pledged themselves to do as he desired.

Hubert then, taking with him a few chosen men, among whom were Henry de Trubleville and Richard Luard, and a few others on whose courage and firmness he could depend, embarked in the principal vessel, saying to the nobles watching him on the shore, "If the enemy should get the better of us at sea, receive them on the beach at the point of the sword while they are upset by their voyage, and before the men-at-arms have time to mount their horses; and let not one of them escape. You will not, I know, be slack in taking vengeance at their hands for our blood and that of your brother soldiers."

The whole fleet was now waiting for his signal, and for the hoisting of his standard. The bishops absolved and blessed the soldiers as they went on board, and the sailors, who were hoisting the sails as they left the shore. The fleet sailed off boldly, but bore up to the wind, as if making for Calais.

When the monk Eustace saw this, he cried out "I know what these miserable fellows are about; they think to plunder Calais like thieves, but vainly would they attack it were their numbers ten times what they are, for the place is well fortified, and prepared to receive them."

And the English, being skilful sailors, and finding that the gale had spent itself, suddenly changed their course, and the wind now favoring them, bore down upon the enemy, and as soon as they touched the sterns of the hostile fleet, threw out drag-hooks and anchors, and drew the vessels forcibly towards them.

But Hubert de Burgh, with his companions, armed to the teeth, followed one especially large ship, in which many standards were flying, and which he concluded must contain the leaders of the hostile force, and, on reaching and making fast to it, he made a mighty jump, and boarded it.

And those who were with him, being provided with axes previously sharpened for the purpose, cut away the sheets and halyards, and the sails fell over the French, enveloping them like birds caught in a net. The most noble among them were spared for imprisonment, but the rest cut to pieces.

Phillip de Albinctus also, with his cross-bowmen and archers, poured such a deadly fire into those still holding their ground, as to cause great havoc among them. The English were provided with iron pointed rams, with which they pierced the sides of the enemy's ships, and sank many of them.

They also threw quicklime into the air, which the wind carried into the eyes of the French and blinded them.

There was hard fighting in some parts, but the French generally were inexperienced in naval warfare, and were soon reduced in numbers. For the English troops, accustomed to fighting at sea, pierced them with their arrows, darts and lances, stabbed them with daggers, cut them down with their swords, pierced and sunk their ships, and blinded the eyes of their crews with lime. All hope of flight or succour being now removed, many of the enemy threw themselves into the sea, rather than be taken alive. The triumphant English, taking the enemy's vessels in tow, ploughed their way through the waters towards Dover, rejoicing in their victory, and giving praise to God for his protection.

The nobles, and the garrison of the Castle, watching this unhoped for and glorious victory, came down to the beach singing praises to God.

The French prisoners were bound in close fetters, and led off to prison. Among them was the long sought Eustace, a traitor to England, and a most vile pirate, who had been dragged out of the hold of one of the ships. He was a native of Flanders, and had formerly borne the religious habit, but coming into an inheritance, his brother having died childless before him, he had apostatized, and thenceforward gave himself up to piracy and the most cruel and bloodthirsty raids.

When brought before the English and identified, he offered immense sums of money for the safety of his life and limbs, and promised to fight faithfully for the King of England in future. But a certain Englishman, seizing him roughly, cried out, 'you shall never deceive anyone again,' and drawing his sword, cut off his head.

But when the victorious Hubert came to land, the Bishops, standing on the shore, met him, vested in their sacred habits, with crosses and banners, solemnly chanting and singing praises to God. The knights and nobles also, who had been waiting on the shore ready to rush upon the enemy had they reached it, seeing the victory consummated, applauded the victors. The booty, consisting of gold, silver, silken garments, arms, horses, and prisoners became, according to custom, the property of the captors.

When Louis heard the news of this defeat, he grieved all the more bitterly over it on account of the disaster that had overtaken him at Lincoln.

Mathew Paris makes no mention of what, according to later accounts, formed a most important incident in the siege, viz.: the relief brought by Stephen de Pencester.

Nor does he mention any second siege by the Dauphin after its abandonment, towards the end of 1216.

After the Dauphin's departure, the constable set to work to increase the strength of the Castle, by forming an outwork (No. 35, *Plate* II.) at the northern angle of the works, from which he could command the main entrance. Towards the end of the last century (18th) this work was altered to its present form, and is now known as the spur ravelin and redoubt. The souterrain, or underground passage leading to it is, in part, the same that was made by Hubert de Burgh. Lyon attributes this work to Stephen de Pencestre.

St. John's tower rises from this souterrain. Lyon says a passage was made across the ditch "from St. John's tower, with a gradual ascent, until it opened in the surface, about the middle of the spur, in three branches. The eastern branch had a circular tower in the parapet of this outwork, close by the opening, to protect the men while entering in case they were repulsed. This tower was demolished in making the alterations in the end of last century."

There was also another gate in the caponier where the three passages met, secured by strong bolts and bars.

Dover may be proud of Hubert de Burgh. He was not only the greatest among the long roll of Constables of Dover Castle, but after the death of the Earl of Pembroke he was the greatest Englishman of his day, and for some time, as Regent, held the supreme direction of affairs. He came to his fall, eventually, from being too much of an Englishman, at heart, to suit either the King or his favourites.

It is recorded, that when dragged from a chapel where he had taken refuge, a smith, who had been ordered to shackle him, cried, "I will die any death before I put iron on the man who freed England from the stranger, and saved Dover from France."

Hubert, however, was thrown a prisoner into the Tower, and the King placed the government of the country in the hands of foreign favourites.

The great Simon de Mountfort, Earl of Leicester, who headed the revolt against this foreign tyranny and the King's capricious despotism, seized Dover Castle by stratagem in the early part of the war, and held it till his death at Evesham in 1265.

After the overthrow of Simon, says Lambarde, "Edward (then Prince, and afterwarde the first King of that name), assayled it with all speede, and (by the aid of the prisoners within, which had taken the great tower to his use), obtained it. There left he prisoned, Grey, the sonne of this Simon, but he escaped soon after, by corruption of his keepers. To make an ende, the nobilitie of that time were fully persuaded, that both the safetie and danger of the whole realme consisted in this one Castell; and therefore (saith Mathew Parise), that at such time as King Henrie the Third called over from beyond the seas his owne brother Richard (then King of the Romanes), the noble men (who had him in some iealousie), would not agree that he, or any of his, should once enter within this Castell."

In an entry in the Close Roll of 1223, it is stated that Henry III. ordered the church to be repaired at the same time as the Castle.

From 1223 to 1239, a sum of £2,923 was spent on works, principally the walls of the outer bailey.

About this time, also, a charge is entered for "making the Great Gate at the going out of the great barbican;" also for "repairing the King's apartments and chapel."

The spur passage was built in 1229, at a cost of £100, "*in un unâ voltâ facienda ad exeundum de castro versus campum.*"

A portion of this old passage now serves as an approach to the spur caponier. At the present end of the passage, beyond the caponier, it branched off in three directions towards the open country. All these branches have now been closed.

From accounts rendered by Stephen de Pencestre, kept in the record office, it appears that he was Constable of the Castle at least from the 7th to the 23rd years of King Edward I.

Darell, however, enters Pencestre on his roll of constables as immediately succeeding Hubert de Burgh, and retaining the office only till the death of Henry.

It seems highly probable that the Stephen de Pencestre, who so gallantly relieved Dover Castle during its attack by the Dauphin, was selected to succeed de Burgh, and it is possible that Darell had good authority for so entering him.

The Stephen de Pencestre, however, whose existing accounts show clearly that he was constable in the reign of Edward I., may probably have been a son or grandson of the first Pencestre. For, assuming the latter to have been not more than 30 years old when he relieved the Castle in 1216, he would have been 84 at the death of Henry in 1272, and could certainly not have lived up to the 23rd year of Edward I.

During the administration of one of these Stephens, certain statutes, or as we should now call them, "Garrison Standing Orders," were drawn up, which have been in part preserved to the present day. What remains of the original document is in the Surrenden Collection. The following translation of the fragment now remaining is taken from Puckle's "Church and Fortress of Dover."

Statutes of Dover Castle.

Promulgated in the reign of Henry III., and in due course declared in the time of Sir Stephen de Pencestre, Constable of the Castle at Dover.

I. At sunset the bridge shall be drawn, and the gates shut; afterwards the guard shall be mounted by twenty warders on the Castle walls.

II. Any warder found outside the walls, or otherwise off his guard, shall be put in the donjon prison, and punished besides in body and goods at the constable's discretion, since for that watch the Castle was trusted to him, not to be surprised through his default.

III. After the last mount, two sergeants shall turn out of their houses, to serve as chief guards. They shall make continual rounds within the Castle, to visit the warders on the walls and see that they right loyally keep their watch without going to sleep, by reason that they have the constable's leave to sleep as much as they like in the daytime.

IV. It is established by ancient rule, that if a chief guard discover a warder asleep, he shall take something from him as he lies, or carry away his staff, or cut a piece out of part of his clothes, to witness against him in case the warder should deny having been asleep, and he shall lose his day's wage, viz., jj*d*.

V. And if it happen that the sergeant will not make such caption, for pity's sake, or even for life's sake, then he shall be brought up before the constable, and be sentenced to prison "*dur et fort*," after which he shall be led to the Great Gate, in presence of the garrison, and there expelled the Castle, besides, he shall lose his wage, and forfeit all his chattels found within the Castle walls.

VI. Either serjeant or warder using vile words shall be brought before the constable, who shall have the thing considered and the blame fairly looked into. And he who had been in the wrong shall lose his day's wage—if the constable likes.

VII. If a serjeant or warder strike another with the flat hand, he shall be liable to penalties *(amendes)* as high as five shillings, and shall for the rest be held at the mercy of the Court. If he hit with his fist, he shall be liable to penalties as high as ten shillings, and be * * * (obliterated).

VIII. And because the Castle is out of the common jurisdiction, it is ordained that at every quarter of the year shall the whole garrison be mustered in presence of the constable, and any shall then before him be addressed and reprehended who may be accused of any notable crime, which ought of right by Holy Church to be dealt with. And if the constable find himself in any perplexity thereupon, he may take counsel of some parson *(perdosme)* of Holy Church, who shall give him advice what to do in any such case.

IX. There shall be one sergeant and one guard, elected in full garrison assembled, who shall be sworn to leal keeping of that light in Holy Church which is not burning inside the chauncel.

X. And because all priests are held obliged on their consciences to keep leal watch and guard over the chauncel lights—(the passage following is very obscure)—if any one knows of their doing other than they ought, he shall report or excuse them before the constable, unless indeed they might be willing to inflict penance on themselves—(passage effaced).

XI. Reliques are appointed to be shown, and such especially as are of the true cross *(verraie croies)* shall be brought out every Friday and placed on the high altar from the hour of ringing prime, to the end of high mass.

XII. They shall be open to all who wish to visit them, for the honour of God, and the benefit of the Chapel. Meantime one of the priests shall stop by the Reliques, or a Clerk, who shall be vested in a surplice *(surpliz)*; these may show and explain the Reliques, and pronounce *(pardonne)* to those who desire it.

XIII. At all great feasts of the year, scilt. of our Lord, and our Lady, of St. John, of SS. Peter and Paul, and of all Saints *(tous les seyns)* and such as are (dubbles) and solemn, shall *(nomie, nocturn?)* be sung. And on the vigils *(veillez)* shall be grand celebration (?) *(seyney)*; and afterwards, at the procession, and sequence, at matins, and vespers, shall be a *Te Deum, Laud and Gloria in Excelsis.*

XIV. At Christmas, Easter, Ascension, Pentecost, and the feasts of Our Lady, as well also at all chief feasts, shall all the peals, great and small, be rung; and once all together, for "the sake of the greater *(gréindre)* solemnity."

XV. Then, after the same manner it is ordered, that if a knight or lady, or a chaplain in the said Castle die, the commendation shall be made by all the priests *(de léys?)*, who shall be vested in *(chapes, copes? de goer)*—

XVI. And at the burial, in like manner as at mass, shall a deacon and a sub-deacon in * * * * * *

(Here the manuscript suddenly breaks off.)

Darell says that this Stephen de Pencestre who succeeded Hubert de Burgh, compiled a book called "The Castles Charter Book," from which Darell himself mainly compiled his own description of the Castle. It is much to be regretted that he did not cause an exact copy of this valuable document to be incorporated in his book.

The original was probably among the documents burnt, or sold to tailors to cut their patterns from, during the 18th century.

In one of the accounts rendered by Stephen de Pencestre, mention is made of supplying fitments to great bells in Julius Cæsar's tower, "*in turri Julii Cæsaris.*"

It thus appears that the old pharos had, at that time, been fitted as a bell tower to the church.

All through the days of the Plantagenets and Tudors, the keep and the outbuildings surrounding it were maintained as a royal residence, with rooms appropriated to the various members of the court and household.

Edward I. was a frequent visitor to it. Edward II. received his bride, Isabella of France, at the Castle. Not long afterwards he assembled his court there, to be present at the coronation of Philip of Navarre.

In the year 1295, the French made a raid upon Dover, but were driven off with heavy loss, not, however, before they had contrived to burn a great part of the town.

Walter Henningford gives the following account of the incident: One Thomas de Turbeville, who had been taken prisoner by the French, induced the French king to release him upon the following conditions:—

He was to make the King of England believe that he had effected his escape from France with great difficulty. He was to obtain from the king the custody of the sea coast and of the ports.

The King of France was to fit out a fleet to cruize along the English coast.

If, at any of the ports, they should see de Turbeville's ensign hoisted over the Royal Standard, they were at once to make in boldly to the shore, and de Turbeville would deliver up the place to them.

The French king accordingly embarked a large army in a fleet of 300 vessels, which cruized along the shore looking out for the appointed signal. Failing to see it, five chosen galleys were sent forward to make a closer reconnaissance.

One, going ahead of the rest, went in to Hythe, where the troops that were on board landed. The English, affecting alarm, retired. The French followed them; but before long the English turned round, fought, and defeated them, killing the whole, viz.: 240 men, and burning their ship. The other four galleys then retired to join the fleet.

On the feast of Saint Peter ad Vincula, the fleet anchored off Dover, where there had been no apprehension of their coming on account of the rocky nature of the shore and the height of the cliffs. About 15,000 warriors *(bellatores fortissimi)* landed, and sacked the town, burning a great part of it.

The inhabitants at first took to flight, but later in the day got together, and with the help of a military force '*qui curam maris habebant*,'* attacked the French so furiously, that they killed 5,000 of them. The rest were scattered in every direction. Some, taking refuge in the cornfields, were discovered and cut down by the country people. Some, however, escaped to their ships.

Thirty bold men defended themselves so well in the Abbot's close, that the Dover people failed up to late in the evening to turn them out, and the attack slackening, they managed to escape to the shore, and got away in two boats. They were, however, seen and followed by two vessels, which made after them, caught them up, and sank them. On the English side only 13 men fell. Of these one was a monk, who was killed before the very altar of his Church.

Thomas de Turbeville's treason being discovered, he fled to Wales, but was caught and executed.

Edward III. frequently visited the Castle. Queen Philippa lodged there in 1347, and crossed from Dover to Edward's camp before Calais.

In the record office is an interesting letter, written in the reign of Edward III., "*à son Seignr. Mestr. Robert de Ayleston, Tresr. Dengleterre* p. *son petit clerk Ambroise de Newburgh*," touching the state of the fortifications, etc., at Dover, which, when translated, reads as follows:—"I beg to inform you, my lord, that your letter *about* the Castle of Dover came to me at Hythe, which is seven leagues from Dover, where all the Mayors and Bailiffs of the Cinque Ports were assembled, the Thursday after the 'Goule Dangst,'† and the same day I went to Dover, and on the day after the sub-constable and I went to count all the loopholes in the Castle, and found that in

* A sort of coast guard.

† Probably "Yule of August, or Lammas Day."

the outer wall of the Castle there are 555 loopholes, and in the same walls are 19 towers, and a grand tower outside the gate, and another grand tower on the north side, of which grand towers the loopholes are included in the aforesaid number, viz., 555.

And because the rule in every castle or town enclosed by a crenelated wall is that there should be three men to every two loopholes, 832 men will be required for this outer wall. And in the tower and round the keep and the inner baileys are 378 loopholes, to guard which 168 men would suffice, making 1,000 men in all." Then follows a long detail of the provisions required to supply the garrison for 40 days, by the variety and amount of which, it appears that the British soldier of the period was remarkably well fed.

From the 2nd to the 17th years of Edward III., William de Clynton, Earl of Huntingdon, was Constable of the Castle and Lord Warden of the Cinque Ports. During his tenure of office, various accounts were rendered of works and repairs to the Castle.

In the 17th year of Edward III., Sir Bartholomew Burghersh succeeded the Earl of Huntingdon.

Between the 19th and 22nd years of Edward III. a new postern was erected near the edge of the cliff, and other minor works were executed.

The most minute accounts exist of the cost of all these works, and are preserved among the rolls in the record office.

About this time the Abbots of Langdon and of St. Radigunds, undertook the execution of various repairs at the Castle, and rendered their accounts for the same.

Roger de Mortimer, or "*de mortuo mari*," Earl of March, succeeded Sir Bartholomew Burghersh as constable. Some accounts of his exist of the wages of the men-at-arms and archers of the garrison of the Castle.

In the 34th year of Edward III., Sir John de Beauchamp (or de Bello Campo) de Warrewyk took over the office of constable. He died in the following year and was succeeded by Robert de Herle, during whose tenure of office various repairs and alterations were effected to the keep and other parts of the Castle.

De Herle held the office five years, when he died, and was succeeded by R. Spigornell, who held it for five years, and was succeeded by Richard de Penbrigge, to whom Edward granted the office for life.

In the following year, however, it appears to have passed into the hands of one Andrew de Guldeforde, and from him to William Latymer, the latter giving a receipt for all the goods, gold and silver vessels, etc., in the said Castle.

During Latymer's time various repairs were effected to the church and to the bell tower, or campanile, as the pharos was now called, as well as to various other buildings in the Castle.

In the early part of the reign of Richard II., Edmund, Earl of Cambridge, was constable. In the 5th or 6th year of King Richard he was succeeded by Robert Assheton, during whose time further repairs were effected to the church bell tower and other edifices within the Castle precincts.

Assheton was succeeded (in 9, R. II.) by Simon de Burley, and he again (in 11–12, R. II), by John Devereux, in whose time is an account of further repairs to the church bell tower "campanilum;" and to the arms, bows, arrows, "*balistis quarellis et aliis artilliis.*"

Devereux was succeeded by John de Beauchamp ("de Bello Campo"), and he again by John, Lord de Bellemonte, in whose time receipts occur for money paid by him to "William Werkyng, parson of the parish church within the Castle of Dover," and to Bartholomew Guypton, parson of the said church.

In the 12th year of Henry IV., the Prince of Wales is referred to as constable, one Andrew Boteler being his lieutenant.

Accounts are rendered by the Prior of St. Martin's for works and repairs to the church, the belfry, the chapel in dungeon, the Marshall's tower and bridge, etc., performed between the third year of Henry V., and fifth of Henry VI.

In the public record office, I have been unable to find any further records of the Castle until the 28th year of Henry VI., when, in the accounts of a certain bailiff and jurat of Romney, Humfrey, Duke of Buckyngham, is referred to as Constable of Dover Castle and Lord Warden of the V. Ports.

Lambarde (quoting John Rosse), says that "King Edwarde the Fourth, to his great expence (which others reckon to have been ten thousand poundes), amended it throughout."

No further note can be found referring to the Castle until the reign of Henry VIII.

For many centuries a gradual accumulation of shingle had been in progress in Dover Bay. The entrance to the harbour, which in Roman times appears to have been in a direct line with the course of the Down, through the Charlton and Buckland valley, was by this action carried further and further to the westward, and the channel at length became shallow and difficult.

Towards the end of the 15th century the state of affairs became so bad, that Henry VII. was induced to take measures for the construction of artificial works to improve the harbour. A pier was thrown out on its western side, with a view, probably, of arresting the travel of shingle from the westward. The work was entrusted to one Clark.

This pier appears to have been of some use, but being at length destroyed by the sea, another was commenced in 1533, by an engineer named Thompson, Henry VIII. advancing £500 for its construction.

It was formed of two parallel rows of piles, 26 feet high, driven into the chalk and fastened together with iron bolts and bars. Between the piles large blocks of stone and chalk were built up, and over these earth and pebbles were laid. Groynes were constructed at right angles to the pier, on its western side. The shingle, however, after filling up the angles formed by the groynes, was driven past the head, and again tended to obstruct the entrance.

It was then determined to carry the pier into deeper water. The end of it was formed into a platform of sufficient size to carry guns, and was called the "Black Bulwark." Beyond the end of the pier proper was a gap, or channel, and beyond this a breakwater was thrown out in line with the inner portion of the pier.

This advanced portion was constructed of solid stone. Henry VIII. took great interest in the work, and occasionally superintended it in person. He spent £63,000 on it, but failed to make the harbour a good one. In the latter part of his reign "his continental affairs, and the siege of 'Boulogne,' entirely withdrew his attention from it."

In June, 1513, the King embarked at Dover for the attack of France, taking with him a large force, which he had been for some time engaged in assembling for the purpose.

In Wriothesley's chronicle it is noted that the Lady Anne, daughter of the Duke of Clive, landed at Dover, and was honorably received by the Duke of Suffolk and other great lords, and lodged in the Castle, whence, after two days rest, she rode to Canterbury, where the King met her.

Lambarde, writing in the reign of Queen Elizabeth, says: "But now, in our memorie, what by decay of the haven (which King Henrie the Eighth, with the cost of 63,000 pounds upon a piere, but all in vaine, sought to restore), and what by the overthrowe of the religious houses, and the losse of Calais, it was brought, in manner, to miserable nakedness and decay.

"Which thing were the lesse to be pitied had it not been accompanied by the ruins of the Castell itselfe, the fall whereof is with our ancient storiers (above all other) most blasing and glorious. This therefore moved the Maiestie of our Soureigne Queene, that now is, to give gratious care to the complaint héerof, presented unto her, so she not only bestowed great favours of her owne gift, but also tooke order by Parliament in the 23rd yèere of her reigne, for a generall helpe upon the tonneage, towards the reliefe of this decaied Harboure.

"By which means, and by the industrious attendance of sundrie gentlemen of the countrie and others (put in trust to further the worke), a Pent and Sluyce hath been made, which open the mouth, and scoure the bottom of the haven, delivering it from that Beache (or bowlder stone) that before choked it, and is now (as it is said of a scorpion) converted to the medicine of that maladie which it had brought upon the place in such sort, as where before was not foure foote of water, a ship of some hundreds may now safely go in and out.

"If the like cure were done upon the fallen wals of the Towne towards the sea, where sometime stood Cowgate, Crosgate, and the Boutcherie Gate, advanced with Towers, the piere were much more both comfortable to the inhabitants and defensible against the enimie."

It is recorded that Henry VIII. also spent large sums on the repair of the Castle.

That it was his special duty to do so is evident; for acting as he had done with the suppressed religious houses, he appropriated to himself all the property that had been given by William the Conqueror for the maintenance and defence of the Castle.

Under Acts of Parliament 14 and 15, Henry VIII., c. 28 (A.D. 1523), it is enacted, that all such manors as were formerly holden of the Castle of Dover should be holden of the King.

The revenues of these lands, which must have increased enormously since the time of their grant to the Castle, thus passed into the King's hands.

During his reign Archcliff Fort was built. Seymour, in his *Survey of County of Kent*, published in 1776, says "on a small piece of chalky cliff, at the Pier, was a little chapel, supposed to have been built by a northern nobleman, who was in great danger of shipwreck at this place, and landed first here. It was called the Chapel of our Lady of Arcliffe, or Pity; it was valued at the dissolution at £59 per annum; and the sacerdotal vestments and decorations of the chapel, some of cloth of gold, some richly embroidered, were reputed worth 200 marks."

It is not quite clear whether this description applies to the site of

Archcliff Fort or to the Archcliff Tower, a bulwark shown in some old plans, nearer the pier. It appears likely, however, that it applies to the present fort, as there is no "small piece of chalky cliff" now standing nearer the pier, other than that on which Archcliff Fort stands, nor is there any record that any other cliff near the pier has been removed.

Henry finished Archcliff Fort before his death. An inventory taken of its stores shows its armament to have been as follows, viz.:

1 demy culverin,
2 sacres of brass,
1 fowler of iron,
3 single serpentines,
12 basses,
12 halbensters.

During Edward VI.'s reign, the harbour works were neglected and went to ruin in several places.

In Queen Mary's reign, attempts were made to repair the works, but without much effect.

Shingle, in large quantities, was driven over the shattered pier, and nearly choked the entrance to the harbour.

The ruinous state of the harbour, and the loss of Calais, reduced the town to great distress.

In Queen Elizabeth's reign, the work of repairing the harbour was again taken up with energy. Funds were raised and various engineers, both English and foreign, were consulted. A good deal of money was at first wasted, but some good work was at last effected.

Seymour, in his *Survey of County of Kent*, says, "Divers plans were formed in Queen Elizabeth's reign to make the ships ride in safety . . . and after several attempts to build a wall, which proved equally abortive, one made of earth and chalk, lined with faggots, was begun in 1583, under the direction of Sir Thomas Scot, with the assistance of Mr. Gilford, Captain of Arcliffe Castle.

"Two walls were made accordingly, but no ship above 50 tons, except at full seas, could come in. At the expiration of three years the work was found inadequate to the design, and instead of a small sluice, at first laid in the cross wall, another, considerably larger, with two gates, was substituted in its room; Lord Cobham, who inspected the new work, keeping an open table for the chief workmen, till the sluice was completed.

"After many subsequent repairs and alterations . . . to keep this harbour in a condition to receive vessels of considerable burthen, a few above 200 tons can come in with safety."

A new pier was eventually constructed on the foundations of that of Henry VIII. This formed the basis of the present South Pier. The North Pier was also constructed in Elizabeth's reign, and a wall was run across the bight of the bay, forming the Pent, its principal object at that time being to retain a body of water to flush out the mouth of the harbour.

This it did effectually, but at the same time undermined the foundations of the Black Bulwark, and other parts of the piers.

The defences of Dover at this time consisted of—

1 The Castle,
2 Moat's Bulwark,
3 Archcliff Fort,
4 The Black Bulwark on S. Head,
5 A platform for guns on W. Head,
6 Arcliffe Tower.

The general outline of the works as then existing was not much altered until the end of the 18th century.

The jetty (still existing) under the Castle Cliff was made in 1753, to check the travel of shingle to the eastward, and to retain it as a protection to the tower.

In 1573, the Queen made her celebrated progress through Kent, and staid at Dover Castle from the 25th to the 31st of August.

Between the years 1624 and 1625, a sum of £1,048 17s. 0¾d. was spent on repairs to Dover Castle, "Moate's Bulwarke and Arcliffe Bulwarks."

The stone used in these repairs was brought from Boulogne (Bulloygne), Portland, and Purbeck.

In the year 1639, the accounts of one "Capten John Paperill, deceased, late Lieut. Collonell and principall Engineer with His Majesty," were rendered.

Archcliff Bulwark is here described as being in a state of great decay, and at the same time of great importance to the defence of the harbour. This account does not describe the actual work done, but is made up of charges for materials and daywork.

In a further account of Alice Paverill, widow and executrix of the above, it is stated that—Four years since the repair of Archcliff Fort was estimated by Captain Paverill at £950, but nothing having been done, the decaies thereof had greatly increased and would require a greater sum to repair; "and forasmuch as the saide

Archcliffe Bulwarke is of great consequence in itself, and of great security to the stranger's ships that ride in the roade," a duty of 16 pence on each "packe of goodes" (on which they formerly paid only 4d.), is to be available for three years to Captain Peverill for the required repairs.

It also includes "Taskeworkes done by severall persons in buildinge of a wall aboute his Majesty's fforte, called Archcliffe Bulwarke, making of a Plattforme and Parepitt, building a Courte of Guarde within the said fforte, making a Gatehouse, squaring and setting and payveing Plattformes and Portholes, and building of lodgeings for Soldiers."

The accountant is allowed as follows :—

Repairs to Deale, Walmore, and Sandowne Castles in the Downes, in the year 1634	£714 13 8
Repairs to Southsea Castle, 1635	555 17 4
Do. do. 1636	394 15 3
Do. do. 1637	304 16 0
Do. to harbor and peere head in Dover ..	427 16 3
Do. same year for wages	244 15 6
Repayring of H. M. Fort called Archcliffe Bulwarke in the year 1639	2596 1 9
	£5238 15 9

Notwithstanding the sums expended on Dover Castle, and the minor works for the defence of the harbour, they appear to have fallen into decay during the reign of Charles I. Various petitions occur between 1637 and 1639, from the Earl of Suffolk, Constable of the Castle, to the King, begging for funds to repair the works. In one report he speaks of the "miserable defects of Dover Castle, wanting in all kinds of warlike provisions." He recommends that "Camber Castle" be sold for the repairs of other castles, and its soldiers, about ten, added to the gunners in Dover Castle, these being now but sixteen.

At another time he points out the inconvenience of removing from Governors of Castles the power of calling in the "garrison soldiers upon their service in the said castles," and that it will subvert the King's strength in that part of the kingdom. He prays that the power may be restored.

Sir John Manwood, Lieutenant of Dover Castle, points out also that for want of repairs and ammunition, the King's forts are unable to perform the duty they owe to His Majesty, and are subject to receive affronts.

In the year 1640, on the motion of the Earl of Suffolk, Lord Warden of the V. Ports, it was ordered by the Privy Council, that the Earl of Northumberland, Lord High Admiral of England, and the Earl of Newport, Master of the Ordnance, "should send an able and experienced man of the Trinity House, and one of the best of His Majesty's engineers to take an exact view of the present state and condition of the harbour and peere of Dover, and of H. M. fforte called Archcliffe Bullwarke."

One Sir Anthony Percivall was then Captain of Archcliffe Bulwark.

A sum of £2,143 13s. 3½d. was spent on the works ordered in consequence of this inspection, of which £1,843 6s. 3¼d. was expended on Archcliffe Bulwark; a work which was considered of vital importance to the safety of the harbour.

The neglected state of the works, and the insignificant garrison by which the Castle was held, made it a tempting prey for the Parliamentarians. The rebellion had not long broken out when it was seized by a party of the townspeople. The following account of its capture is given by Lyon.

In the year 1642, a merchant of the town, named Drake, a Parliamentarian, formed a plan to surprise the Castle. On the 20th August, about midnight, Drake, with ten of his fellow townsmen, climbed up the rock fronting the sea, each of them carrying a loaded musket. By means of ropes they drew up scaling ladders after them, to get over the walls in the quadrangle.

Having accomplished this feat without being perceived, they surprised the guard, which consisted of only four men, who finding themselves surrounded in the dark by an armed force, and concluding it was much greater than it really was, surrendered without resistance.

The assailants then demanded of the porters the keys of the castle gates. They, threatened with death if they refused, gave them up. The remainder of the garrison (only twenty in all), thoroughly surprised, surrendered to Drake and his party.

On receipt of the news of the surrender, the leaders of the Parliamentary party immediately sent Sir Edward Boise (or Boys) to Dover with a sufficient force to take charge of the Castle.

In the following month (September, 1642), an attempt was made by the Royalists to recapture it, but without success.

On the 14th September, an order was issued thanking the volunteers of Canterbury for their defence of Dover Castle.

In July, 1643, an order is issued by the Parliament for the payment of £400 to Sir Edward Bois, out of a fifth part of the Estates of Delinquents in Kent, upon account, £200 for payment of the garrison, and £200 for mending a breach in the walls of the Castle.

In the following month, a prohibition is issued against the erection of buildings on waste ground adjoining the Castle "of dangerous consequence" to the safety of the fort.

Various plans were made by the Royalists for the recovery of the Castle, but they were discovered before they could be put in execution, and no serious attack was made until 1648. In that year, however, the loyal party in Kent managed to raise a sufficient force to make an attempt upon the Castle.

The Royalist troops were commanded by Sir Richard Hardres (or Hardresse).

They succeeded in seizing Deal, Walmer, and Sandown Castles, and brought a force of 2,000 men before Dover. Works of attack were thrown up on the north side of the Castle, in front of the spur.

The Royalists had, however, not long opened fire, when a superior force of Parliamentarians, under Colonel Rich, came to the relief of the garrison. The siege was then somewhat precipitately raised.

No further attempt was made by the Royalists to recover the Castle.

At the Restoration, in 1660, the Duke of York was appointed Constable of Dover Castle and Lord Warden of the Cinque Ports.

In the beginning of 1661, a general retrenchment was made of the garrisons of Upnor, Walmer, Dover, Archcliff, Sandown, Sandgate and Deal.

In March, 1661, a grant was made to Sir Bernard de Gomme of "Engineer of all the King's Castles, etc., in England and Wales," with a fee of 13s. 4d. a day. He was ordered to keep an exact account of all engines to be made by him and disbursements of money.

In the same month, a grant was made to R. Woodward of the office of Keeper of Mote's Bulwark, under Dover Castle. Fee twenty pence a day and sixpence each for two soldiers, to be nominated by him.

In 1662, Sir Francis Vincent is appointed Governor of Dover Castle.

In 1660, the following establishment was laid down for the garrison of Dover Castle and Moat's Bulwark, viz. :—

"The Governor, who in his absence, is to appoint a Deputy Governor.

"The whole garrison is manned with two companies, consisting of two Captaines, whereof the Governor to be one, at 8s. per diem, two Lieutenants at 4s. per diem, two Ensigns at 3s., foure Sargents at 1s. 6d. per diem, 6 Corporals each at 1s., two drummers each at 10d., and 200 soldiers each at 8d. per diem. One Gunner at 1s. 6d. per diem, two Gunners Mates at 1s., four 'Matrosses' at 10d. per diem, fire and candles 3d. per diem."

The Governor of Dover Castle is to take care that Moat's Bulwark "is alwaies suplyed out of the two companies before mentioned, with 30 men and an officer."

Archcliffe Bullwarke.

"This Bullewarke is to be maintained with one company, consisting of a Captaine, to be also Governor, at 8s. per diem, a Lieutenant at 4s., an Ensign at 3s., one Sargeant at 1s. 6d., two Corporals at 1s., and sixtie Souldiers each at 8d. per diem., one Drummer at 10d., one Gunner at 1s. 6d., two Matrosses at 10d., Fire and Candles at 6d."

The above appears to have formed the garrison of Dover at the time of the Restoration.

Very shortly afterwards, however, viz.: in 1661, it was reduced to a mere nominal strength.

In a letter to the Sheriff of Kent, dated 25th June, 1660 (Legal year), or 1661 A.D., the garrisons of all the coast forts are ordered to be cut down. Dover Castle is to be maintained by the Lord Warden, one Gentlemen, and 17 Gunners, and Moat's Bulwarke is to have a Captain, a Lieutenant, a Master-gunner, and 12 other Gunners.

In May, 1661, the mayor and citizens of Dover appeal against this wholesale reduction. In their petition they state that in the late distractions the Castle and ordinary garrison were surprised by a small party and possessed all along by the enemy, who kept the Loyalists in continual slavery. They fear a like surprise again. This petition is numerously signed. A similar appeal is made by the inhabitants of the county.

On the 20th May, 1652, a Dutch fleet anchored in Dover roads. The guns of the Castle and of Moat's Bulwark opened fire upon it, but were unable to reach it. The Dutchmen appeared to have done no damage to the town, and to have been contented with making a demonstration of their force.

On 20th May, 1660, Charles II. landed at Dover, having been escorted from Scheveling by a fleet of twenty sail, under Admiral Montague, afterwards created Earl of Sandwich. General Monck met him on the beach, and was most graciously received.

The mayor, on behalf of the town, presented a richly mounted Bible, which the King said was the thing he loved above all in the world. He made no stay at Dover, but drove at once to Canterbury, accompanied by Monck.

But few records can be found of anything connected with Dover in the latter part of the 17th, and in the early and middle part of the 18th, centuries.

During Marlborough's wars Dover Castle was one of the places of confinement of the French prisoners, many of whose names may still be seen cut on the walls of the keep, especially in King John's Chapel.

About the middle of the century barracks were built in the Castle, on the site of the present drill-ground. New batteries were also constructed, one for four guns near the old church, and one for six guns where the Bell Battery now stands. Alterations were also made to the advanced work at the north salient, which had been formed by Hubert de Burgh after the siege in 1216.

A copy of an old plan of the Castle, made in 1756 (see *Plate* V.), is attached, showing these and other minor works executed about that time. *Plate* VI. gives a general view of the town in 1739, and shows approximately the positions of the fortifications.

The correspondence on record in the Royal Engineer Office at Dover begins in November, 1778, with an estimate for the following year for works in various parts of the district, including Sheerness, Gravesend, Tilbury, "Cinque Ports Division," and Dover.

Mr. Page, afterwards Sir Thomas Hyde Page, was at that time Commanding Engineer.

In the year 1779, England was at war, not only with her American Colonies, but also with France and Spain. As the two latter powers possessed a combined fleet greatly superior in numbers to our own, some apprehension arose that an invasion might be attempted.

Various preparations were made along the coast to meet this contingency. Earthen batteries were hastily thrown up at Dover; one of these, called North's Battery, was erected in the centre of the Bay, opposite the present gardens at the end of Waterloo Crescent.

Another, called Amherst Battery, was a little east of the north pier, and a third, Townshend's Battery, to the westward of the harbour, about where the South Eastern Railway Station now stands.

The Commanding Engineer appeals to the mayor to assist him in carrying on this work with all expedition.

The positions of the above batteries are shown on *Plate* V.

During the spring and summer of 1779 these works were developed into permanent batteries, and about the same time the first earthworks were thrown up on the Western Heights.

Under date 29th May, 1779, the Commanding Engineer writes to the mayor, complaining of difficulties made by a certain timber merchant in the execution of the works, and points out that they were first undertaken at the pressing solicitation of the Corporation, "but are now become immediately necessary at this alarming crisis for the safety and preservation of this town, its harbour, and inhabitants."

The works were executed chiefly by military labour from militia regiments.

The authorized rates of working pay were for artificers 1s. 3d. per day, labourers 9d. per day, if tools were found by Government.

When no tools were found they were paid double the above amounts, or about the ordinary rate of "country wages."

In August Sir Hyde Page reports to the Master-General that he has twenty-eight guns mounted in the new batteries, with a guard of only twenty men, which is to be withdrawn into the Castle in case of danger.

He suggests drilling volunteers from the town to work the guns and defend the batteries. He states that several French privateers are within sight of the town, and no English ships in the Downs.

In November, Lieutenant Page forwards his abstract of estimates for 1780. It contains, among many others, the following services:

Converting the old church into a cooperage and storehouse, in order that the keep may be given up for the use of the troops	£700
Repair of Moat's Bulwark, as arranged by Master-General	£1,200
Reform of Archcliffe Fort, as approved by ditto	£1,200
Powder magazine in Dover Castle	£2,200

In September, 1781, the Commanding Engineer proposes to arm the new works upon the Heights with the following ordnance, viz.:—

24-pounders			16
18	,,		20
6	,,		24
68	,,	canonades	12
		Total	72

The progress of the works appears to have been impeded by the want not only of men, but of money.

In February, 1782, Mr. Bigges, First Assistant Engineer, urges the necessity of an immediate grant of money, so that he may not be under the necessity of stopping the works "both in respect as it would be highly prejudicial to the service, and extremely mortifying to my friend Page, whose only wish is to have the defences in such forwardness early in the spring, as to place him beyond the fear of insult. To keep the daily labourers on I have left myself bare indeed, but I do not in the least regret my own situation, if by it I can forward the wishes of so deserving an officer."

In another letter the same officer states: "the little stock of ready money I could raise of my own has been expended, to keep the labourers at their work. All permanent employés have been kept without pay for two months."

Happily, the patriotism of the Engineer officers of the present day is not required to stand the test of having to pay large bodies of labourers out of their own pockets.

In September, 1782, Sir Hyde Page writes to General Conway that the Admiral's ship, and all the trading vessels from the Downs, had sailed for the Nore, or Thames, to avoid the danger of meeting the Dutch fleet. This was probably the last time that a Dutch fleet was treated with such respect by a British Admiral.

About the end of the year 1782, peace having been concluded with France, Spain and Holland, all military establishments were at once reduced to the lowest possible scale.

In Dover, an overseer and eighteen labourers only were retained to carry on the ordinary engineer repairs.

From this date the correspondence is for some time confined to uninteresting details regarding the maintenance and repair of the various forts and works.

In September, 1785, arrangements were made for connecting the triangulations of Great Britain with that of France, by means of a large instrument to be fixed on one of the towers of the keep of Dover Castle. France's revolutionary troubles stopped the work for a time, but it was resumed at the close of the war.

About this time the first company of Royal Military Artificers was raised for service at Gibraltar, and the Commanding Royal Engineer at Dover is ordered to endeavour to enlist artificers for it. In the following year six more companies were raised.

Lieutenant Hay, who was in charge of the works at Dover at this time, reports on the state of the works, and proposes to run out a pier, or breakwater, for the protection of Amherst Battery, which has been damaged by the sea. In doing this he suggests making use of the foundations of an ancient breakwater he has discovered there.

These works were executed in 1788.

In December, 1788, Townshend redoubt and breakwater were much damaged by the sea. The cost of repair was estimated at £1,249.

In January, 1793, war with France being imminent, a close inspection is made of the works at Dover, and repairs are recommended for immediate execution at Dover Castle, Moat's Bulwark, and Archcliff Fort. Most of these were put in hand in the following month.

In June, the re-building of Townshend's Battery is authorized.

In 1794, arrangements were made for accommodating more men in Dover Castle. A part of the proposal was to fit up for sixty men a "room at present occupied as a barrack store, formerly made use of as a chapel." The building referred to was probably the Castle church, which, in 1779, had been converted into a "cooperage and store-house."

In this year the shaft of communication from the Castle to Moat's Bulwark was commenced. A temporary barrack for sixty men was erected in Archcliff Fort.

In February, 1795, Lieutenant Bruyeres reports on arrangements for sinking a third shaft from Dover Castle to Moat's Bulwark. The access to the Castle from Moat's Bulwark, known as the "Guilford Shaft,' really consists of four separate shafts connected by inclined galleries. The shaft here spoken of would therefore mean the third of the above series of shafts.

The barracks, at that time (a time when less than half the cubic space now allowed, per man, was considered sufficient), were calculated to contain—

Dover Castle	724
Archcliff Fort	120
Western Heights	60
Total	904 men.

To increase the strength of the garrison, it was proposed to convert four new stables on the Western Heights into barracks for eighty men each, to build additional barracks on the Western Heights for sixty men, to convert the existing hospital in the Castle, much complained of as such, into quarters for fifty-six men, and in view of the contemplated formation of the new entrance, to convert the building at the old entrance (the Constable's Tower) into a barrack for forty-four men.

These additions would raise the accomodation to 1,384.

Considerable alterations were made this year to the debtor's prison,* and Bodar's house in Dover Castle.

In August of the same year, a hostile landing was considered so imminent, that the General Commanding demands coals for heating shot to be supplied to the various batteries, so as to be in immediate readiness to meet an attack.

In this year a new gateway and drawbridge at the new entrance was erected, and a covered communication to the detached works made, and the advanced works called the spur was re-modelled.

In this year extensive alterations were made to the old works at the spur, and by the end of the following year they were brought into much the same state in which they now exist.

Hudson's bastion, the east demi-bastion, and other works on the east front, including the caponiers and galleries, were completed about the same time.

The cliff casemates, formed by tunnelling into the face of the chalk cliff, were also finished about this time, and Colonel Twiss reports that they "exceeded his expectation both in point of solidity and dryness."

He recommends the immediate construction of others at the same level, to serve as stores for provisions and liquor.

The General Commanding thinks this so necessary, that he immediately orders twenty-five miners from Ashford to Dover to get on with the work.

* This building is that now used as a Division Royal Engineer Office.

In July, 1798, the Board of Ordnance approve of the employment at Dover of Mr. Burgoyne (afterwards Field-Marshal Sir John Burgoyne, G.C.B., Bart.) as an assistant engineer until a vacancy shall occur in the Corps of Royal Engineers.

On the 29th of August of the same year, Mr Burgoyne receives his commission as 2nd Lieutenant.

In this year, 1798, the new road up the Castle Hill was handed over to the trustees of the Dover and Deal public road, in place of the old Castle Hill road, which became the property of the Board of Ordnance.

A bombproof was formed over an old well in Dover Castle, and a machine was constructed for raising water from it. The well was 370 feet deep.

Another machine was erected over the new well (200 feet deep).

A new hospital was ordered to be commenced, to accommodate sixty men, at a cost of £2,109. This would seem to be the existing old hospital at the edge of the cliff.

In April, 1800, General Morse, Chief Royal Engineer, writes to Colonel Twiss, who has been temporarily employed on special duty away from the district, desiring him to take up his former duty "upon the coast of Kent and Sussex, and to resume the charge of the Engineer Department in the Southern District, as well as your duty as Lieutenant-Governor of the Academy at Woolwich." As at that time the coast was bristling with forts and batteries, and there was a constant anticipation of attack, the Woolwich cadets cannot have been troubled with much of their Governor's presence.

In this year the parapet of Lord North's battery, which had fallen into decay, was removed, the Corporation being allowed to use the materials in the new bridge across the Dour, at the entrance to Bench Street.

In the early part of 1801, an invasion was again considered imminent, and large supplies of ammunition and provisions were laid in at the Castle.

Countermines were formed in the salient of the spur ravelin, and a number of traverses thrown up along the ramparts.

The following detail was drawn up for the distribution of the garrison, in view of an expected attack:—

Return of the Bomb-proofs provided in Dover Castle for the Lodgment of the Garrison, distinguishing what are appropriate for the men off Duty, for those on Picquet, and them on Guard.

			Off Duty. Present berths contain.	Off Duty. May be fitted to lodge during a siege.	On Picquet.	On Guard, of which one-third will be sentries.	Where artillery or picked men must be kept.	
Out-works.	East Demi Bastion.	Sally Port.	—	—	12	17	—	1 officer
		Guard Room.	—	—	12	17	—	1 officer
		Suffocating Chambers.	—	—	—	—	3	—
		East Arrow.	—	—	—	10	—	—
		East Ravelin.	—	—	—	14	—	1 officer
	Hudson's.	Communication.	—	52	—	—	—	& offirs.
		Guard Room.	—	—	34	29	—	& offirs.
		Suffocating Chambers.	—	—	—	—	7	—
		Curtain.	-	—	—	—	8	—
	Averanche's.	Guard Room.	—	—	24	17	—	& offirs.
		Suffocating Chamber.	—	—	—	—	16	—
	Spur.	Guard Room.	—	—	—	28	8	—
	Bastion old entrance. Low flank	Guard Room.	—	—	—	14	—	—
	curtain.	Guard Room.	—	—	—	14	—	—
	Flat Bastion.	Guard Room.	—	—	—	8	8	—
	Guilford's Battery.	—	—	—	—	24	12	1 officer
Caponnieres.	East.	Upper floor.	—	18	—	—	—	& offirs.
		Ground floor.	—	50	—	—	—	—
		Entrance.	—	—	—	11	4	—
Caponnieres.	Spur.	Floor.	—	20	—	—	4	& officer
		Round Tower.	—	16	—	—	—	—
		East Wing.	—	—	—	—	12	—
		Entrance.	—	—	—	15	4	& officer
		West Wing.	—	—	—	—	12	—
	Old Entrance.	Ground floor and entrance.	—	—	—	17	—	
		1st Floor.	—	10	—	—	4	& offirs.
		2nd Floor.	—	8	—	—	—	
		3rd Floor.	—	8	—	—	—	
	New Entrance.	Sally Port.	—	—	—	17	—	—
		1st Floor.	20	20	—	—	4	—
		2nd Floor.	27	27	—	—	....	—
Ramparts.	Hudson's.	Entrance.	—	60	—	—	—	& offirs.
	Averanche's.	Casemated flank.	—	—	—	—	—	—
		Lower flank.	—	—	—	—	—	—
	Between the	Spur and Averanche's	—	—	—	—	—	May be made for 300 men. Thisyear probably 100.
	Spur.	on two floors.	320	400	—	—	—	No. 1. for Officers
	Old Entrance.	—	—	—	—	17	—	—
	Bake House.	—	—	—	—	17	—	—
	Shaft.	—	—	—	—	—	—	10 Master Artificers and Overseers.
	Four cliff case-	mates havi g 2 floors each	392	592	—	—	—	& offirs.
	Roman	Intrenchment.	72	72	—	—	—	& offirs.
	Keep.	—	100	400	—	—	—	& offirs.
		Total..	931	1753	82	312	122	

The armament of the Castle was fixed as follows:

Mortars	13-inch	4
,,	10-inch	8
,,	8-inch	4
,,	$5\frac{1}{2}$-inch	3
,,	$4\frac{2}{5}$-inch	9
Howitzers	10-inch	4
,,	8-inch	1
Carronades	68-pr.	10
,,	24-pr.	15
,,	12-pr.	19
Guns	32-pr.	22
,,	24-pr.	10
,,	18-pr.	18
,,	12-pr.	12
,,	9-pr.	8
,,	6-pr.	4
Amusetts		10
Wall pieces		50

The above, proposed by the Commanding Royal Engineer, was approved by the Board of Ordnance, and in the early part of 1801, the ordnance and ammunition to complete it was ordered to be sent at once.

In 1801, the Commanding Royal Engineer examines and reports on the batteries along the coast of Sussex. At Littlehampton he proposes the substitution of French 36-pounders for the existing 18-pounders. At Brighton the 12 old guns are so defective that the officer commanding the "Sea 'Fencibles' reports that some of them take a horn of powder to prime them."

In the same month he reports on the defence of the coast from Selsea Island to Dover. He considers "Hythe Bay, and indeed all the coast from Romney Marsh to Dover, in a very formidable state of defence." But the defences of the coast further west he thinks weak, and require much watching.

With regard to Selsea Island and Bognor, he says: "There are no troops on this part of the coast, except 100 employed at these three batteries (Selsea Island, Bognor, and Littlehampton), and was an enemy to move directly from Arundel to Kingston-on-Thames, about 45 miles, no troops in the southern district could be brought to act against him unless our troops moved faster than the enemy."

He concludes his report as follows :—

"I have always supposed it improbable that the enemy will land in any very regular order, or even in the place he is destined to on leaving France, for short as the passage is, he cannot quit his own coast a single mile without the utmost dread of meeting our naval force, and if the winds and tides fail him, or deceive him, his fears will hardly permit him to delay his landing, until he can assemble his force, but he will probably make on shore as soon as possible, let the situation of his boats be what it may; hence it appears wise to disperse our force in a manner which would not be justified if the enemy was master at sea, and could arrange his landing as the English did at the Helder and in Egypt." Colonel Twiss thinks great impediments might be offered to an enemy by opening the sluices under proper management.

There is no doubt that the command of the sluices in Romney Marsh will at all times form an important element in the defence of the coast of Kent and Sussex.

Supplies of intrenching tools, and of axes, saws, etc., were issued to the various stations along the coast, as well as to the troops occupying an inner or second line further inland, and the Commanding Royal Engineer takes the precaution of having all axes sharpened, and all saws set, so as to be ready for immediate use.

In August, 1801, the Commanding Royal Engineer is authorised to insert in the annual estimate for 1802 an item for revetting the scarps of the redan, or ravelin, at the spur, and for "constructing in it a bombproof guard-room and passages, and hanging the doors with a proper drawbridge." Pending the approval of the estimates, the escarp is to be cut down "to the greatest slope it will bear, in order to guard against an assault."

In the same month, the Commander-in-Chief, His Royal Highness the Duke of York, makes a tour of inspection along the coasts of Kent and Sussex.

The following arrangements are approved by his Royal Highness for the distribution of the troops along the line of coast :—

Place.	No. of Men.	Remarks.
Arundel, on opposite side of river.	500	To defend or destroy bridge at Arundel, over the Arun.
Little Hampton.	200	To man the present battery, or any that may be erected to defend entrance of river Arun.
Old Shoreham.	500	To defend or destroy the bridge near Shoreham, over the Adur. On account of health, and the toll payable on this bridge, the barracks should be near Old Shoreham.
Newhaven.	200	To defend or destroy the bridge over the Ouze, as well as to man and defend the battery at the mouth of the river.
Southbourne, or Eastbourne.	500	To defend the landing at, or near, Langley Point, and to co-operate with Royal Artillery stationed at Ringmoor, against any enemy who may land in Pevensey Level.
Bopeep.	—	The present barracks to be occupied, and proper ones built for officers. The objects to defend, the landing at Bulverhither, to protect the road and bank through Crowhurst Park, and to command the sluice near it.
Hastings.	—	To assist the Volunteers and Sea Fencibles in the town in defending the very strong coast between Bopeep and Hastings, as well as to protect the great road leading over Fairlight.
Winchelsea. Scot's Float, or within one mile of it.	700 300	To protect the landing between Fairlight and Rye Harbours, also to defend or destroy the great sluices at Scot's Float, through which the sea would form an inundation round Oxney Island, and reach up within two or three miles of Silver Hill. Likewise Guilford sluices, through which the sea would form an inundation over a considerable part of Romney Marsh, and would meet the waters which might be let through the sluices in Dymchurch Wall at the foot of the high ground behind Romney Marsh.
Total...	3,200	

The following note is added :—

"These, with the barracks already established, seem to form a good line for the coast, but leave the necessity of a second line of defence.

"It appears further necessary to place guards, and perhaps a few heavy guns, at the principal sluices which drain Pevensey Level and Romney Marsh, and if a regular meeting could be had with the commissioners of these levels, it is supposed measures might be taken that on the appearance of enemy in force, these sluices might be in part destroyed, so as to overflow so much of the interior of the the country as would greatly embarrass an enemy in his movements, both forward and on his flanks, and perhaps prevent a great part of his army from procuring a supply of fresh water, and this without the smallest injury to individual property unless the enemy did actually make his appearance in force."

In September, 1801, owing to a want of sufficient Royal Engineer Officers on the active list, Captain Smart, on the retired (or invalid) list, was appointed to take charge of the thirteen batteries between Dungeness and Hythe.

The following is a list of the batteries existing along the coast of Kent in 1801 :—

		Guns.
Dungeness.		
4 Batteries of 4 guns each		16.
Redoubt		8.
Hythe Bay.		
Moncrief Battery		8.
Sutherland's Battery		8.
Twiss's Battery		6.
Lympne Heights		4.
Shorn Cliff	24-prs.	10.
Sandgate Castle	Do.	4.
Do. do.	18-prs.	4.
Folkestone	Do.	4.
Dover Castle.—(See anti-separate return).		
Walmer Castle	36-prs. (French)	10.
Do.	9-prs.	1.
Deal Castle	36-prs.	10.
Do.	9-prs.	1.
Sandown Castle	36-prs.	10.
Do.	9-prs.	1.

Tennant Hill Battery ... 36-prs. .... 6.
Do. ... 9-prs. .... 2.
Maiden Hill Battery...... 36-prs. .... 6.
Do. ...... 9-prs. .... 2.

Besides the above, there were roughly formed batteries at Ramsgate, Broadstairs, and Margate. They were armed, but the number of guns is not stated. They were in the hands of volunteers.

The batteries on the coast of Sussex were as follows:

	No. of guns.		Nature.
	Mounted.	Dismounted.	
Rye	2	14	
Greedy Gut	2	—	
Winchelsea	2	—	
Fairlight Signal House	1	—	
Hastings	5	5	24-prs.
White Rock	3	—	
Eastbourne, East Battery	6	—	
Do. West Battery	6	—	
Anthony Hill	2	—	
Seaford	5	—	
Newhaven	8	—	New 24-prs. to be changed for 36-prs.
Brighton, East Battery	4	—	
Do. West Battery	8	—	
Signal House	1	—	
Do. Shoreham	1	—	12-prs.
Brighton	1	—	
Littlehampton...	9	1	18-prs to be changed for 36-prs.
Barn Rocks	2	—	36-prs.
Selsea	3	—	

In October, 1801, the preliminaries of peace between France and

England were signed, resulting in the peace of Amiens, which was concluded in the following year.

In the expectation that the war had now come to a close, the works undertaken to improve the defences were cut down as much as possible.

The following were, however, allowed to proceed in Dover Castle, viz.: Countermines in the salient angle of the spur, the bombproof guard-house behind the great traverse covering the new entrance, and the removal of the right face of the spur bonnet.

In April, 1802, orders were issued for the immediate dismantlement of the batteries round the coast of Great Britain. The guns and ammunition to be taken into store.

At this period all guns and carriages mounted in batteries were in charge of the Commanding Royal Engineer, who was responsible that they were kept in proper repair. When dismounted the carriages were taken to pieces by him and defects made good.

In July, 1802, a general order was issued that soldiers were always liable to be ordered on working parties as a duty.

"But His Majesty, at all times anxious to promote the comfort and advantage of the soldier, has been graciously pleased" to allow working pay as follows, when employed on permanent military works, public roads, and the military services of the Ordnance in Great Britain and Ireland, viz.:—

Subaltern Officers ....4s. per day.

	Summer.	Winter.
N.-C. Officer (overseer), 1 for every 20 men ...	1s.	1s.
Do. or privates as artificers	1s. 8d.	1s. 4d.
Privates as labourers	10d.	8d.

The hours of labour in summer are 10, in winter 8.

His Royal Highness the Commander-in-Chief desires it to be clearly understood that except on very special duties, at sieges, etc., no working pay is to be allowed for work in camp or on service, "when work becomes the most important of duties, when the bodily exertion of every individual of every rank must be commanded to facilitate the operations, strengthen the positions, and ensure the general safety of the army, and when the spade and pickaxe and barrow are as essential for the defensive as that of the musquet and bayonet are for the offensive operations of the army."

In the spring of 1803, war having again broken out between France and England, the whole of the guns were ordered to be immediately re-mounted in the batteries on the coast of Kent and Sussex.

In July of this year, Colonel Twiss reports that he has "attentively viewed" the Western Heights, with the "idea of improving the works begun there during the American War, by a system of field fortification, so as immediately to form this position into an intrenched camp where a corps of 5,000 or 6,000 men might remain in security, and with tolerable convenience, and in readiness to move against an enemy whenever required."

He considers this impossible during the present summer, "besides, a corps stationed here would have the sea in its rear, and such strong ground in its front and on its left flank that it might be kept in cheque by an equal force, and, so situated, would in a great measure be deprived of the security of a fortress and the power of moving as a corps in the field."

He continues: "I do not conceive that this opinion militates against the idea of occupying Dover Heights with a respectable fortress, or by several detached redoubts well revetted, as I am convinced that by either of these systems many essential advantages would be obtained, but the expediency of immediately beginning such works can only be determined by those high powers who are acquainted with all the means and all the wants of the country."

Sandgate Castle he thinks should be strengthened "by throwing arches over some of the towers," and by making other alterations.

He recommends the erection of towers in Twiss, Sutherland, and Moncrief batteries.

These precautions, with Shorncliff battery and a barrack of 500 men in its rear remaining as it was, and with the addition of a projected barrack for 1,400 men behind Hythe, should, he thinks, effectually secure the bay.

He lays great stress on the guarding of the sluices in Romney Marsh, and for that purpose recommends the erection of towers at Dymchurch, Scot's Float, and East Guildford, near Rye.

With the command of the sluices, the ditches in Romney Marsh could be kept filled with water to such an extent as to prevent an enemy from penetrating far into the country if he landed between Rye and Dymchurch, "and if the bridges on the Rother, between Rye and the forges, were secured," the country could be inundated as far as the forges near Silver Hill.

The intervals between Moncrief Battery and No. 2 Battery, Dungeness, and also between No. 4 Battery, Dungeness, and the old

Rye Harbour, are not defended, on account of the difficulty of landing, due to the great distance to which the tide ebbs out.

The shore between old and new Rye harbours he considers well secured by nature, but the line of coast from thence to Fairlight should, he thinks, be occupied by three towers, with batteries of four guns each, supported by a regiment of 700 or 800 men in barracks between Winchelsea and Rye.

From Fairlight to Hastings he considers the coast inaccessible, owing to the cliffs and the clay, except at a few passes which should be occupied by troops as soon as an enemy is known to be prepared for sea.

About this time the Commanding Royal Engineer reports on the general principles on which Dover Castle was occupied during the late war.

He says: "It was obvious that the great ditch which surrounds Dover Castle afforded the means of obtaining a post defensible against a *coup de main* in a shorter time than could be done by occupying any other place near Dover; and in commencing works for the purpose, the degree of defence aimed at was that the enemy shall not possess this Castle in fourteen days from the day he has made his landing good.

The first objects pursued were interior and exterior communications, forming ramparts of earth behind the old walls, deepening ditches, and making their escarps and counterscarps more inaccessible; then obtaining by excavations and other means bombproof casemates and powder magazines, as well as securing a proper supply of good water.

The Commanding Royal Engineer recommends that a set of young soldiers who can run well should be employed to catch the enemy's engineers while reconnoitring at night."

The posts of next importance he considers to be the east demi-bastion and the new entrance, which should also be commanded by selected officers. He recommends that the same officers should, as far as possible, mount guard on the same work, so as to become well acquainted with the defences.

Three sets of countermines exist in the front of the spur, each set having three tiers of mines, so as to blow up the same ground three times.

A proportion of cavalry should be in the Castle, to be employed, among other duties, in catching the enemy's reconnoitring officers.

A portable telegraph should be established in the castle.

About this time the first suggestion appears to have been made to erect a system of towers along the coast to defend all convenient landing places. Captain Ford, R.E., makes a proposal to that effect. The towers he proposed were to have "the inferior part so covered by the exterior profile as not to be battered from the sea."

They would have been more formidable had they been all so constructed, instead of being left as many of them are, completely open to an enemy's fire.

There would, however, have been many difficulties in providing cover for such of the towers as were built close to the sea, and in many cases they could not be retired from the shore without losing the full command of the coast line.

Towards the close of this year, the question of erecting permanent fortifications on the Western Heights was again brought forward.

Brigadier-General Twiss proposes "detached works, each of which would require a distinct attack to reduce it." These works were to have towers in the gorge.

General Twiss lays great stress on these towers, which he considers will answer as powerful retrenchments. At "the drop" he proposes a simple redoubt with ditch and demi-revetment, and a tower as a keep, the east face low enough to be open to fire from the Castle. Between the drop and the western front he proposes to erect a tower, to prevent artillery being established on the intermediate ridge.

He also proposes a tower on Shakespeare's Cliff, with a battery "under its protection," to flank the enemy in his advance along the ridge of the Western Heights.

He considers the defence of Dover Bay weak. Archcliff Fort is masked by houses in that direction.

Amherst Battery has only two guns, and both that and Guildford Battery are perfectly open to assault.

He proposes a small redoubt on the site of the old Townshend's Battery.

He also proposes to make arrangements for inundations round the town.

The committee of Royal Engineers submit, in the early part of 1804, a project for the occupation of the Western Heights. They propose utilizing the existing unfinished works, and closing the "gorges of three salient works with lines reciprocally flanking each other."

From the work on the left wing they propose carrying "a line of parapet or scarping down to the right of Archcliff Fort."

From Archcliff Fort there should be "a continuation of defence or obstruction as far as the entrance of Dover Harbour, assisted by Townshend redoubt, to be restored for that purpose."

In the same month he is authorized to proceed immediately with the works of defence on the coast reported as most urgent, viz. :—

Towers and batteries at east end of Dymchurch Wall, at the east part of Pett Level, and at the two stations near the great sluices in Pevensey Level; also, two towers in rear of batteries on Langney Point.

As an additional security to the town, in case of a hostile landing in Dover Bay, a ditch was commenced this year from the new bridge at the entrance to Bench Street up to Guildford Battery. It probably ran nearly along the line of the present Liverpool Street, but there is no plan on record to show its exact position.

In June, Captain Ford reports to General Twiss that in excavating for this ditch it was found that the soil two or three feet below the surface was composed entirely of shingle, which would not stand at the required slopes, and would not retain water.

He recommends piling.

In the following month he reports that "the line of defence towards the sea may be now considered as complete, except the ditch, which is nearly one-half planked and piled; the different batteries are in good order, and all the barriers and stockades finished, so that there is no point of penetration between Archcliff Fort and the new bridge; the space between that and Guildford is partly occupied by the ditch, and is laid under a very heavy fire from the castle, etc."

In September of this year, four Engineer officers, of the Hanoverian service, are placed under the command of the Commanding Royal Engineer.

In October, arrangements are made for the immediate delivery of bricks along the coast for the construction of the martello towers; also for the supply of labour from London, as a sufficient number of workmen and labourers cannot be obtained in the neighbourhood.

One, Mr. Gooding, of Ipswich, is engaged to deliver bricks at £3 13s. 6d. per thousand. The price of local bricks varied at the time from 50s. to 70s.

The barracks, now known as the Shaft, or "Grand Shaft," barracks, were put in hand this year, and in November the Commanding Engineer is authorized to proceed with the shaft or "gallery and staircase of communication between the town of Dover and the barracks on the Western Heights."

About this time, also, arrangements are made for the construction of the military canal, which was to be executed under the head of "Field Works," by the Royal Military Staff Corps, under the Quarter-Master-General's Department.

In the beginning of 1805, orders were given for the "reform" of Sandgate Castle.

A rather peculiar contract was made with a Mr. Hobson for building the towers along the coast. Advances of money were to be made to him to pay for all labour and materials required for the work. He is to account for the same on oath. He is in addition to be paid all "his expenses of every kind necessary, the wages of clerks and foremen, travelling expenses and the keep of three horses for riding to and from the various parts of the works for himself and principal clerks, but not to include any housekeeping expenses, and to be allowed £1 10s. per rod, clear of all expenses as above, as his profit."

General Twiss had at this time the following Royal Engineer Officers under his command :—

Capt. SMART,	Lieut. NICHOLAS,
,, FORD,	,, SMART,
,, GOLDFINCH,	,, PARKS,
,, CARDEW,	,, BOTELER,
,, LEFEBORE,	,, MULCASTER,
,, SQUIRE,	,, ROMILLY,

also four Hanoverian officers.

In December, a well is sunk at the Western Heights, 440 feet deep. Water was found at 420 feet.

The Commanding Royal Engineer points out the weakness of the coast between Sandgate Castle and the east end of the great canal, and proposes to build six towers on high ground, "having under their protection as many detached guns as may be thought necessary; also to improve Shorncliffe battery and to connect it with the canal by a ditch;" and receives authority to do so.

A letter from the Board of Ordnance to the Commanding Engineer, in October, 1806, shows the complete ignorance that existed at the time of the laws and principles of electricity.

The Board, in calling on Captain Ford to report whether he can make two large rooms in the keep secure from lightning, ask, "whether the iron bars enclosing the windows could not be sheathed with copper, or, if that is impracticable, whether the bars could not be taken out and a copper grating substituted."

Nothing is said about connecting the metal with the ground, and it is evident that copper was considered to possess a charm capable of keeping lightning at a distance.

Captain Ford says that North's Battery was erected at the express request of the Lord Warden, but was destroyed by the sea in 1791, since which time it has been dismantled as a battery. "The Ordnance buildings are all within the site of this work, which lies entirely on a bed of shingle close to high water mark. Two jetties were put down by the Ordnance, at great expense, on the flanks of this work, in 1792, which have been of infinite service to the harbour by securing the bed of shingle in the bay, and preventing further encroachments of the sea."

Amherst Battery was built under the same circumstances as North's. Its front is on piles defended with jetties, and Captain Ford considers it has been the means of saving the north pier from destruction by the sea. Townshend's Battery, on the other side, was also built under the same circumstances, and has been a great protection to the south pier.

During the year 1807 the martello towers along the coast were nearly completed, as well as the two circular forts at Dymchurch and Eastbourne.

The works on the Western Heights had been in progress since 1805.

In June, 1807, Major-General Twiss writes to Captain Ford: "In an interview I had yesterday with Lord Chatham and Lieutenant-General Morse, on the subject of revetting the citadel on the Western Heights, it was determined that a regular front should be constructed on paper, and applied in the best manner possible on the plan of the present citadel, so as to form the western front thereof, instead of the present imperfect figure."

It was then to be considered whether the eastern front of the citadel might not be secured by "a thin line, or even palisades, looking to the great strength of the right and left of the newly constructed works."

In forwarding a project for the completion of the works on the Western Heights, Captain Ford says: "The position of Dover should be defended on one of two principles, viz., either with detached works requiring a small garrison, but of that nature which would force the enemy to a regular siege before he could obtain so important a *tête de pont* to all his operations; or upon a scale sufficiently large to cover an army, which, although the place were invested, could always be thrown in from the sea, and which would hang on the rear of the invading force, and on its line of operations, and render its passage into the interior extremely hazardous, if not impracticable."

The Defence Committee of 1860 took much the same view of the defences proper for Dover.

In December orders are given for each of the martello towers along the coast to be armed with a 24-pr. gun; those of 26 feet diameter, placed on heights where an enemy can approach under cover, to have a $5\frac{1}{2}''$ howitzer in addition. Those of 30 feet diameter to have a second 24-pr. gun.

In July, General Twiss reports that the casing of masonry put up against the wall of the old keep "about 50 years ago," which had been giving way for some time, has lately come down in such quantities as to cause alarm among the troops, and that for the safety of the garrison the whole had been removed. He recommends securing the old masonry by a coating of "Parker's cement," which would render the surface "so smooth that the wet would not hang upon it," and that thus damage by frost would be avoided. Authority is shortly after received for casing the walls with Portland cement. This barbarous treatment of the grand old work appears to have been actually inflicted, and in some parts, especially of the south-east face, the cement still remains. The greater part of it, however, fell off or was removed, and the walls have been thoroughly repaired in later times without altering its original structure.

It is not known at what date the existing very ugly windows were inserted in place of the old arrow slits and narrow windows, which, although picturesque, no doubt admitted but little light into the interior of the keep.

At this date large barrier gates existed on what was then the new bridge in the town, at the south-east end of Bench Street, and which still goes by that name. They appear to have been erected to complete the line of defence along the front of the town formed by the Pent on one side, and the ditch extending to Guilford Battery on the other.

In the course of the year 1808, the Corporation petitioned the Government to remove these gates nearer to the sea and to place a wicket at each side of them. It is not clear whether this request was complied with, but it would seem that the gates were removed altogether not very long afterwards.

About the same time authority was issued for the appropriation of the old church in Dover Castle as a coal store. However barbarous and irreverent such a proceeding may appear, it probably saved the walls from complete demolition to make way for a barrack or other building to be erected on their site.

In this year, also, authority was given for the erection of an artillery establishment near Shorncliff, and for forming a road to it from Sandgate.

During the year considerable progress was made with the works on the Western Heights.

In October the casemates in the Drop Redoubt were finished. Their first occupants were a company of Royal Military Artificers.

A large grant being available, the works were pressed on with great vigour, and authority was issued for them to proceed on Sundays, at General Twiss's discretion.

A good deal of correspondence occurs during the year about bricks for revetments at the Western Heights. Captain Ford rejects large numbers, and insists on hardness and soundness without regard to colour. He appears to have succeeded in obtaining bricks of very good quality, as the outer revetments at the heights are still in good order, while the bricks used in many of our later works show signs of decay. By far the best material, however, for revetments is flint, used, I think, chiefly in the later works. This material is not only imperishable in itself, but for some reason, not easy to explain, the joints in flint work last uninjured, while those made of exactly the same material in brickwork fall out and have to be re-pointed.*

The estimate for 1810 was kept low. No fresh grant was made for the Western Heights, but a large sum remained available from former grants, which enabled the Commanding Engineer to carry on the works vigorously.

In July, General Twiss reports that several of the new casemates are ready for occupation. He, at the same time, suggests that iron bedsteads be supplied for the men, and also, which appears to have been considered quite a modern innovation, that one bed should be supplied for each man. He sends to Woolwich, for approval, a pattern iron bedstead, made to turn up. This was no doubt the model from which those now in use throughout the service were made.

* Probably because the flint does not absorb as much moisture as the brick, and bricklayers in those days, probably, had the same objection to wetting their bricks before using them as they have now.

In October, Major-General Twiss resigns the command of the Royal Engineer Department in the Southern District, and Major Ford is appointed to the charge of the works in the county of Kent, "to be called in future the 'Dover Division.'"

Dymchurch Circular Redoubt was finally completed either in this year or in the end of 1809.

In November, Major Ford reports considerable damage by the sea to North's Battery, and also to the ditch constructed in 1804, from the Pent to Guildford Battery, to secure the town from attack. He considers it unnecessary to spend money on the ditch, "as the works above the town are in so great a degree closed and the garrison much stronger than when it was undertaken."

In December, a large mass of cliff (from 2,000 to 3,000 cubic yards) fell from the southern boundary of the Shoulder of Mutton field into the Ordnance buildings below. Mr. Poole, master carpenter, and his family were buried in the ruins. Mr. Poole himself was dug out little hurt, but the rest perished.

During 1811 a good deal of correspondence occurs about a work to secure the left flank of the military canal, but no plan or clear description of it is on record.

In September, the Commanding Royal Engineer forwards a claim from a local surgeon for attendance on two artillerymen, blown from a gun in Archcliff Fort, in 1808, while firing at some privateers.

This is, I believe, the only recorded instance of a gun being fired in anger from Archcliff Fort, and as we hear of no injury to the privateer, the result was hardly satisfactory. The surgeon's charge was only 7s. 6d., but it is left doubtful whether he ever received payment.

The principal works in hand this year outside Dover (exclusive of the actual canal works which were carried on under a separate vote by the Royal Staff Corps) were the Royal Artillery Barracks at Shorncliffe* and the work below Shorncliffe to secure the left flank of the canal.

These works had been commenced by military labour, but the demands for men at the seat of war were now so urgent that none could be spared for other employment. The Commanding Royal Engineer therefore proposes employing a gang of men, called "navigators," who are to be paid at the high rate of 5s. a day for ordinary labourers, and 6s. for the head men.

* The stone for the Shorncliffe barracks was obtained from a quarry on the drill field, afterwards filled in.

In one of the casemates at the the Western Heights, the Commanding Royal Engineer mounted two 12-pr. carronades. He says: "I wished to ascertain the practicability of doubling the fire from the same point, by making the gun recoil in a circle instead of in the usual manner.

"After various trials it was found that with 8 ozs. of powder, the service charge of grape, and no wads, five artillerymen could fire 213 rounds in one hour from one embrasure under all the disadvantages of a new contrivance.

"The upper carriage is connected with the lower by a bolt or pivot, about which the former moves freely, so that the muzzle is expeditiously brought round for the act of loading while the other gun is at the embrasure, and the time appears to be just balanced in the execution of these two services."

The experiments were conducted by Lieutenant-Colonel Dixon, Commanding Royal Artillery, and other Royal Artillery officers, "who were much pleased with the simplicity of the contrivance. One advantage is that of loading the piece entirely under cover."

The idea seems to be much on the same principle as that of the modern Moncrieff carriage, with the advantage of having one gun always in the firing position. It does not appear, however, that the invention was ever carried into practice.

In the estimate for 1813 no further grant was provided for the Western Heights, but the work was kept going on the balance left from former grants. Provision was also made for completing the Royal Artillery Establishment at Shorncliffe, as well as the works at Hythe and Seabrook.

In addition to the votes taken at various times for the new works at Dover and Shorncliffe, a yearly provision was made under the head of "general service," which, for Dover alone, averaged from 1805 to 1814 about £8,000 per annum. Under this head were charged the extra pay of all Royal Engineer officers except the Commanding Royal Engineer, the pay of the civil establishment, 33 drivers at 2s. a day, and the keep of 100 horses at 3s. The horses and drivers were originally supplied by the Royal Artillery, but placed entirely under the command of the Commanding Royal Engineer, and employed solely on Royal Engineer works.

In April, 1813, the Commanding Royal Engineer reports that the sea has encroached greatly on the coast near Battery No. 4, at Dungeness (see *Plate* VII.), and has now, at a high spring tide, breached the exterior wall of the parapet. He states, that in 1798 the "full" of the beach was 60 feet from the front of the battery, but that it is now many feet within it.

The remarkable growth of the spit of shingle forming Dungeness Point, as well as its gradual "waste" on the western side, are shown in the accompanying plan, taken from Redman's *Alluvial Formations* in the "Minutes of the Proceedings of the Institution of Civil Engineers," 1851-2 (see *Plate* VII.).

In May, the Commanding Royal Engineer reports to Lord Rosslyn, commanding the district, that "the four batteries and the redoubt, now in ruins, were constructed on the promontory of Dungeness about 18 years back," with a view to protect the anchorage and coasting trade against privateers. Now that the Royal Military Canal is formed, he considers a defending force would find it hazardous to manœuvre with a corps in front of the canal, and therefore troops at Dungeness could not be properly supported.

As the power of Napoleon, the great disturber of the peace of Europe, had now much diminished, the necessity became less urgent for large expenditure on military works, and when the French Emperor was finally overcome and removed to Elba all military expenditure was at once cut down, and in the estimates for 1815 little provision was made except for so far completing works already in a forward state as to preserve them from injury by the weather.

In October, the Commanding Royal Engineer reports on a proposed redoubt in front of Dover Castle, apparently on the ground now occupied by Fort Burgoyne.

In July, arrangements are made for landing at Dover about 9,000 cavalry from the Duke of Wellington's army.

In August of this year the first mention is made of a steam engine being employed on the Engineer works.

In July, the Commanding Royal Engineer reports on the question, whether or not to abandon and surrender to the authorities of Dover Harbour, the sites of Townshend, Amherst, and North's Batteries. He considers them not *essential* to the general defence of the position, as Guilford Battery and Archcliff Fort "afford a powerful fire from the flanks of the bay, and as the cliff under the Drop Redoubt presents excellent situations for as many batteries as may be thought necessary to bear on the entrance of the harbour and to command the whole beach."

He points out that the lower line of batteries is open to assault, while the upper is not; but that if the belt of shingle between Guilford and Amherst Battery (where the Marine Parade, Waterloo

Crescent, and Esplanade now stand) be built upon, they would mask the fire of the cliff batteries.

On the whole he recommends the retention of the various positions along the shore as likely to be valuable in case of a renewal of the war.

The following statement is rendered by the Commanding Royal Engineer towards the close of the year, showing the armament and disposal of the batteries before and after the peace.

STATIONS.	No. of guns at end of late war.			No. to remain mounted during peace.			REMARKS.
	Heavy.	Light.	Mortars	Heavy.	Light.	Mortars	
Western Heights	44	..	9	14	..	9	The guns are in the Drop Redoubt and are kept for the purpose of salutes.
Archcliff Fort	5 26m	12	..	5	..	..	To be kept up as a sea battery.
Townshend Battery	2	..	..	2	..	..	Do. do.
Amherst Battery	4	..	..	4	..	..	Do. do.
Guilford Battery	4	..	..	4	..	..	Do. do.
Moat's Bulwark	3	..	..	3	..	..	Do. do.
Dover Castle	41	34	12	7	6	5	Ditto, except the light guns, which are kept for saluting.
St. Margaret's Bay	2	..	..	..	..	..	Dismantled.
Walmer Castle	8	..	..	8	..	..	To be kept as sea batteries.
Deal Castle	7	..	..	7	..	..	
Sandown Castle	11	..	..	11	..	..	
No. 1 Battery	6	..	..	..	..	..	
No. 2 Battery	8	..	..	..	..	..	
Pegwell Bay	2	..	..	..	..	..	
Ramsgate, West Battery	3	..	..	..	..	..	Dismantled.
Ramsgate, East Battery	2	..	..	..	..	..	
Broadstairs, West Battery	2	..	..	..	..	..	
Broadstairs, East Battery	2	..	..	..	..	..	
Margate, East Battery	2	..	..	..	..	..	
Margate, West Battery	2	..	..	..	..	..	

In 1821, the Navy took into their own hands the repairs of the greater part of the Coast Guard stations, the Board of Ordnance reserving to themselves the repair of such as were still required for purposes of defence, although temporarily occupied by the navy.

In October, 1823, it became necessary to abandon No. 3 Battery, Dungeness, owing to the encroachments of the sea. No. 4 had been abandoned in 1818.

In 1826 and 1827, the sea wall at Dymchurch was seriously damaged, and a dispute arose as to the liability of the Commissioners of Level to repair it. As the Board of Ordnance pay "Scot and lott," or "wall scote," for their portion of the beach, they consider that they can claim the protection of the Commissioners of Level equally with other proprietors.

In 1830, the Maison Dieu was purchased by the Board of Ordnance, and converted into an Engineer depôt and offices, as well as an ordnance store for gun carriages, shot, etc.

It had been for some years in the hands of the victualling department of the navy.

A convenient brick house, adjoining the Maison Dieu, was taken as a quarter for the Commanding Royal Engineer, and the house and offices in Archcliff Fort were let to an Artillery officer.

North's Battery, in which the Engineer depôt had hitherto existed, being now no longer required, the land was sold to the Harbour Commissioners.

The occupation of the Maison Dieu as an Engineer depôt did not last long. Its purchase seems to have been soon acknowledged to be a mistake. Since the termination of the war the Engineer works had been very small, and there was no necessity for keeping up the large stores and shops which had been established when extensive works were in progress. Moreover, nearly all the work now in hand was done by contract.

In the course of the year 1833 the question of disposing of the Maison Dieu was under consideration. The Commanding Royal Engineer strongly opposed it, but it was finally decided that it was unnecessary to retain it, and in the summer of 1834 the whole of the premises were sold by auction. The Commanding Royal Engineer then returned to his old quarters and office in Archcliff Fort.

In the year 1836, the Commanding Royal Engineer was called on to report on the necessity of maintaining Deal and Sandown Castles as works of defence. He refers to former reports of Colonel Twiss and Colonel Ford in favour of maintaining them, and states that he considers them still necessary for the protection of merchant vessels lying in the roads as well as for the security of the coast.

In this year the archway at the entrance to St. John's Chapel, in the keep, was opened. It had been blocked up for at least 70 years, and the chapel itself used as a store.

A good deal of correspondence passed in 1837 about a proposed line of railway to Dover.

In 1840, the charge of the military canal, which had been constructed and hitherto maintained by the Royal Military Staff Corps, under the Quarter-Master-General's Department, was placed under the Commanding Royal Engineer.

In 1841, Colonel Thompson, Commanding Royal Engineer, was appointed to special duty under the Treasury, in connection with the proposed Harbour of Refuge at Dover.

In November, the sea wall of the Circular Redoubt, at Dymchurch, was damaged by a storm, but repaired.

In the same month, Lieutenant Hutchinson, R.E., is appointed to assist Mr. Cubitt, Engineer to the South Eastern Railway, in the removal, by blasting, of a large mass of cliff, westward of Shakespeare's Cliff, called Round Down Cliff. The mass to be removed was a little over 400,000 cubic yards. The necessary works were completed in January, 1843, and on the 26th of that month the explosion took place. Three mines were fired simultaneously, containing in all, 18,500 lbs. of powder. The lower part of the cliff was blown into the sea, and the upper part, thus deprived of support, glided down so quietly that a flagstaff, planted on its summit, remained unbroken and as upright as in its original position.

In the year 1843, Amherst Battery was given up to the Harbour Commissioners, the latter giving in exchange, on a 99 years' lease, a site for new Ordnance buildings and £5,000 towards erecting a new battery.

In September, 1843, Townshend battery was sold to the South Eastern Railway Company.

In 1847, Colonel Tylden submits a report on the Dover Defences. He says that the citadel was left quite in an unfinished state at the close of the war, in 1815, and that nothing has been done to it since. The works now known as the inner, centre, and outer north-east bastions, existed as at present. The centre and outer works were called "the wings." They were constructed to obtain a flank fire on the steep sides of the hill, which are not seen from the main work.

The ditch between the inner and centre work existed and was flanked by loopholed casemates; that between the centre and outer work was unfinished. There was a well in the citadel 409 feet deep.

The entrance to the citadel was by a standing wooden bridge, at the northern extremity of the work.

The citadel was unarmed. Colonel Tylden considers that the ridge west of the citadel, where the western outworks now stand, is the most probable point of attack.

The Drop Redoubt had escarps revetted up to a height of 23 feet, but the counterscarps were unrevetted. The ditches were not all excavated to their full depth, and were without flank defence. The entrance was on the south face, from a flight of steps leading up the glacis by a wooden foot swinging bridge, as at present.

The connecting lines on the north front, between the Drop Redoubt and the citadel, were in an unfinished state, as was also an irregular work called the North-Centre Bastion, in advance of the left flank of the curtain.

In the ditch of the curtain bombproof tanks existed, holding 175,000 gallons. The glacis was partly formed.

The military road leading from the Castle entered these lines by a breach in the curtain.

On the south the citadel was connected with the precipitous cliffs by lines of good profile. The escarp of these lines was demi-revetted to a height of 25 feet. The counterscarp, for about half its length from the citadel, was also revetted. There were casemates in the flank, half way down, to hold 136 men. The South Lines were entered by a standing bridge and gateway, through which passed the old Folkestone road, as at present.

Colonel Tylden considers the harbour and anchorage very inadequately defended.

Its defences, on the west side, consisted of Archcliff Fort—a work of little strength, mounting six 32-pounders. Its front had a good masonry escarp, lately built.

At the date of Colonel Tylden's report, the sea defences on the east of the position were: 1st, a battery of four 24-prs., called the Shoulder of Mutton Battery; under this were, 2nd, Moat's Bulwark, mounting three 18-prs., its fire a good deal masked by buildings lately erected in its front; and 3rd, Guilford Battery, mounting four 32-prs.

A site was reserved for a battery on the beach, 500 yards to the eastward of the harbour's mouth, to compensate for the loss of Townshend's and Amherst Batteries, which had been removed, the first to make room for the South Eastern Railway Terminus, and the second for improvements to the harbour.

Correspondence occurs during the year on the subject of falls of chalk at the East Cliff.

Petitions are made by the mayor, as well as by private proprietors, for action to be taken by the Government to secure the cliff, but the Board of Ordnance decides not to accept any responsibility in the matter.

In the course of the year, 1855, the Castle was occupied by the British Swiss Legion, one of the auxiliary contingents raised during the Crimean war. As barrack accommodation could not be found for the whole of this force, a large number were encamped on the open ground at the Castle and Heights.

During this year the machinery for pumping water at the Castle and Heights was supplied and fitted.

Colonel Portlock becomes Commanding Royal Engineer. Shortly after his arrival he makes a report suggesting that Shorncliffe should be made a camp for practical military instruction. He considers more land should be bought, including part of the adjacent Downs, and that specimens of different forms of field-works should be thrown up. He proposes that men under instruction at Hythe should be practised in covering themselves "either by pit, gabion, or parapet." His Royal Highness the Commander-in-Chief highly approves the report, and begs Colonel Portlock's further suggestions as to the best mode of carrying out his project.

In the course of this year the London, Chatham and Dover Railway Company were allowed to drive a tunnel under the Western Heights, on condition of making a cut, or ditch, across it, flanked by a small casemated work excavated in its side. This work exists, the line being carried by strong trussed beams across the ditch.

In the winter of 1858-59, No. 1 Battery, near Deal, which in 1853-54 had been completely reconstructed, was again so much damaged by the sea that it was considered unworthy of repair, and finally abandoned.

In 1861, the Castle Hill Fort, now called Fort Burgoyne, was commenced.

At Dover Castle the restoration of the old church was completed recently, the work having been executed under the direction of Mr. (afterwards Sir) Gilbert Scott.

This brings us to the end of the history of the defences of Dover; great improvements have been going on lately, but as they are not at present matters of history it would, for obvious reasons, be unwise to describe them in a published account.

C. S. A.

PAPER II.

HISTORICAL SKETCH

OF THE PERMANENT

COAST DEFENCES OF ENGLAND.

By Walter H. Tregellas.

This sketch (for which the notes were collected nearly 20 years ago) must inevitably commence with an apology for the incompleteness and imperfections which, it is feared, will be found in work performed under the disadvantages of being done in a very limited time, and in the sparse intervals of official business. The subject is a large one, and the obvious difficulties attendant upon researches of this nature, and especially in this particular subject, are very considerable. This should, therefore, be considered merely as a rough outline, to be completed hereafter.

It must not be expected that anything more than a passing reference will be made to periods antecedent to that of King Henry the VIII.; for, previous to the reign of that Monarch, there were scarcely any coast fortifications properly so called.

The very few scattered examples, such as that at Portsmouth,* referred to by Leland (temp. Henry VIII.) in his Itinerary, in the following words:—"I learned in the town that the tourres† in the haven mouth were begun in King Edward iv. tyme, and set forwarde yn building by Richard iij. King Henry vij. ended them at the procuration of Fox, bishop of Winchester"‡—must be regarded only as forming the defence of isolated positions (often against *internal* attacks), and not as bearing upon the question immediately under consideration, namely, the defence of the coasts of this realm against the landing of a foreign enemy.

Until the middle of the 16th century invasions were generally met by the inhabitants of this country in the same spirit, if not always

* For a sketch of the rise and progress of the Portsmouth fortifications, see Appendix A, and Plan.

† No doubt the towers at Point Battery and Blockhouse Fort.

‡ King John appointed a Bishop of Winchester guardian of his realm during his absence at Poitou, dated Portsmouth, 1 Feb., 1214—(Rymer's *Fœdera*).

in precisely the same manner, as Holinshed states was practised in the days of Richard III. : "The custome of the countries adioining neere to the sea is (especiallie in time of warre) on euerie hill or high place to erect a beacon with a great lanterne in the top, which may be seene and discerned a great space off. And when the noise is once bruted that the enimies approch neere the land, they suddenlie put fire in the lanterne, and make shouts and outcries from towne to towne, and from village to village. Some run in post from place to place, admonishing the people to be readie to resist the ieopardie and defend the perill. And by this policie the fame is soon blowne to euerie citie and towne, in so much that as well as citizens as the rurall people be in short space assembled and armed to repell and put backe the new arrived enimies."*

By some such means as these we may conceive that King John† made his ineffectual endeavour to resist that descent upon the coast which the French successfully effected on the Isle of Thanet, in 1216. In fact, the histories of England contain numerous accounts, between the time of the Norman Conquest and the close of Henry VIII.'s reign, of invasions having been resisted by methods such as these; most frequently, it must be added, without success. Dover, for instance, was taken and partly burnt by Montmorenci, in 1296. In 1339, the French took Portsmouth and sacked it, in retaliation for the English attack upon Boulogne. In the following year, the English coasts were ravaged by the French during the absence of Edward III. in Flanders; and at this time Plymouth was burnt nearly to the ground, several ships were destroyed at Hastings, and the greater part of Southampton was reduced to ashes. Rye and the Isle of Wight were attacked by the same nation in 1377; and in their retreat, the French made considerable havoc at Portsmouth, Plymouth, Dartmouth and Hastings. Winchelsea, and many other towns, were pillaged three years later; and in 1403 and 1404 the Isle of Wight was again subject to the presence of an enemy.

Up to this period the southern portions of the undefended coast line of England were the chief points of attack; but in 1405, a landing was effected at Milford Haven by Charles V. with 12,000 men; and, before our Henry IV. could come to the rescue, Carmarthen, with other towns, was plundered, and the Frenchmen re-embarked in safety.

* Holinshed (Vol. III., p. 432) (A.D. 1485) ed. 1808.—See also "Calendar of State Papers, Elizabeth, Domestic, 1598-1601," sub "Beacons."

† John surrounded Portsmouth Dockyard with a wall.—See Appendix A.

During the troublous times of the Wars of the Roses no further descents of importance, by foreigners, appear to have been made, except in so far as they were partisans of either the York or the Lancastrian causes.

But the successful landings on the Sussex Coast by Prior John, in 1513 and 1514, during the war between Louis XII. and Henry VIII. (examples which were followed by a descent upon the Isle of Wight in 1545, during the reign of Francis I.), and the experience derived from the history of the past reigns, especially the teachings of the French campaigns of the 15th century, when the superiority of the French in artillery turned the tide of conquest in favour of that nation, led Henry to give his anxious consideration to the question of permanently fortifying the most vulnerable points along our coasts.

The following extract from *Hall's Chronicle* gives an account of the above landing on the coast of Sussex :—

In 1514 "Prior Ihon, a great capitayne of the Frenche navy, with his Galeys and Foyates charged with great basylyskes and other greate artillery, came on the border of Sussex and came aland in the night at a poore Village called bright Helmston (Brighton), and or the watch coulde him escrye, he sett fyer on the towne : then the watch fyred the bekyns and people began to gather ; whiche seynge, prior Ihon sowned his trompett to call his men aborde, and by that tyme it was day. Then VI. archers whiche kept the watche, folowed prior Ihon to the sea, and shott so faste that they bett the galymen from the shore, woundyng many, and prior Ihon was shott in the face with an arrow, and was likely to have dyed, and therefore he offered his image of wax before our lady at Bolleyn (Boulogne), with the English arrow in the face for a myracle."—(*Hall's Chronicle*, p. 568, ed. 1809.)

Mr. Froude points out that "Henry VIII. was one of the first men to foresee and value the power of artillery." He adds that "Sebastiniani mentions experiments on the range of guns which were made by the King in Southampton Water;" and goes on to say that "When the history of artillery is written, Henry VIII.'s labours in this department must not be forgotten."*

The King seems to have taken that prompt and vigorous action which might have been expected from so prudent and energetic a prince. Holinshed tells us, "The same time (about 9 March, 1539) the King caused all the havens to be fensed with bulwarks and

* Froude, *History of England*, Vol. II., p. 299.

blockehouses, and riding to Dover, he tooke order to have bulworks made alongst the sea coasts, and sent commission to have general musters made through the realme."* He adds, at page 809, that "The king being informed that the Pope, by instigation of Cardinal Pole, had mooued and stirred divers great princes and potentates of Christendome to invade the realme of England; without all delaie rode himselfe toward the sea coasts and sent diverse of his nobles and councellors to surveie all the ports and places of danger on the coast where enie meet and convenient landing place might be doubted, as well in the borders of England as also of Wales, in which dangerous places he caused bulworks and forts to be erected." He also ordered the navy to be got ready, general musters to be made, and armour and weapons to be seen and viewed, etc.

Lord Herbert of Cherbury, in his life of Henry VIII., amplifies Holinshed's account of this very interesting epoch in the history of our coast fortifications as follows. He says that "the king had formerly sent sundry nobles and expert persons to visit the ports and places of danger, who failed not for their discharge upon all event to affirm the peril in each place so great as one would have thought every place had needed Fortification * * * all which preparations being made against a danger which was believed imminent seemed so to excuse the king suppressing of Abbies as the people (willing to spare their own purses) began to suffer it easily: especially when they saw order taken for building divers Forts and bulworks upon the sea-coast, many if not most of these we have at this day, being thought not so exact as the modern yet of his raising."†

The State Papers for this period are now undergoing arrangement and calendaring, so that for the present it is extremely difficult to give details of the works executed at this time, and of the circumstances attendant upon their construction. The following, however, may probably be accepted as a list of the most important fortifications made by Henry VIII., as appears by a document in the State Papers of Edward VI. (Domestic, Vol. XV., No. 11, temp. 1552),‡ entitled—

* Holinshed, Vol. III., ed. 1808, p. 808.

† Kennet's *History of England*, ed. 1706, p. 217.

‡ It may be noted here that there is an interesting letter of Sir Anthony Knyvet to the King, dated 22 October, 1541, *State (Papers (Commission)*, 1831, Vol. I., p. 773), in which the new Fortress at Portsmouth, recently executed, is highly extolled; and in which the writer begs that the King will take an early opportunity of inspecting the plans of the great work; thus indicating that the Sovereign took a close personal interest in the question.

Fortificacons and Buildings for the Warre within the Realme of Englande, with the wages of the same, between the firste of Marche, Anno XXX Henrici Octavi and Michãs Anno vj Edwardi Sexti.

County.	Place and Name of Work.	Remarks.
Kent.	Dover. The Bulwark of Arcliff super Montem. The (*a*) Bulwark subtus Cast: Dovor, and the black bulwark in Dovor Cliffe.	(*a*) Moat's or Mote's Bulwark.
	The Downes. The Castell of Deale, Walmer and (*b*) Sandhill juxta Sandwich, with the (*c*) 4 greene bulwarkes and the clay bullwark there.	(*b*) Sandgate Castle. (*c*) Two of which are probably those now known as Deal Batteries.
	Sandgate juxta Folkestone,	
	Queenborough Castle, Gravesend Bullwark, Milton Bullwark	The sites of these works are indicated on plan X 6/6 in the War Office. New Tavern Fort, Gravesend, does not stand on either site.
	Higham Bullwark.	Probably either Hope, Cliffe, or Shorne.
Sussex.	The Castle of Camber.	On the tract of shingle, East of Winchelsea; cost £23,000, built in 1539-40, and is conjectured to be on the site of a still older work.—(*Beauties of England and Wales*, Sussex, p. 199.)
Cornwall.	The Castle of Pendennis on the west side of the Falmouth Haven in the said Countie. The Castle or Fort of St. Maws in the said Countie.	
Southampton and the Isle of Wight.	The town and Isle of Portesmouth with the (*d*) newe Castell, the (*e*)South Castell, Hasellwood Point, St. Andrew's Point, (*f*) Calshote Point, the (*g*, *h*) Castell of Sandhambaye, (*g*) the Greene Bullwark there, Castell of Hurst, Yarmouth (*g*) Castell, the Este and West Cowes, Sharpwood, (*i*) St. Ellins and Carisbroke.	(*d*) (?) Semaphore Tower. (*e*) No doubt Southsea Castle. (*f*) St. Andrew's Castle is mentioned in a grant by James 1st, 18 June, 1611. (*gh*) Considerable sums were spent in reforming Sandown and Yarmouth Castles in 1634-5 (*i*) The site of either Fort Albert or Fort Victoria; probably the former, which is also known by the names of Round Tower Point and Carey's (? Sir George Carewe's, Lieut.-Genl. of Ordnance, temp. Eliz.) Sconce.
	The following portions of the Portsmouth fortifications are also mentioned in the detail, viz., The Windmill bulwark and Shaderton's bullwark. The Tower of Portesmouth, Sportes bullwark and the blockhouse next Portesmouth.*	
Dorset.	The Castell or Fort of Portelande in com. pred. The Castell of Sandefote in dict. com.	See Hutchin's *Dorset*, part 9, page 817, ed. 1868, for a sketch of the history of Portland Castle, and a list of its Governors, etc.
York.	The Towne of Hull with sonderie fortes made there.	
Essex.	Harwich, Langor Point, St. Osithe's marsie (*j*) and Brakellsey (*k*) in the said countie.	(*j*) Mersey or Mersea, at the entrance of the river Colne, for the defence of the river approach to Colchester, possibly on the site known as St. Osythe's and Mersey Stones. (*k*) Brightlingsea. There is a farm close by, still called Blockhousewick.
	(*l*) Este Tilbery and West Tilbery within the said countie.	(*l*) On the point a little to the south of the present Coalhouse Fort. The trace of the piles on which the old Castle was built is shown on X 6/6. The plan is the same as that of Sandgate Castle, etc. The present Tilbury Fort was then merely a blockhouse.

*For sketch of the rise and progress of Portsmouth fortifications, see Appendix A and Plan.

Fortifications were also constructed at Alderney, Jersey and Scilly.

It will be observed that nothing is said in the foregoing list of the fortifications of Plymouth; but it is certain that fortifications existed there in Henry VIII.'s time, as appears from a chart of the period, preserved in the British Museum, and copied by Lysons in his *Devonshire*. (See *Plate* I.) This chart shows a strong fortress at Stonehouse; coast batteries under the Hoe, called the "fortresse of Plymouthe;" and at Eastern and Western King, called the "fortresse of Stonehouse;" also at the part now known as the Barbican, where a chain was stretched across the entrance of the inner harbour—Sutton Pool; but as yet there appears to have been no battery on St. Nicholas' or Drake's Island.

During the short reigns of Edward VI. and Mary little or nothing seems to have been done for the defence of the coasts. In 1547, the fortifications of Portsmouth were said to have been out of repair. Matters necessary for the defence of Portsmouth, Southampton, and the Isle of Wight were discussed, and notes were made of the charges of the blockhouses in Essex. These documents, which are the only ones that I have found referring to the subject, are preserved in the Public Record Office, as is also an account of the Queen's (Mary's) Castles in 1557. The only difference of any importance between this list and that already given at p. 71, is that one or two additional batteries appear to have been constructed in the neighbourhood of Deal, for the greater security of the Downs; but is is by no means clear that even these small additions were actually made. In fact, no active measures appear at this period to have been considered necessary, either for extending our system of coast defence, or even for efficiently maintaining works which already existed.

Under these circumstances, it is not a matter for surprise that the state of the defences of the country at the commencement of the reign of Queen Elizabeth has been thus described—"At this time, England being actually at war with the second power in the world, the whole naval force in commission amounted to seven coast guard vessels, the largest of which was but 120 tons, and eight small merchant brigs and schooners altered for fighting. Of ships in harbour fit for service, there were 21—one newly built, of 800 tons, one of 700, one of 600, one of 500, and one of 400 tons, four from 300 to 200 tons; the rest sloops and boats.

"In artillery the destitution was even more pitiable—Of cannon* (48-pr.), and demi-cannon (24-pr.), in all the dockyards there were but 30 which were reported sound, with 200 culverins (12-pr.) and minions (3-pr.), and falconets. Of bows, arrows, lances, corslets, and harquebusses, there were not enough to arm 3,000 men. For the troops, Captain Turner, who was sent to command at Portsmouth, and was in daily expectation of a visit from the French, reported to Cecil on 6th March that 'they were all grown to misorder and mischief, and to the greatest ill that man's head could imagine.'"†

The state of the Defences of Portsmouth a little later is quaintly described in a letter from Lord Sussex to the Council, dated 1st November, 1587:‡ "I am most heartily and earnestly," he writes, "not only to require, but also for the defence of the realm, as duty leadeth me, to charge your honours to be a means for the present sending down of the gunners, without whom I wish the ordnance at the Tower again; the platforms to be repaired, and that of the round tower to be new made, for that it is so old and rotten as, on the day of Her Majesty's coronation, I durst not shoot off the piece: which place is the only chiefest for the defence and safeguard of the haven." The forts at Gravesend and Tilbury were in no better plight, as we find by a letter from Walsingham to Leicester, in July, 1588 (the Armada almost in sight). At the former place, he says, "he did not find one platform to bear any ordinance, neither on the ground nor aloft"; of Tilbury, "I find it further out of order than the other, save that there be some better peces of artillery, but not a platform to carry ye least pece." On the day following this letter, however, he reports that he has "putt these Fortes in as good strength as tyme wyll permytt."

But the country was gradually aroused to a conviction of the necessity for taking active steps towards improving the state of the defences; and we now hear, for the first time, of a system of batteries for the defence of the Medway. It appears from Vol. XI. No. 72, of the State Papers of Elizabeth, that there were, in 1558,

* The sizes of the guns are given from "A Military Dictionary, explaining all Difficult Terms in Martial Discipline, Fortification and Gunnery, by an Officer who served several years abroad."—London, 1702.

† Froude, VII. 58 (Feb. 1559).

‡ Sir Sibbald Scott's "*British Army*," Vol. I., pp. 368, *et seq.*

garrisons at Sheerness* and Queenborough,†—and in 1561 (p. 172 of same vol.) orders were given for the Bulwark at Upnor, which had shortly before been commenced, to be completed.

It is not until 1580, so far as I am aware, that any traces are found of the construction of permanent fortifications for Milford Haven. In that year, as appears from State Papers, Elizabeth, Vol. CXLVI., No. 37, orders were issued that three forts must be made there: viz., at Rate Island, Dale, and Stack Rock; all which forts were "to be sette in hande at one instante, and great expedition used upon them."

Although the works for the defence of the Medway and of Milford Haven would appear to be the only ones of any great importance commenced in Elizabeth's reign, there were several minor works undertaken at this period, especially along the south coast, several of whose sites are still occupied by forts or batteries. Thus it appears from a survey of the defences of the coast of Sussex, in 1587, now in the King's Library, British Museum, that the "ordinance at Newhaven was unmounted, and littell worthe," and "that a bulwarke of earthe were needfully to be raised there for the planting one demi-culverin (6-pr.) and two sacres." At Bletchington Hill "two rampiers of earth" were considered necessary; and "some more trenches" should be made at Seaford. There was a decayed earthern bulwark at Borne (? Eastbourne); "a rampier" was recommended for Bulver Hyde Point; and Hastings was considered well furnished with ammunition, and, from its strong position, "easily to be fortified." Winchelsea, being "a dangerous platte" if the enemy should possess it, should have "one demi-culverin and two sacres at least." Camber Castell was in good repair, and well armed; and Rye was walled and well furnished both with "good ordinance of Her Majesty," and with brass and iron guns of their own.‡

The defence of the Thames was, as we have seen, carefully considered; and £1,470 had been spent on the chains and forts for the Medway, up to January, 1588. A chain was placed across the river opposite to Upnor Castle, and, "on both sides of the river,

* The "Garrison" at Sheerness, in Elizabeth's time, was doubtless the Square Tower and Great Platform there, shown in Sir Bernard de Gomme's plan for "the New Fort at Sheerness," in 1667. (Plan in British Museum.)

† Queenborough Fort existed in Henry VIII.'s time.—See ante.

‡ It appears from a State Paper in Charles I.'s time, that many pieces of ordnance were claimed as their own by the inhabitants of the neighbourhood of His Majesty's forts and castles. (Charles I., Vol. 288, No. 90, State Papers—Domestic, 1635.)

fortifications were erected according to the prescription of Frederick Genebelli, an Italian."*

But the best general view of the state of the defences of the country will be obtained from the following summary of opinions, as to the coast fortifications of England, expressed by the Privy Council of Queen Elizabeth, in November, 1596; when a second invasion by the Spaniards was expected. It is condensed from a "Report on the Arrangements which were made for the internal Defence of these Kingdoms when Spain, by its Armada, projected the invasion and conquest of England; and application of the wise proceedings of our ancestors to the present crisis of public safety." This Report consists of extracts from the Archives of the State, made for Dundas, the colleague of Pitt, by Mr. Bruce, in 1798, and was printed for the information of members of the Government only.†

The 5th of the eleven points submitted by the Earl of Essex for the consideration of the Council, as to the best mode of resisting the enemy, was, "*Whether any places that are of importance near to those parts*, (viz., the ports which the enemy was likeliest to seek to lodge in) *being now undefensible, should be fortified or not?*" On this point the Earl himself remarks that Plymouth‡ should be fortified.—"Two or three ravelines of earth should be made at Southampton. Portsmouth, the only place fortified in those parts, should be better garrisoned;§ and if, besides, we had a great fort over against Hurst Castle, we need not fortify nowhere else." Lord Burleigh concurs generally as to the necessity for fortifying Plymouth, as the armaments at Falmouth and Dartmouth should be withdrawn thither, in case those two places fell; but thinks Southampton safe unless Portsmouth and the Isle of Wight were first taken. He agrees to place a fort at Sharpwood, opposite Hurst Castle.

Lord Burrough, Lord Willoughby, Lord North, and Sir William Knollys, Comptroller of Her Majesty's Household, express very similar opinions; but Sir Walter Raleigh, whilst agreeing that all

* Hakluyt 1, 595.

† Grenville Library, British Museum, Nos. 16,245 and 16,246.

‡ Plymouth was fortified to a considerable extent in Henry VIII.'s time (see ante); and moreover, there must have been a fortification on St. Nicholas Isle before *this*, as in 1583, a petition to the Council was put forward by the Mayor of Plymouth that Sir Francis Drake should be appointed Captain of "the Isle and Castle."

§ In the British Museum there is a plan of Portsmouth fortifications in Elizabeth's time.—Cott. MSS. Aug. A 1 (Vol. 2, 117).

existing forts on the coast should be provided with ammunition, thinks that no additional fortifications are necessary, except for the Thames, where, he thinks, the enemy will make his attack—adding, "For my poor conceit, we have few places guardable, Portsmouth excepted."

Sir George Carew, Lieutenant of the Ordnance, is very anxious for the fortification of Plymouth,—"whence all our fleets have gone to do the enemy grievance." As to Milford, a blow so far from the heart is not mortal. Bristol is not to be feared, "as the Severn is full of dangers and no good harbour in either side." A citadel should be constructed for the Isle of Wight; and the island of Portland, strong by nature, should be made, by a little help of art, impregnable.

The rest of Mr. Bruce's report consists mainly of an account of the various counter-attacks and *offensive* measures which have been taken by this country, from early times, when invasions were threatened.

With the accession of James I. came peace with Spain, and a general decadence of the military efficiency of the country. No new fortifications were constructed, and the only traces found amongst the Public Records, as to the old ones, are complaints of their want of repairs, the undisciplined state of their garrisons, the rusty condition of the ordnance, and of arrears of pay not being forthcoming. It is not till the close of his reign, when the war with Spain was expected, that any steps seem to have been taken to maintain the existing works of defence in a due state of efficiency. Surveys were then made, and it was ordered that the necessary repairs should be executed; but the funds do not seem to have been forthcoming from the Exchequer,* although it was reported that "the English forts were unfit to bear the winter."†

In the early part of Charles I.'s reign we find a continuance of the same sort of complaints; a remarkable illustration of which will be found in Sir John Jephson's letter to the Earl of Pembroke, dated Portsmouth, 14th March, 1627, wherein he urges the immediate repair of the fortifications, which now, he says, consist merely of "ruins that show that it was once a fort." At Plymouth, also, "the Fort and Island" were out of repair (probably the work at Fisher's Nose and at St. Nicholas Island). It may be observed, that at this period there must have been a project for removing Camber Castle,

* State Papers, James I., CLXX., 31 July, 1624.

† State Papers, James I., CLXXI., 12 Aug., 1624.

one of Henry VIII.'s constructions, which, owing to the petitions of the inhabitants of Rye, Winchelsea and Hastings, dated 10th March, 1627, nevertheless still stands, amid a waste of shingle.

The proposal for its destruction is adverted to in a letter from Sir John Hippisley, from Dover Castle, to the Duke of Buckingham, dated also 10th March, 1627; wherein he states that the materials of Camber Castle would not yield £1,200, and that Winchelsea and Rye would think themselves "quite undone" if the castle be taken down. He adds, that the country are humble suitors that there may be a fort built at Dungeness; nothing would do Buckingham more honour; and that the castles in the Downs must be repaired, or the country cannot be in safety in the event of war.

In this year (1627), when there are rumours of war with France, Pendennis Castle (whose captain, Sir Robert Killigrew,* describes himself as having been a continual suitor for nine years for the necessary works to be performed), Sandham Castle in the Isle of Wight, and St. Mary's Castle, Scilly, were also repaired. Sandgate Castle, a great part of the "rampire" of which had fallen down, is reported by its captain as being neither habitable nor defensible, and the repair of Tilbury Fort and of Deal and Walmer Castles (the latter two being in jeopardy from the inroads of the sea) is again urged. The deputy-lieutenants of some of the counties, also pray for grants of "great ordnance," having themselves constructed *bulwarks*, but their *ordnance* (probably given to the county by Henry VIII.) having become unserviceable; whilst others, as in East Kent, direct that the landing places along the coast may be made impassable. The fortifications at Aldborough, Dunwich, and Southwold, and of St. Michael's Mount in Cornwall, are also reported upon. On 14th September, in the same year, a petition was made to the Council by the Mayor and Masters of Dartmouth, which is interesting as illustrative of the mode in which, in some cases at least, the funds were provided for the strengthening of the coast defences at crises like that now under consideration. The petition states that, in obedience to the commands of the Council, the town had erected fortifications for the defence of their port, and had repaired their iron chains; but the fortifications were unfurnished with ordnance, and, the town being from sundry causes very poor, the petitioners besought power to assess a sum for completing the fortifications,

* For an account of this officer, see the writer's *Cornish Worthies*, 2 vols., E. Stock, 1884.

and begged that the landsmen of the town might be exempted from impressment for some time to come.

In 1628,* a brief descriptive enumeration was made of the principal castles upon various parts of the sea coast of England and Wales. With trifling exceptions, however, no material additions appear to have been made to the list already given of important works constructed by Henry VIII.

On 1st July, 1631, was issued the first "Royal Commission" on the subject of Fortifications which I have been able to trace.† It is addressed to the Earl of Danby and three others, and the question to be reported upon is the defence of the Scilly Islands; Sir Francis Godolphin, Captain of the fort there, having called attention to great defects in the works.‡

Till 1634-5, Chatham was unfortified. About this time the Admiralty issued orders for the construction of a brick wall round the dockyard and buildings and the rope house; and of a blockhouse at the entrance of St. Mary's Creek (now Gillingham Fort) to prevent an enemy's boats from using that channel, and so evading the guns of Upnor Castle.

War with "the neighbouring princes" was now thought imminent, and musters were made, old ordnance was returned into the Tower, and new supplied, and lists of all the fortifications were again prepared, apparently with a view to determining which should be repaired and maintained, and which should be demolished; but on an inspection of the original documents no addition of importance is yet traced.

Inventors now appear upon the scene. A Mr. Wilford submits a project for fortifying the most easily assailable parts of the English coast; and a Mr. W. Engelbert informs the King that he has "devised how to make a moving fort of cannon-proof, capable to have within her 30 or 40 pieces of ordnance, with men, victuals, and other things. He will also carry the same fort and fix it at the mouth of any river or harbour, so that it shall not be possible for any ship to go in or out without leave of the fort.§ The fact of projects of this nature having emanated from private individuals is interesting as

* State Papers, Charles I., Vol. CXXVI., No. 43.

† State Papers, Charles I., Vol. CXCVI., No. 1. General Collinson, however, states that a Royal Defence Commission was appointed in 1572.

‡ For an account of Sir Francis, see the writer's *Cornish Worthies*, 2 vols., E. Stock, 1884.

§ For this invention Mr. Engelbert asks £200 a-year for two lives.

evidence that the defence of the coasts was beginning to be considered by all classes, and from a general point of view.

That Charles I. himself also personally took a minute interest in the subject of our fortifications, as well as in other affairs of State, appears from a document preserved in the Public Record Office, in which, in the King's own handwriting, are ordered the demolition of Tynemouth Castle and the building of a blockhouse (Spanish Fort) below it, instead of the Castle; and the demolition of Camber Castle; also that the question of the forts in Holy Island, Landguard Castle, and a fort for Mount's Bay should be discussed.*

The State Papers, between 1636 and 1660, in the Public Record Office, were not calendared, and it would be a matter of considerable time and research, without such assistance, and in the absence of any monograph history of our defences, to trace what was done in the way of fortifying the coasts during this interval. That the military energies of the period were, however, absorbed in the contests of the civil war during great part of this period, appears from a list of the King's Castles in 1661, wherein the only additions to former lists are too trifling to require to be specified. On the accession of Charles II. (1660) Sir Bernard de (or le) Gomme, whose name is so intimately associated with the history of some of our principal fortresses, petitioned for, and obtained, a renewal of the appointment which he had held under Charles I., of Surveyor General of Fortifications, &c. In March of the following year he received the appointment of "Engineer of all the King's Castles, &c., in England and Wales"; and, during his tenure of office, several important additions were made to our defences; amongst the principal being Portsmouth Lines,† Plymouth Citadel, Sheerness,‡ and Harwich.

In 1666 there was war with France, Denmark, and Holland; and the House of Commons, to quote the words of Macaulay,§ "readily voted sums unexampled in our history," towards putting the country into a state of defence. The Governors of the various forts and garrisons were ordered to fortify and repair the walls under their charge, and to victual the same for two months. This order was addressed to Portsmouth, Plymouth, Tynemouth, Dover, and Hull;

* State Papers, Charles I., 1636, Vol. CCCXXVI., No. 14.

† For money spent on Portsmouth fortifications, by Sir P. Honiwood, between August, 1665, and April, 1667, see Sloane MSS. 873; and for a sketch of the rise and progress of the fortifications, see Appendix A.

‡ The land front of Sir Bernard's work no longer exists, but much of the river front remains.

§ Macaulay's *History of England*, Vol. I., p. 191.

also to Pendennis Castle, Berwick, Scarborough, Landguard Fort, the Isle of Wight, and Holy Island; and the Public Records contain numerous scattered references to the strenuous exertions which were made about this time to increase and strengthen the fortifications. The period appears specially interesting, as showing the course pursued when our fleet, as Macaulay describes it, "existed only upon paper," and our enemies had the command of the sea. It will perhaps be convenient to give the results of the notes which have been collected, under the respective heads of those places where new works were constructed, or the old ones reformed.

Portsmouth. The old "mud walls," which attracted Leland's notice, had fallen into decay, and new Lines were ordered from the designs of Sir Bernard de Gomme. The plans and estimates for the work are in the British Museum;* the estimate amounted to £16,356 6s. 6d. The Commissioners for carrying out the works were appointed on 15th May, 1666; and early in 1667 we find several letters and documents in which it is stated that the fortifications are going on at a great pace, and to the admiration of all. In April of that year it is reported that there are three companies of foot wholly employed in perfecting the work, and that the townspeople also assisted. The chief portion of the work, which is substantially the same as was afterwards known as Portsmouth Lines, was completed in July, 1667. About this time were also constructed two small works—Charles Fort, and James Fort on Burrow Island, in Portsmouth Harbour, for the defence of Gosport.†

The fortifications of the Isle of Wight were jealously examined, and, by the strenuous exertions of all concerned, the whole position was put into so excellent a state of defence that it is by no means surprising to find by letters, which were intercepted from the Dutch Admirals De Ruyter and De Witt, dated 24th July, '67, that they were deterred by the strength of Portsmouth and the Island from making their intended attack.

Plymouth. The Citadel on the Hoe was built at about this time, from the designs of the same engineer. The warrant for its con-

* Book 16,370, and Box 16,371.

† The lines of Gosport, which enclosed only the *Town* of Gosport itself, though designed and actually commenced by Sir Bernard de Gomme, were not completed till the middle of the next century. In fact, Franklin, the historian, writes, in 1726, that, on the land side "Gosport is only defended by a mud wall which surrounds it, and a trench or dry ditch of about 10 feet depth and breadth." The accompanying map gives a general view of the rise and progress of the fortifications of Portsmouth.

struction is dated Oxford, 16th November, 1665;* but there does not appear to be any detailed information available respecting it, nor was there apparently any other important addition now made to the defences of this place. *Plate* II. shows the state of the defences about twenty years before this time, and the attack of the Royalists in 1643.

Thames and Medway. The City of London granted a loan of £10,000 for the defences of these rivers, and the fortifications were pushed on with much vigour.

Sheerness was fortified now, also after the designs of Sir Bernard de Gomme, though neither the works nor their armament were in a sufficiently advanced state to prevent the 12 guns which were there being captured by the Dutch, under Admiral Ruyter, on 10th June, 1667, as they swept up the Medway to Chatham. At this place, it is recorded, they found, with the exception of Upnor Castle, "only works which had been hastily thrown up," to oppose them.†

The fortifications at *Gravesend* and *Tilbury* were also strengthened in June of this year, and 80 guns were placed on both sides of the river, 20 of which were mounted at Gravesend.

At *Woolwich*, there were batteries erected under the superintendence of Prince Rupert, and mounting 60 pieces of ordnance.

In the *Downs*, the castles of *Deal*, *Walmer*, and *Sandown* had "turfs laid on their walls" by the men and boys of Deal; but it is written of Sandwich, that "the chief magistrates there kept to their old trade of disagreeing, and have left off fortifying themselves." It is, however, gratifying to find, by a subsequent document in the Public Record Office, that the advantages likely to accrue from the proceedings of their brethren along this part of the coast were at length perceived, and that their example was followed.

Of *Dover*, it is recorded that the fortifications were "strengthened" in June, 1667; Of *Weymouth* and the *Scilly Isles* it is reported that the fortifying of those places goes on rapidly. The newly raised works at *Fowey* were so effective that they repelled an attack by the Dutch fleet, and Sir Bernard de Gomme expresses himself perfectly satisfied with the state of the fortifications at *Dartmouth*.

Along the east coast, too, the indefatigable Chief Engineer found

* State Papers, Charles II., Domestic, CXXXVII., No. 21.

† Pepys, in his diary, 27th February, 1667, tell us that the King and the Duke of York went to Sheerness to see the ground which Sir Bernard had staked out for the new fort there. *Plates* III. and IV. are a view and plan of this attack.

scope for his energies, and at *Harwich*, works of defence were conducted under his superintendence which received the marked approbation of the Duke of York, on the occasion of his visit to that place on 20th March, 1667. By May, the fortifications are said to have been "very forward;" and, on the 3rd July, the Earl of Oxford reports that "Harwich is not now an enterprise for Dutch courage." On the following day, however, the Dutch fleet attacked it; but were repulsed "by the guns from the forts."

In the north, a battery was ordered for *Bridlington Quay*, in April, 1667. £200 was issued for the repair of *Tynemouth Castle* and the forts to secure the mouth of the river; and *Scarborough* is reported as well fortified, and as having a newly erected platform. The fortifications of *Hull* were also examined, and, it is presumed, found satisfactory.

Doubtless other works of defence were erected or strengthened at this juncture, but the foregoing are the principal that were executed up to the date of the peace which was concluded between England and her three foreign enemies in the autumn of 1667.

During the short reign of James II., little or nothing seems to have been done to our coast defences; and even the military genius of William III., a commander who carried war into the enemy's territory, instead of waiting for it in his own, appears to have been mainly directed to the judicious organization of his combatant and non-combatant forces, and to generalship in the field itself, rather than to the art of the military engineer. Yet he perceived the necessity of erecting a strong work at the head of Loch Linnhe, to overawe the Highlanders; and this fortress, named Fort William, after the King, still exists.

In the British Museum, there is a project for Portsea Lines, signed by King William III., but this project was not carried out until the following reigns.

In the middle of the reign of Queen Anne, an invasion of England was projected by the King of France, on behalf of the Pretender. This project received both the pecuniary help and the prayers of the Pope; and great preparations were made for the extension of our fortifications, so far as the purchase of the necessary *lands* was concerned. Large quantities were taken, under Acts of Parliament, at Portsmouth (for Portsea* Lines, &c.), at Harwich, and at

* Queen Anne visited Portsmouth, with Prince George, to examine into a complaint made by the Governor of the town that the artificers at the dockyard and others had erected houses on the site of the modern town of Portsea,

Chatham; but, with one exception, I do not find that works were commenced at any of these places until the latter part of the reign of George II., and during that of his successor. The exception referred to was the small redoubt at Portsbridge, which defended the point where the great road from London to Portsmouth crossed Hilsea Channel. This work, which was the original representative of the modern Hilsea Lines, was probably constructed during the reign of Queen Anne.

The chief works of importance constructed during the reigns of George I. and George II. were Chatham,* and Devonport Lines which were commenced towards the end of the reign of the latter monarch. The fortifications round Priddy's Hard at Gosport, batteries at Lumps and Eastney, and a small work (since replaced by Fort Cumberland) were erected at about the same time. Batteries were also ordered on sundry points in Milford Haven, and at Little Hampton, Brighton, Blatchington, Seaford, Hastings, Rye, Folkestone and Hythe, along the south coast, the cause for all these preparations being, as cited in the preamble of the Act 31 Geo. II., cap. 39, "the unjust and hostile invasion made on His Majesty's dominions in America and the Mediterranean, and great preparations made in France for invading these realms."

Towards the middle of the reign of George III., when the Duke of Richmond was Master General of the Ordnance, and during the French Revolutionary War, still further additions were made to our coast defences. At Portsmouth, Portsea Lines were built; Fort Cumberland was entirely re-constructed; the old Hilsea Lines were thrown up; and the western defences were extended by the construction of Fort Monckton, and a few small batteries for the defence of Stokes Bay. Numerous small earthworks were also built, at this juncture, at various parts of the English coast; but they were allowed to fall into decay after the war.†

At Plymouth, large quantities of land were acquired at various points in the vicinity of the town and dock, but the chief works

which masked the fire of the guns on that side of Portsmouth Lines. The Governor had threatened to destroy the houses with artillery if they were not removed, but the result of Her Majesty's visit was a resolution to acquire the ground on which Portsea Lines now stand.—(Slight's *History of Portsmouth.*)

* They were, however, considerably reformed and increased some 20 or 30 years later.

† The local authorities appear, in many cases, to have constructed the batteries, whilst the Government supplied the armament.

constructed were the line of redoubts and barracks which occupy the position known as the Maker Heights.

Next in order of date came Sheerness Lines, constructed during the last decade of the eighteenth century.

Between that date and the issuing of the Royal Commission in 1860 to inquire into "the present state, condition, and sufficiency of the fortifications existing for the defence of our United Kingdom," little was done to the fortifications beyond executing the necessary repairs. At Portsmouth, the northernmost of a line of works, forming the Gosport advanced position (Fort Elson), was commenced, and two or three batteries were erected for the defence of the Needles Passage, and of Freshwater Bay in the Isle of Wight. At Plymouth, batteries were constructed at Picklecombe, and at Cawsand Bay, for the defence of the Haven, and the forts at Tregantle and Scraesdon, forming the western defences of Plymouth, were commenced. Some of the old batteries at Milford Haven were re-formed, and one or two new ones were constructed. The great citadel on the Verne, Portland, and the Fort at the Nothe Point, near the site of the former battery there, were begun, and sundry other minor works were undertaken; and in pursuance of the recommendation of the Royal Commissioners, dated 7th February, 1860, vast additions were made to our national defences, which it does not come within the province of this brief sketch to describe.

The writer hopes it may be clearly understood that he has merely attempted a rough sketch of this great subject, which, slight though it is, may nevertheless serve as the nucleus of a more exhaustive and complete treatment of the history of our permanent fortifications.

APPENDIX A.

Historical Sketch of the Rise and Progress of the Fortifications of Portsmouth down to the time of the Duke of Richmond, Master General of the Ordnance.

Portsmouth may be cited as a good illustration of the gradual rise and progress of our fortifications. (See *Plate* V.)

Without going back to any details as to Roman times, it may be observed—First, that the port was used as a point of departure for France by our Plantagenet Kings, and at Porchester Castle they embarked. Here the royal stores were kept, and it was whilst the castle was occupied by King John, both as a fortress and as a storehouse, that he issued orders for the construction of those docks from which the modern Portsmouth dates its origin.

The next step seems to have been the erection of the two towers at the mouth of the harbour, attributed by Leland to the middle of the 15th century. In the middle of the 16th, the town of Portsmouth was enclosed by "a mud wall," and Southsea Castle was erected to prevent a landing on the adjacent coast. Works, strong for the period, were constructed at various points on the Isle of Wight, viz., at Sandown Bay, Yarmouth, East and West Cowes, Sharpwood Point, etc.; and on the mainland, at Hurst and Calshot.

Another century elapsed, and the old Portsmouth Lines were taken down and re-constructed, much as they till lately stood; two works, Charles Fort and James Fort, were erected in the harbour near Gosport, and the fortifications of the town of Gosport were commenced, but not completed.

In the reign of Anne, a slight extension of the system of defence was made by the construction of a small work, to command the point where the main road from London entered Portsea Island, at Portsbridge: this was the earliest representative of Hilsea Lines. Up to this time the dockyard was merely enclosed by a defensible wall; but the lands were now acquired for Portsea Lines, and also for the extension of Gosport Lines, so that the latter might include the site now occupied by the Clarence Victualling Yard. The execution of the intended works was, however, delayed for a considerable period.

By the year 1750 Cumberland Fort (subsequently re-constructed under the auspices of the Duke of Richmond) was erected, under the name of Eastney Fort; and, in the course of the next few years, this part of the coast line was still further defended by the two batteries at Lumps and Eastney, erected in 1759. Old Hilsea Lines and Portsea Lines were also built during this interval; Gosport Lines were completed, much as they now stand; and the magazines at Priddy's Hard were enclosed by ramparts.

The next great addition made to the fortifications of Portsmouth was soon after 1780, when the defences were pushed still further westward by the erection of Fort Monckton, and six small batteries along that part of the coast now occupied by the Stokes Bay Lines.

AREAS DEFENDED BY

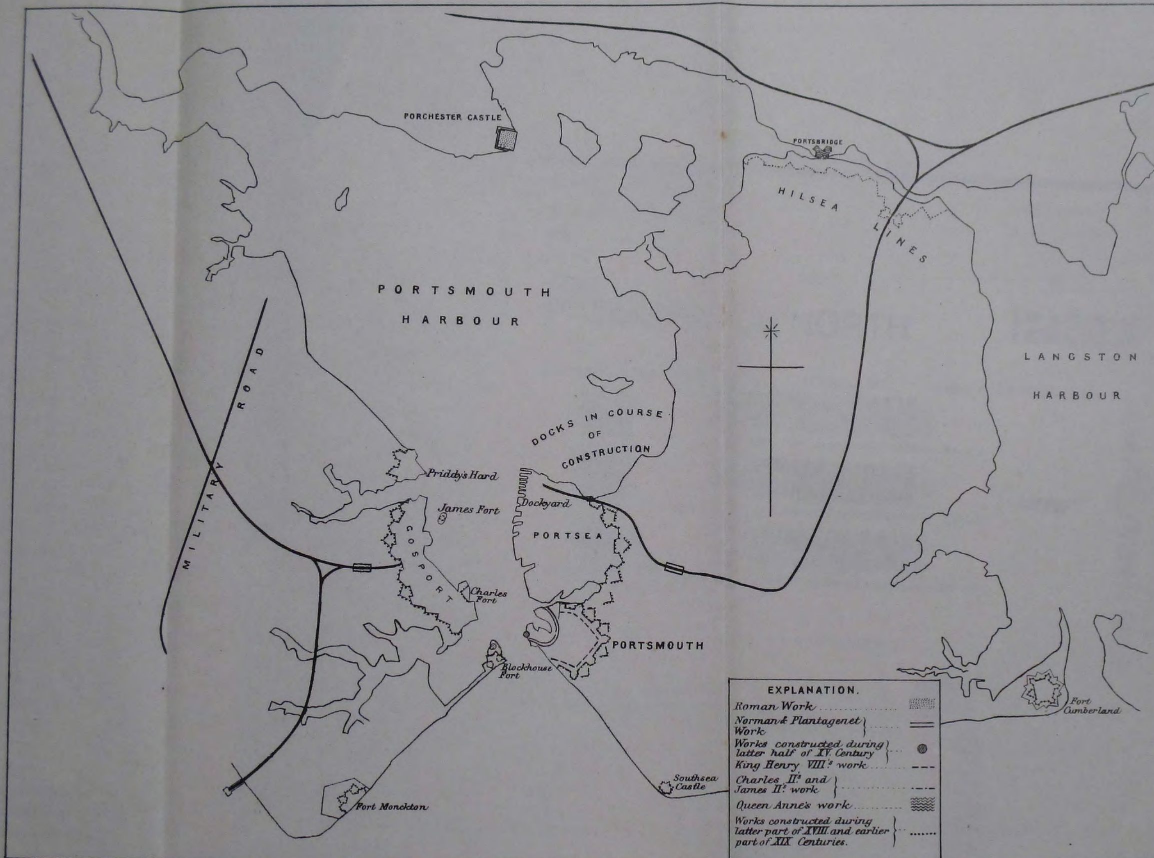
Roman work	...	6 acres.
Norman and Plantagenet ditto	...	20 acres.
Latter half of fifteenth century ditto	...	—
King Henry VIII. ditto	...	250 acres.
King Charles II. and King James II. ditto	...	500 acres.
Queen Anne ditto	...	—
Latter part of the eighteenth century ditto	...	9,000 acres.
Works erected during the last few years	...	33,250 acres.

W.H.T.

PLYMOUTH HAVEN. From a Chart drawn in the reign of King Hen VIII preserved in the British Museum.


A TRVE MAPP AND DESCRIPTION OF THE TOW-
-ne of Plymouth and the Fortifications thereof with the wor-
kes and approaches of the Enemy at the last Seige A 1643
Salte Ash
Saltash Passage
St Buloks
St Stephens
Enemy
The River of Liner
Weston mills
Warn
Peirse Crosse
Drakes Water
Eg Buckland
Corn
Enemy
Hamwose
Stonehouse mill
Enemy
Maudlyn
Holiwell
Compton
Lipson mill
Penycomquick
New worke
Stonehouse
St George drawbridge Spurr
Charles fort
Resolution fort
Lipson
Lipson mill worke
PLYMOUTH
Leery point worke
The Leeree
Plymton mole
Stonehouse worke
Injworth
The River of Tamar
Passage point
Bloodehouse
Crunell Passage
Vallie
Mountedgcomb
Killbare
The hoe of Plymouth
Castle
Fort
Catdowne
Prince rock
Catsdowne worke
Saltram
Beckley
Catwater
Plymstock
Stanforde
Oreston
Enemy
Radforde
Maker
S. Nicholas Iland
Cawson
Plymouth Sounde
A Scale of Miles
1
2
3
Penlee
Ramehead
Wenburie


A Scheme of the Posture of the Dutch-Fleete and action at Shere-nesse and Chatham 10th 11th & 12th of June 1667 taken upon the place by J B.
Part of Essex
Lee
Thamesis flu.
Black-house
Tibery
the Hope
Gravesend
Blith sand
nowre head
oze edg
mouse
Spaniard
pan sand
Loda
GREANE
Swale
Shere-nesse
SHEPY
Q: borow:
Skell Ness
Ks Ferry
East swale
Medway fl.
Rayman
Gillingham.
Feversham.
Upnore castle
Chatham yard
Strood
ROCHESTER
Burnt.
Sunk
N
E
W
S


PORCHESTER CASTLE
PORTSBRIDGE
HILSEA LINES
PORTSMOUTH HARBOUR
LANGSTON HARBOUR
DOCKS IN COURSE OF CONSTRUCTION
MILITARY ROAD
Priddy's Hard
James Fort
Dockyard
PORTSEA
GOSPORT
Charles Fort
PORTSMOUTH
Blockhouse Fort
Southsea Castle
Fort Monckton
Fort Cumberland
EXPLANATION.
Roman Work
Norman & Plantagenet Work
Works constructed during latter half of XV. Century
King Henry VIII's work
Charles II's and James II's work
Queen Anne's work
Works constructed during latter part of XVIII. and earlier part of XIX Centuries.

PAPER III.

RECENT RESEARCHES ON MALARIA.

By Lieutenant J. E. Clauson, R.E.

The purpose of this paper is to record the most recent results attained in the study of malaria. Professor Tommasi-Crudeli and Professor Klebs, to whom the honour of discovering the *bacillus malariæ* is due, have also demonstrated that the fever germ is developed primarily from earth, and not from water. Moisture is indeed essential for the growth of the fever germ, but in very much smaller quantity than has hitherto been considered necessary. The advantages, climatic and otherwise, of extensive and thorough land drainage remain uncontested, but this alone must not be expected to prove a complete cure of malarious districts. In fact, it appears that in some cases covering a sodden soil with water is safer than attempting to drain it. This discovery has not given unmixed satisfaction at Rome, as it shows the sanitation of the Campagna to be a far more difficult problem than it was believed to be. But it is information that is important alike to the military engineer, who may be called upon to advise respecting the encampment of troops, or the location of garrisons, and to the civil engineer, who has to grapple with fever in all parts of the globe. For instance, in great expanses, like Burmah, drainage may be utterly impossible, while the management of large volumes of water may be practicable, and in every way advantageous.

§ 1.—Introductory Remarks.

It has been estimated that malarial fever, in one or other of its many forms, is answerable for one-half of the entire mortality of the human race. This may perhaps not be literally correct, but malaria has again and again come to the front as an important factor to be dealt with in political and military undertakings. In support of this statement it will be sufficient to quote as instances the British occupation of Cyprus in 1878, and the recent works at the Isthmus of Panama. Nevertheless, this subject has of late years ceased to attract much attention from the general public in England. This is no doubt to be attributed to the fact that, as an endemic disease, malarial fever has almost entirely disappeared from the country. The drainage of the Fens of the eastern counties, and of other malarious districts, has robbed it of much of the significance it had in the last century. At the same time, it must not be forgotten that, although Englishmen are especially favoured in this respect at home, the subject of malaria has acquired a regrettable importance in connection with many of the British possessions and dependencies abroad. Unfortunately, the very variety of our experience has interfered with a connected and distinct enquiry into the methods of dealing with this formidable class of diseases.

In Italy the case is very different. The question of improving the sanitary condition of the Roman Campagna has always been a leading political problem. Rome was proclaimed the capital of United Italy in 1870, and this was almost the first subject considered. On the 20th September, of that year, the Italian troops entered the city. Two months later, on the 20th November, a Royal decree submitted the problem of the improvement of the Campagna to a commission of the most distinguished scientists of the day, and since then Rome has taken the lead in researches into the nature of malaria. The results of these researches are embodied in a recently reprinted course of lectures, delivered some months ago before the Roman Institute of Experimental Hygiene, by Professor Tommasi-Crudeli *, whose own labours in this field have been of the highest importance. To him, and to his works, the writer is indebted for the greater part of the subject matter of this paper.

Within the last seventeen years every imaginable expedient has been devised to improve the condition of the Campagna. It might have been expected that such increased attention devoted to this vexed question would soon have found for it some practical solution. Indeed, it was the universal opinion among English authorities on the subject at the time, that the task set to the commission was an easy one, compared with many similar land improvements in England. It was generally supposed that one of the most efficient

* *Il Clima di Roma.* Loescher & Co., 1886.

remedial measures would be deep cultivation of the land surrounding the City of Rome by steam or horse-power, to break up the soil and expose it to atmospheric influence. This system was put to the test not many years later. The newspapers took up the cry of cheap corn for Rome by extensive cultivation of the Campagna, which had previously been almost entirely devoted to pasture. Large tracts of country were ploughed up. Unfortunately, the hillocks, which constitute four-fifths of the area, consist for the most part entirely of tufa, with only a few inches of vegetable mould on the surface. The result was that the first heavy rains carried down the greater part of this soil into the valleys below, and many hills may now be seen absolutely denuded of soil, a network of shallow furrows scratched on the bare rock indicating the track of the plough. This failure was only one of a long series of futile attempts to improve the Campagna. Many more will have to be referred to. But before doing this, and before describing other systems that have met with more success, it is essential to explain roughly the general local characteristics of the district under consideration.

§ 2.—The Roman Campagna.

The district known as the Roman Campagna is of triangular form, with a base about fifty-five miles in length on the sea. It is bounded on the other two sides by the southern slopes of the Tolfa heights, and by the Sabatine, Simbruine, Tiburtine and Latial hills. The area thus enclosed exhibits a most extraordinary variety of geological features, considering that its whole extent is less than three times that of Middlesex. It will only be necessary for our purpose to classify it, physically, under three headings :—

(i.) The uplands formed mostly of tufa, pozzuolana, and ashes of volcanic origin.

(ii.) Valleys formed by erosion. These are sometimes of considerable depth, with precipitous sides often a hundred and fifty feet or more in height. The hollows of the wider valleys are of somewhat complicated geological nature, the original local formation of the valley being mixed up with alluvial soil of volcanic or other origin brought down by the streams.

(iii.) The purely alluvial plains, including the delta of the Tiber, and a narrow strip along the coast.

The portion of the Campagna which can be called level is only a small fraction—perhaps one-fifth—of the whole. A glance at a good geological map of the district will be sufficient to show the fallacy of the popular idea that the Campagna is a large plain. On the contrary, it consists for the most part of hills of no inconsiderable magnitude. The effect of the rainfall on these hills deserves notice, as it is somewhat peculiar. When the subsoil of a hill is composed of such elements as gravel, sand-stone, or strata of lava, rain-water, after passing through the few feet (or sometimes inches) of mould above, escapes through the interstices between the particles of gravel and sand, or through the numerous vertical fissures in the lava. Such hills, however, are the exception, the usual subsoil formation being marl, clay, or tufa. The latter is permeable by water to a certain extent, though not so much so as the vegetable mould above it. The marl and clay are almost impervious to water in the rainy season, when they have once become thoroughly saturated. The consequence is that rain-water finds its way with comparative facility through the thin layer of vegetable soil, but cannot sink so readily through the tufa or clay, and therefore after heavy rains a sheet of water collects on the top of the impervious subsoil. When the hill has a uniform slope, this water slides down to the valley beneath, carrying with it more or less of the scanty layer of vegetable soil, and converting the low-lying ground into a marshy bog. When, on the other hand, there are undulations in the tufa forming reservoirs on the hill-sides, the water of course collects in these, and the place is converted into a permanent swamp during the rainy season. It will be observed that the saucer-like depression in the under-lying tufa is not at all necessarily reproduced on the surface of the ground above, and hence these small swamps easily escape notice. They may also be found at considerable heights above the valley, and even on the crest of a hill. In many cases the depressions are of considerable size, having once been volcanic craters. The Valle Ariccia, near Lake Albano, is an example of these. It is nearly a mile across, and after heavy rain becomes a bog, there being apparently no adequate outlet for the water. It is exceedingly fertile; but, as might be expected, very unhealthy.

Of timber, as generally understood in England, there is very little. Large tracts of country, amounting to about one-fifth of the whole, are covered by woods, but these are chiefly scrubs consisting of stunted brushwood growing on boggy and damp soil. This is an important point to bear in mind when discussing the relation of malaria to wooded localities.

§ 3.—Roman Malaria; Its History.

The references made to malaria by the classical writers are, perhaps, not as numerous as one might be led to expect. Professor Tommasi-Crudeli, however, points out a very convincing proof of its antiquity. All ancient nations had a tendency to personify the chief enemy of their new colonies. Thus, Pelasgic races made of it the Lernean Hydra slain by Hercules. The Greek colonies of Pæstum, Sybaris, Agrigentum and Selinus called it an evil spirit, or a monster which devoured men. The Latins, confusing cause and effect, invented the myth of the goddess of fever. Temples were dedicated to this deity, and it was hoped that she might be propitiated by prayers and gifts.

In later times we find more direct allusion to the fevers. It is recorded by Livy that the legionaries who were employed in the Samnite war at the siege of Capua (B.C. 339) mutinied after the capitulation of the town, on the ground that it was not right that the people of Capua, who had surrendered to them, should inhabit a fertile and pleasant land, while they themselves, after their exertions in the war, had to labour in the barren and pestilential country round Rome.

The question of the real condition of the Campagna under the Empire is one of some difficulty, and of considerable importance.

It is an undoubted fact that in the first century of the Christian era the most wealthy Roman patricians possessed country houses in the Agro Romano. This is proved not only by the numerous references to these villas in the writers of the Augustan age, but by the remains which are constantly being found in all parts of the Campagna. The sites of these buildings are often placed on spots which are now considered quite uninhabitable. The natural conclusion to be drawn from this is, of course, that the country was much more free from malaria in ancient times than it is now. This assumption is probably true, but to a more limited extent than might at first sight appear. Its truth is influenced by the two following considerations. In the first place, the standard of uninhabitability of a place was probably somewhat different in earlier times. Human life was not then held so precious as it is now, and the conquerors of the world would attach little importance to the loss of a few slaves through fever. Suetonius tells us that in Nero's reign thirty thousand people died of fever in a single autumn. It was the old story of the Minotaur, which was to be appeased only by the sacrifice of a certain number of victims annually. The Romans paid their annual tribute with almost oriental fatalism.

Secondly, we must remember that the want of remedies against malarial fever in the past increased the resisting power of a race against its ravages. The converse is true for our own times. This is only another form of the principle of the survival of the fittest. In support of this a parallel instance may be quoted, which occurred after the Spanish invasion of Mexico in the fourteenth century. Cortès resolved to create a port on the Gulf of Mexico, at a place where yellow fever, as an endemic disease, is found in its most virulent form. In spite of its constant and deadly ravages, this port has since developed into the city of Vera Cruz. No specific remedy against yellow fever is yet known, so the process of natural selection has continued unchecked. The permanent population now withstands attacks of yellow fever in such a way as to astonish not only foreigners, but even the Mexicans of the interior themselves. The latter, when visiting Vera Cruz, contribute so many victims to the disease that they have named the place the City of Death. It has been supposed that some such conditions held good, as regards malaria, in times when medical knowledge on the subject was less complete than it is at present.

§ 4.—Researches into the nature of Malaria.

In 1879, Professor Tommasi-Crudeli conducted, in concert with Herr Klebs, a series of experiments, the results of which must be classed among the most important discoveries ever made in connection with the subject of malaria. It has been generally supposed that malarious fevers are solely due to putrid emanations from marshes and marshy places. This theory, which appears plainly enough in the terms of "paludal poison," and "marsh miasm," is not correct. The specific ferment which generates malarial fevers by its accumulation in the air breathed is not of exclusively paludal origin, and still less is it a product of putrefaction. Professor Tommasi-Crudeli maintains that malaria is produced in earth, and not in water. The first occasion on which this fact was made clear to him was when he was acting as medical officer to one of Garibaldi's columns, marching along the north coast of Sicily on Milazzo, in July, 1860. Preparations were being made to encamp one night on the steep declivity of a high cliff overlooking the sea, when the Sicilian guide advised the colonel not to occupy the position, as it was malarious. The medical officer was called upon to give his opinion, and, after satisfying himself that there were no marshes or swamps near the spot, came to the conclusion that the guide was mistaken. In the result, however, the man proved to be right, for on the following morning several of the soldiers were attacked by intermittent fevers. Dr. Charles Creighton mentions that West Indian experience has shown that the high limestone ridge is often more unhealthy than the swamp at its base, and that the same fact has been observed on the Kentish shore of the Thames estuary.

The results of the experiments referred to a few lines back may be briefly summarized as follows :—

(i.) The immediate cause of malarial fevers is an organism of the genus bacillus.

(ii.) This organism is frequently to be found in land which is not, properly speaking, marshy.

(iii.) All earth which contains this organism is not necessarily malarious. The danger begins only when certain conditions favouring the multiplication of the bacillus are fulfilled. Until then, the parasite remains in a state of inertia.

These conditions, as stated by Professor Tommasi-Crudeli, are three in number :—

(*a.*) A temperature not lower than 68° Fahrenheit.

(*b.*) A certain amount of permanent humidity in the malarious soil.

(*c.*) The direct action of air upon the malarious soil.

The absence of any one of these three conditions is sufficient to prevent the development of this organism; and consequently the danger to health, which depends directly on this development, ceases also.

The importance of the knowledge of these conditions can scarcely be over-rated. They elucidate at once many curious and apparently contradictory phenomena, which have hitherto much perplexed specialists. It is, for instance, a well-known fact that immunity from malarial fever is at its maximum during the winter. It has, however, also been observed that a similar immunity is experienced in the Campagna during very hot summers. The former circumstance is explained by the first condition, viz. :—that the temperature must be at least 68° Fahrenheit. The latter circumstance, which at first sight seems inconsistent with the former, is reconciled to it by the second condition—for, during a very hot summer, there is an insufficient amount of permanent humidity in the earth to render it malarious.

The third condition is perhaps the most novel, and explains several anomalies often observed. Thus, for example, it has frequently been found that malarious districts when flooded have been much improved thereby, from a sanitary point of view. A still more remarkable illustration is to be found in the city of Rome. It has long been a subject of wonder that such squalid and low-lying quarters as the Ghetto have been free from malarial fever, while the hills round the city (such as the Pincian) have been quite the reverse. Doctor Tommasi-Crudeli, in the work already referred to, gives two lithographed plans of Rome, showing, by difference of colouring, the malarious districts existing in 1870 and in 1884 respectively. The more recent plan shows a great increase in the area built over—roughly speaking, the city has doubled in size. The remarkable feature is, that immunity from malaria has steadily followed the extension of building operations. This fact is adduced in support of the third of the elementary conditions indicated above, and it must be admitted that the presumption is very strong that the increased freedom from malarial fevers has been the direct outcome of the covering over of the soil by the new town.

§ 5.—CULTIVATION *versus* MALARIA.

These considerations with respect to the surface of the soil lead us naturally to the question of the influence of a high degree of cultivation in checking the evil effects of malaria. In this connection we must distinguish carefully between surface cultivation and subsoil drainage. We are at present confining our attention to the former of the two. A high state of cultivation applied to land previously malarious is not always an unmixed benefit. It is not unfrequently very much the reverse. The fact is, that the conditions of malarious lands are so various that we cannot always say *a priori* that a system successful in one place will not be positively injurious in another; and it follows that extreme caution should be exercised in adopting a policy of cultivating a malarious district in the hope that malaria will disappear from it. It has often occurred that extensive movements of earth undertaken for this purpose in the Campagna have actually increased the amount of fever found there. Several examples of this in particular localities are quoted by Professor Tommasi-Crudeli, but the following is as striking as any. Prima Porta, on Via Flaminia, was noted for its unhealthiness as long as the land surrounding it was cultivated with corn. Of late years, however, in consequence of agricultural depression, these fields were converted into meadows, and as a result, fevers have disappeared from Prima Porta. This instance confirms the explanation given for the increasing healthiness of the parts of Rome recently built over, viz. :—that covering over malarious soil by some means, so as to prevent the action of the air on it, has a most beneficial effect in checking the growth of the malaria bacillus. In one case the covering medium is pavement, and in the other turf, but the effect in both cases is identical.

Of fancy systems of cultivation proposed for malarious districts in the Campagna there has been no lack. They have all been more or less empirical remedies, and have all failed in procuring satisfactory practical results. One proposal was to plant sunflowers. These were to have a doubly beneficial effect. In the first place they were to counteract the malarious effects of the soil in which they were planted; however, no proof of the correctness of this assumption seems forthcoming. In the second place their seeds were to attract numbers of birds, and the flight of the birds through the air was to purify it in some mysterious manner, presumably best known to the originators of the scheme. The sunflower craze seems to have met with some little favour, and it had at least the merit of harmlessness. The eucalyptus theory, which came to the front several years ago, was a more pretentious scheme. The tree was to have a threefold action. Its roots were to extract the water in damp and marshy ground, and thus have all the beneficial effects of drainage without the expense; the aroma given out by its leaves was to neutralize the malarious germs in the air; and lastly, its fallen leaves were to prevent the formation of the same germs in the earth on which they dropped.

The history of the eucalyptus tree in Italy was a somewhat remarkable one, and deserves some mention. In 1880 a large convict establishment was founded at a place called Tre Fontane, the traditional place of execution of St. Paul, some three miles from Rome. The works were directed by the inmates of a neighbouring monastery of French Trappists, and the whole district was supposed to have been entirely freed from danger of malaria, thanks to a high degree of surface cultivation, to extensive plantations of the eucalyptus tree, and to the use of a cordial extracted from its leaves by the Trappists.

Here, then, was an experiment under the most favourable conditions possible. Government provided labour at a very cheap rate. It also undertook all the expenses incidental to feeding and lodging the convicts, and provided a good infirmary and sound medical treatment for the sick. No private landowner could have afforded such an excellent opportunity for proving the practical value of the eucalyptus tree as a preservative. Nevertheless, the experiment proved a failure. The settlement was attacked by malarial fever from the very commencement, and nearly all the inmates suffered more or less severely. It was endeavoured to explain this away by asserting that the season had been a particularly bad one for fever in the surrounding districts, and that some of the infected air must have found its way to the Tre Fontane. Unfortunately for this theory, the year 1882 was conspicuously healthy for the country in general, and the only district severely attacked was the very one which was supposed to have secured immunity by the eucalyptus. In the course of the summer and autumn of that year, every single inhabitant of the place had malarial fever. The worst cases seem to have occurred among the convict-warders, presumably on account of the small amount of exercise they had compared with the men under their charge. The amount of sickness was hushed up as much as possible by the Trappists, who were, of course, interested in not losing the services of the convicts. All the cases were treated on the spot, and, thanks to excellent medical treatment, and to the consumption of three kilogrammes of quinine, no lives were lost, but many patients had, on convalescence, to be sent away to recover their strength. In the Italian Chamber of Deputies the whole matter was flatly denied, and Dr. Tommasi-Crudeli, who raised the question, seems to have met with considerable abuse from various persons interested, and especially from the French clerical press, which, of course, did all in its power to support the French monks of the Tre Fontane monastery. However, another serious outbreak of fever occurred in the autumn of 1885; and this could not remain concealed, as many free labourers employed at the place returned to the hospitals of Rome for medical treatment. This failure was the natural outcome of a crude and ill-considered scheme. The originators of it had not made sure of their facts beforehand, for although the eucalyptus seems to have done good service in some localities, it is always unreliable, and it was certainly unsuited for the shallow soil at Tre Fontane. Its root is by nature of a long spindle shape, and the soil was not as a rule more than four feet deep; indeed in many places it was found necessary actually to blast pits in the rock for the reception of the trees. It was stated by Mr. W. North, in a lecture recently delivered at the London Institution, that the trees were planted much too closely together, and were altogether under such disadvantageous circumstances that they did not attain to more than half their normal growth. These facts were given on the authority of two gentlemen who had acquired considerable experience in the subject in South Africa. The eucalyptus tree is also particularly apt to succumb to the frosts of European latitudes, and it is recorded that on a single night—January 4th, 1886—no less than 150,000 trees were destroyed by frost in half an hour on this small estate of some twelve hundred acres. But, besides this unsuitability of the eucalyptus for colder climates than its own, it should be added that the beneficial effects of the tree as regards malaria are by no means fully established. Professor Liversidge, of the University of Sydney, has shown that the existence of malaria has been considerable in the very plantations where the tree is grown, and this fact is confirmed by recent investigations in Algeria.

A few remarks on the relation of woods and forests to malaria may be of interest. It is a well-known fact that the clearing of forests in malarious countries has often proved very beneficial. The true cause for this is not quite so obvious as it at first sight may appear. The explanation usually given is, that malaria is produced by the decay of leaves, boughs and dead insects, which accumulate on the ground and slowly decompose. This theory, however, will not bear examination, for in malarious countries we often find woods in which the amount of decaying matter is enormous, but which are not malarious places. The fact is, that woods are not productive of malaria except in an indirect way—they do not actually produce it, but they favour its development when they cover ground which contains the germs of malaria. Professor Tommasi-Crudeli puts it very plainly :—" Trees intercept the sun's rays and prevent active evaporation from the soil ; the latter, consequently, retains much moisture in the hot season, even where it is in direct contact with the air. If these portions of the soil contain no malarial ferment the wood is harmless ; but if the germs exist, the wood favours their development by holding the moisture. And as the presence of this germ in the soil is only too common in nature, instances of malarious woods frequently occur ; and examples of sanitation effected by felling such woods occur with proportionate frequency."

In very damp malarious districts, a combination of subsoil drainage and clearance of woods has seldom failed to produce highly beneficial results. An example of this occurred near Cisterna, about thirty years ago, when large tracts of woods were cleared, and the ground converted into meadows and corn-fields. The result was, that the healthiness of Cisterna was much improved, and its population, which had been dwindling away, began to increase. When these facts were brought forward, considerable discussion on the subject ensued, and the result was the appointment of a Commission, which, after a minute investigation on the spot, came to the conclusion that no case of increased malaria in consequence of the clearance of woods had ever been proved, and that the reverse had rather been shown.

§ 6.—The Drainage of Marshes.

The heading of this section has been chosen less from the suitability of the expression than from the want of a better one. It is proposed to consider the means available for getting rid of an extensive marsh under various conditions. The conversion of marshes into "polders," that is to say, into basins drained by means of pumping machinery, is a method extensively practised in the Netherlands. Drainage thus worked by wind or steam power has resulted in the reclamation of large tracts of fertile land. The course adopted by the Dutch was the only one available. They were unable to utilise their rivers for alluvial deposition of soil in the basins, and the carting up of sufficient earth to cover such large extents of country was of course out of the question. The drainage of two marshes near Rome (Ostia and Maccarese) was decreed by a law in 1878. It was subsequently proposed that this improvement should be effected in the same way as in the case of the Dutch "polders." Professor Tommasi-Crudeli was the first to point out, in the course of the lectures previously referred to, that this system was unsuited to the local conditions, and that another course would be preferable. This statement caused much interest, and the reasons for his opinion were given in a long article published in the *Nuova Antologia* for the 15th June, 1885. The results arrived at are of such importance to engineers that it is proposed to give some short account of them.

Before proceeding to the extensive and often hazardous works involved in dealing with a marsh, the first question to be considered is the amount of importance which ought to be attached to such marshes as causes of malaria. Recent investigations all tend to prove that this importance has been largely exaggerated. A theory, which has already been alluded to, attributes malaria exclusively to the influence of adjacent marshy ground. It has frequently been the case that malaria has been severe in places far distant from marshes. To the advocates of this theory the exact distance seems to have appeared of small moment. The most conspicuous example of this was the attribution of the malaria in Rome to exhalations from the two districts mentioned above. These marshes, situated close to the mouth of the Tiber, are distant some fifteen miles from the city, in a south-westerly direction. It would, of course, be quite impossible for these exhalations to have any effect on the health of Rome unless they were brought by the wind, and that a south-westerly one. Now, it has been demonstrated from meteorological statistics by Professor Tacchini, that of all the twelve years from 1871 to 1882, it was in the year (1882) in which the greatest number of south-westerly winds *(Libecci)* were recorded at Rome, that the smallest percentage of the population suffered from malarial fevers.*

It will be seen then that the existence of the marshes of Ostia and Maccarese was not really injurious to Rome, except in so far as it affected the healthiness of one of the principal approaches to the capital. The inference is, not of course that marshes are healthy, but that the causes of malaria must be sought rather in the local character of the soil than in the influence of a more or less distant marsh.

There are, however, occasions when it is absolutely necessary to deal with marshes. It has already been mentioned† that the immediate cause of malaria is the *bacillus malariæ* when developed under the three conditions in the earth of a sufficient temperature, humidity, and exposure to the atmosphere. It is simply the amount of humidity in marshes which makes them potentially dangerous, and it is this humidity which renders a marsh in a malarious district tenfold more dangerous than the surrounding country.

The hygienic disposal of the water of low-lying marshes in close proximity to the sea is one of the most difficult problems that an engineer can be called upon to deal with in a malarious country. If the general idea that the stagnant water is the single cause of malaria were true, the solution would be a comparatively easy one. It would consist simply in drawing off the surface water by means of trenches and pumping machinery. It is, however, unfortunately the case that a very moderate degree of humidity during the hot

* The observations for each year are, of course, restricted to that portion of it to which malarial fevers are practically entirely confined, viz:—the three months from July to September.

† In § 4.

season is sufficient to induce the worst forms of malaria. This has been repeatedly proved in the Campagna, and in many other parts of Italy. The consequence is that nothing is gained by removing the sheet of water which covers a malarious marsh, unless steps are also taken to prevent the possibility of the upper layers of earth remaining damp during the hot season. Failing this, the end attained is contrary to that proposed, for the removal of the sheet of water causes an increase in the production of malaria, on account of the malarious soil exposed. In fact, the water plays much the same part as the pavement at Rome and the turf at Prima Porta, which were referred to in the fourth and fifth sections of this paper. It helps to prevent that immediate contact between air and earth which is essential for the development of the *malaria bacillus.* Nature often supplies an example of this kind of sanitation in many marshes situated in malarious districts, which are not dangerous to health, even during the hot season, so long as the waters are sufficient to cover them to a certain depth, but when the level falls and more or less extensive tracts of ground are laid bare they produce malaria to a great extent. This hint, given by nature, has often been profited by, and many instances can be quoted of improvements of malarious districts effected by water.

Professor Tommasi-Crudeli points out two remarkable examples.

The fortress of Mantua is one of the most important strategical points of Upper Italy. Its strength arises chiefly from its relative position to the other three corners of the celebrated Lombard quadrilateral. But it has also an additional importance on account of the surrounding plains. This has been frequently realized by the various armies which have laid siege to the fortress. The valley of the Mincio widens out just above the city, and forms a lake of considerable extent. The latter is kept at a constant level by a dyke thrown across the valley. Some of the sluices cut through the dyke are used only in time of war to effect inundations. Others are constantly worked for regulating the amount of water in the lake. Besides this upper lake, there are also two others which receive the surplus waters from the sluices of the upper lake. It has been shown by experience that when the water in these lakes falls below a certain level there is an immediate outbreak of malaria. Until the year 1848 this was prevented by means of the sluices at Governolo, near the junction of the Mincio with the Po. Whenever the water in the lower lake fell below this level the water-gates were closed. By this means the banks of the lake could always be kept under water. In the year 1848 the Austrians destroyed the Governolo sluices for military reasons, and a series of outbreaks of malaria immediately followed whenever the level of the lake fell. When the Austrians quitted Italy in 1866, the inhabitants of Mantua at once demanded the reconstruction of the Governolo sluice.

The second example is afforded by Lake Avernus, at the western side of the bay of Naples. The sanitation of this volcanic hollow has been effected by increasing its depth and embanking its sides. The operation was completed by filling it with water, and has proved eminently successful. This method, when allowed by conditions of level and water supply, is a very valuable one, especially in the case of small operations, but when the area to be dealt with is of larger extent, the expenses of the works required in increasing the depth and heightening the banks is practically prohibitive. The limits of financial resource are, however, sooner reached when it is attempted to cover a marsh with earth carted from elsewhere. The system of draining by means of pumping machinery, as adopted in Holland, is still more costly, and should only be employed when all other methods are impracticable. The working of the machines involves a permanent and not merely a temporary expenditure. Besides this, there is always a considerable element of danger arising from the fact that the moisture may not be completely eliminated. Thus, in 1857, and in following years, there was a succession of very severe outbreaks of malarial fever, as a result of the conversion of the Lake of Haarlem into a "polder." In many "polders" malaria has become endemic. If such facts are observed in such comparatively cold climates as Holland, it may safely be assumed that the dangers of such operations in more southern latitudes would be very great.

The last method that requires notice is that technically known as *warping*. This system is only available when a river carrying a large quantity of solid matter in suspension is at hand. It consists in flooding the marsh with turbid water, and allowing the solid matter to settle. The clarified water is then drawn off and the operation repeated. This method, in time, produces very good results, but it is rarely feasible.

§ 7.—Land Drainage.

Allusion has already been made (in § 2) to the very unsatisfactory state of the disposition of water in the hills of the Campagna. It was shown how the rain falling on some of these hills of peculiar geological formation, partly collected in subterranean hollows in the hill-sides, and partly helped to convert the low-lying ground beneath into a permanent swamp. Similar geological conditions will often be met with in other localities, and it will be useful to describe how they have been more or less successfully dealt with. The first proceeding is to run a trench along the foot of the hills, with the object of intercepting the water which drains from the higher land before it can soak into the lower ground. This water is then led away to the river, together with that which has been collected in the ditches cut across the fields. The writer had the opportunity of observing the excellent results obtained by this system, on the estates of Signori Piacentini, at Valchetta and Prima Porta, on the right bank of the Tiber. Large areas of low-lying land, which were before this practically bogs, have been reclaimed. The depth of trench required depends, of course, upon the distance below the surface of the impervious substratum of the hill, and the cost of excavating trenches deep enough to serve the purpose required is very considerable, but the result obtained is that ground previously a swamp is converted into good arable land for agricultural purposes.

Unfortunately the valleys which are dealt with by this system form only a fifth part of the whole Campagna. The problem of relieving the interior of the hills of the water, which is dammed up inside them, and maintains them in a constant state of humidity, is a far more difficult one. Nevertheless, this problem was attacked by the ancients and, what is more, seems to have been satisfactorily solved by them.

The existence of numerous shafts sunk in various parts of the Campagna has long been known, as many people who have attempted to hunt there are aware, to their cost. Their real use has only lately been discovered. These drainage systems are often found in tufaceous hills, and consist of a network of mine galleries, about five feet high and twenty inches wide. In many cases several of these systems are superposed, so that the hill is honey-combed with tunnels. At intervals vertical shafts rise to the surface (or in the case of lower storeys to the storeys above). Their object was to allow ventilation and easy removal of excavated earth, and also a means of ingress for attending to the clearance and repair of the tunnels—for this purpose the shafts were supplied with foot-holes cut in the sides. These works are often found under houses, and the water draining through them was then frequently utilized for domestic purposes. Mr. Benjamin describes the same method of securing a good supply of water in his book on Persia, and a reviewer in the New York

Nation (of 22nd December, 1886,) points out that the supply is col-collected from the subsoil water—not, as Mr. Benjamin suggests, from the springs and streams which are liable to become dry in midsummer. The same method is successfully employed in California, where it is called "developing water," and might be of service in forts when the necessity warranted the expense. Visitors to Pompeii may remember that several of the larger houses there have a number of wells round the piazza of the court-yard, and usually a single marble *puteal*, or well-head, which could be moved from one shaft to the other as the water in each became exhausted. The house would be supplied with hard water from the aqueduct for irrigation and general purposes, while for drinking the inmates evidently relied on the wells; these, no doubt, yielding softer water.

The number of the drainage systems discovered in the Campagna has been immense. They are, as a rule, completely choked up with the sediments deposited during their long period of neglect, but many of them have been cleared out and have proved of great use both in supplying cattle-troughs and in draining the soil. There can be little doubt that when all these systems were in full working order the condition of the Roman hills must have been very different from what it is now. Perhaps this is the key to the greater immunity of the Campagna from malaria in ancient times.

It is unnecessary to discuss here whether the ancients in executing this drainage fully realised its hygienic advantage. The probability is that they looked upon it only as a means of agricultural improvement, and occasionally of removing damp from the foundations of buildings. The water obtained would often be utilized, but would not, as a rule, be the primary object of the works.

In the Appendix to this paper will be found the plans and description of a very complete drainage system. They are reproduced from a communication addressed by Professor Tommasi-Crudeli to the Accademia dei Lincei, an institution which corresponds roughly to our own Royal Society. A letter from Rome in the *Times* (10th January, 1887,) mentions an exactly similar shaft:—

"Under the villa, in the tufaceous rock, was found a vertical shaft of 23 metres in depth, with steps cut in the sides, and provided with *cuniculi* half-way down and at the bottom. These curious underground passages are common in certain parts of Etruria . . . I believe them to have been prisons."

There can be no reasonable doubt that the work described was the main shaft of a drainage system, and by this supposition it is unnecessary to assume that the Romans dropped their slaves down a well, seventy-five feet deep, for purposes of safe-keeping. It has always been the fashion with the old school of archæologists to call every piece of underground work, whose object they did not understand, a prison. The long wine-cellars in Diomede's house at Pompeii were set down as prisons, although there was an exit at every few yards. The step running along the wall was supposed to be for the slaves to lay their heads upon instead of being simply a rest for the wine-jars.

In the present state of our knowledge it is difficult to say very much of the exact extent of the increased immunity from malaria which would result from an extended application of the cunicular system of drainage; but everything tends to prove that it would be very great in a soil which, like that of the Roman hills, is apt to hold large quantities of water. This water cannot be reached by open trenches, and the cunicular system seems the only alternative.

§ 8.—The Preservation of Man in Malarious Countries.

This subject falls naturally under two heads—prevention and cure. The latter is a purely medical question, and is therefore only of indirect interest to engineers, whose province is more especially prevention. Several preventive measures have already been described, but there are others which can be carried out by anyone.

Experience has shown that, as a general rule, malaria is most to be feared at sunrise and at sunset. It is well to keep this in mind, and to avoid unnecessary exposure at these times. Particular care should also be taken that clothing is sufficient to prevent chills; and that all bodily exhaustion resulting from want of food or from excessive labour is avoided. At the same time the opposite extreme of taking too little exercise is equally objectionable. The great principle is to keep the blood in good and equable circulation. It is advisable to continue these precautions for some time after leaving a malarious district, for everything tends to prove that when the malarial ferment has once entered the system it is difficult to get rid of. Cases are common of people being attacked by malaria two or three days after leaving a malarious district, in consequence of the neglect of this.

The fact that malaria decreases very rapidly at any height above malarious ground is a very fortunate one, and is availed of in several ways. In the Campagna the shepherds, when obliged to stay with their flocks, always remain on the tops of the hills as much as possible. In the Pontine Marshes platforms, four or five yards high, are erected, and occupied with comparative safety by the men who are compelled to pass the summer nights there. The Indians of central and southern America hang their hammocks as high as possible in trees in malarious districts, and it was perhaps this fact which suggested to the engineers of the Panama Railway the construction of wooden huts on branches twenty or thirty feet from the ground. The same principle is turned to advantage by building houses with no openings in the exterior walls except a door. Light and air is obtained by having a central courtyard upon which the windows of the rooms open. The result of course is, that when the outer door is closed all the air obtained in the house is taken from an altitude above the ground equal to the height of the house.

Care must, of course, be taken that no development of malaria takes place in the courtyard itself. This is easily prevented by careful paving of its surface. When a house is too small for the courtyard system, a similar result is attained by placing the windows close under the eaves. Preservation from malarial fever by innoculation is impracticable. This is a method which is only applicable to diseases which have a definite duration, and which do not return to the same person after one attack (or at least return in a less violent form). Malarial fevers are not diseases of this kind. On the contrary, they often appear as a chronic ailment, and each attack predisposes the patient to fresh ones. It is for the same reason that the acclimatisation of an individual is also impossible. The only safeguard of this sort is the collective acclimatisation of a race by survival of the fittest, as in the case of the Vera Cruz yellow fever, referred to in § 3.

With regard to drugs as preservatives against malaria, a very few words will be sufficient. Quinine is well known in this country. A daily ration was issued to all English soldiers in Ashantee. Arsenic is fairly common as a remedy, but as a preservative also its use has been strenuously advocated by Dr. Tommasi-Crudeli. It is much used in Italy, and has already come into use in the United States. Its progress in popular favour was at first slow, chiefly owing to its name; it might well be administered under some less alarming designation, on the same principle as the name of Trinitrine is the medical euphemism for Nitroglycerine. Arsenic was successfully used for two years and a half by Dr. Leslie, in the Congo Free State. It is believed that it is being employed by Dr.

Parker, the medical officer attached to Mr. Stanley's expedition for the relief of Emin Pasha.

A very convenient method of administering arsenic with safety is by means of a gelatine slab (in appearance much resembling a small sheet of talc) divided into fifty small squares, which can be separated from one another like postage stamps. Each small square contains two milligrammes of arsenic.

A very simple popular remedy against malarial fever, which has sometimes produced wonderful effects, is as follows:—A fresh lemon is cut into slices and boiled with its peel and pips in a clean earthenware pipkin full of water. Boiling is continued until two-thirds of the liquid has evaporated, and the remainder is then passed through a sieve, and finally allowed to cool slowly. The liquid is generally cooled during the night, and given to the patient in the morning. It is said that this remedy has been successful when both quinine and arsenic have failed.

APPENDIX.

The plates which accompany this paper represent one of the most complete cunicular drainage systems hitherto discovered in the Roman Campagna.

Plate I. is a plan of the environs of the modern fort Bravetta, showing the position of the excavated galleries. The fort itself is represented by the black star.

Plate II. is a ground-plan of the excavations.

Plates III. and IV. show various sections, etc., of the system.

In this case all the water procured was collected and utilized. There were three stories of galleries in the system, indicated on the plans by the numbers 1, 2, 3. The two upper storeys (1 and 2) were discovered when the ditch of the new fort was excavated a few years ago. The lowest storey was only discovered when the clearance of the middle storey had been almost completed. One of the galleries of the middle storey came to an abrupt termination and a perforated plate of lead was found at the end. The discovery of this pointed to the existence of further galleries; and Professor Tommasi-Crudeli, on enlarging the hole beneath the plate, found the lowest storey consisting of several galleries of larger dimensions discharging their water into two wells.

All the wells of this system are provided with foot-holes, so that the deposits collecting in them and in the galleries could easily be removed.

Fig. 1, *Plate* III. is a longitudinal section on the line F G (*Plate* II.). It shows the long gallery of the upper storey throwing its waters into a well, which also received the waters of two other galleries. The ditch of the modern fort also appears in section. The ancient cistern on the right appears as 3*a* in *Plate* II. It was probably originally also a drainage system converted into a cistern, in order to collect the waters of the *impluvium* of the building above, and its walls and roof were made watertight with cement *(opus signinum)*. It may also have received some water from the gallery 1

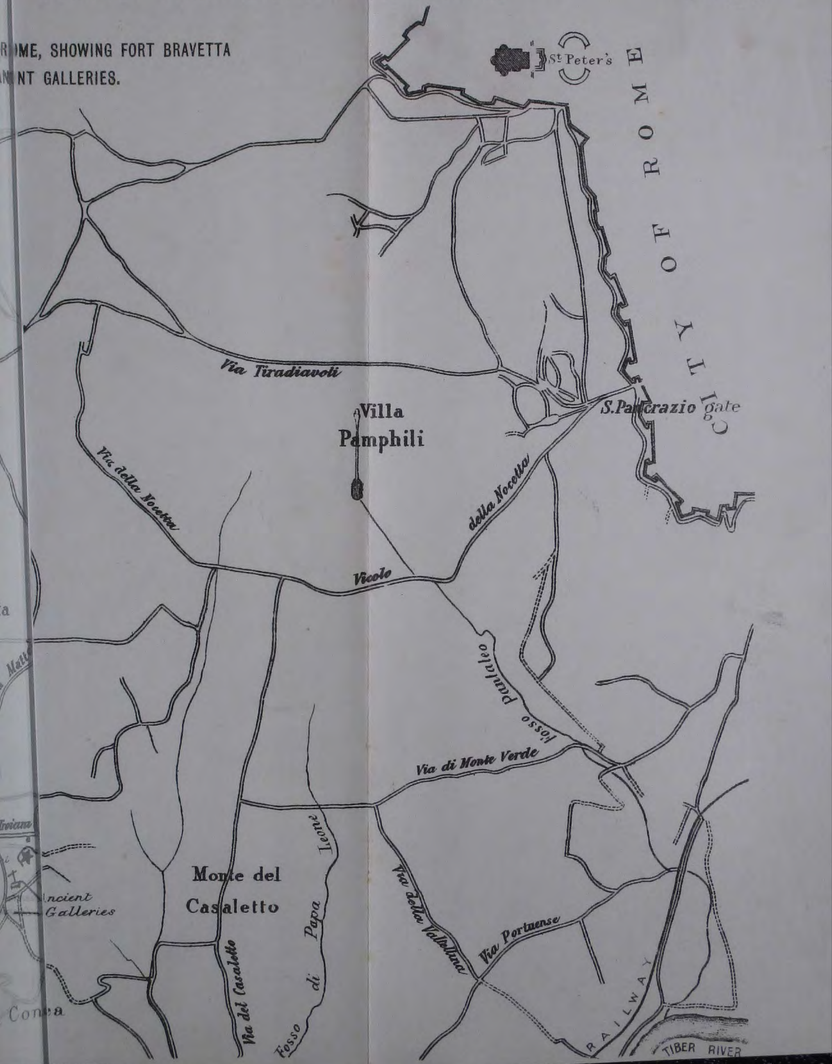
(*Plate* II.). A wall of the fort built between the gallery and the cistern has destroyed all traces of such connection, if it ever existed.

Fig. 2, *Plate* II., is a cross-section of the same gallery, at that portion of it marked O in *Fig.* 1. It differs here from the rest in that a small drain of tiles is laid at the bottom, no doubt to preserve the water from particles of the vegetable soil through which the upper part of the gallery here runs. The other figures explain themselves.

J. E. C.

MALARIA. Plate I.

PLAN OF COUNTRY NEA
WITH
N
S
Via Aurelia nuova
Via Aurelia
Strada della Pisana
Bravetta
Strada della Casetta
V.Troia
Fort Bravetta
Scale 1/25.000


ROME, SHOWING FORT BRAVETTA
GALLERIES.
St Peter's
CITY OF ROME
Via Tiradiavoli
Villa Pamphili
S.Pancrazio gate
Via della Nocetta
della Nocetta
Vicolo
fosso Pantaleo
Via di Monte Verde
Monte del Casaletto
Fosso di Papa Leone
Via della Vallelluna
Via Portuense
Via del Casaletto
Galleries
RAILWAY
TIBER RIVER

PAPER IV.

THE MILFORD HAVEN EXPERIMENTS.

BY CAPTAIN F. RAINSFORD-HANNAY, R.E.

MY SUBJECT is the "Milford Haven Experiments," a title which seems preferable to the one generally in force at the time, namely, "Combined Naval and Military Operations." The word *experiments* gives a better idea of the objects in view of the committee when they drew up the "General Idea." It was distinctly laid down that the operations were "to be regarded in no case as a trial of skill between the forces engaged, but only as a practical *experiment*, with the object of gaining information," on certain specified points connected with the defence of harbours.

In operations of this nature it is of course difficult to prevent a certain amount of rivalry between attack and defence, and for some reason it is a thing to be encouraged, as everybody works more keenly. At the same time it should be noted that the numerous conditions and restrictions imposed made the experiments utterly unlike a hammer and tongs fight between attack and defence, and any argument as to who won is quite out of the question.

At the time there was far too strong a tendency to such arguments; newspapers and others all jumped to the conclusion that the attack had scored an easy and bloodless victory, quite regardless of the fact that nobody could have the slightest idea of the *real* results until the very numerous reports of umpires and sub-umpires had been collected together in an intelligible form. This has now been done in a very full and clear manner in the chief umpire's report, and my remarks are to a great extent a *réchauffé* of that report; necessarily so, I think, as it is the only reliable description of the experiments as a whole.

I shall give you the results as estimated by the chief umpire, and leave it entirely to your own judgment to say whether the opinion prevalent at the time was or was not the correct one.

The opinion has been expressed that the conditions imposed told mostly against the attack. Perhaps so, but you must bear in mind that moral effect must always be absent from experiments of this nature, and the moral effect of mines will always tell strongly in favour of the defence in actual warfare.

The "General Idea" drawn up by the operations committee was as follows:—

"The operations should take the form of an attack by a fully equipped squadron, reaching the English Coast from abroad, upon a military port defended in the manner proposed for actual service, viz., by submarine mines and obstructions, by a powerful artillery mounted on shore, and by guard-boats acting in co-operation with a naval flotilla.

"The defence will be restricted to a portion of the main channel, 3,000 yards in length and 700 yards wide." (See *Plate* I.)

This restriction had a double object; the attacking force wished to know definitely the *depth* of the defence, so as to ensure having sufficient countermining stores; also, if the defended channel had been too *wide* the experiments would have been more scattered and less under the eyes of the umpires, and the number of mines to be laid by the defence would have been greatly increased without any corresponding advantage.

"All other portions of the channel to be considered impassable. As the garrison consists of only a small number of troops, the attacking force will be prohibited from landing."

Of course for an actual attack the garrison would be largely augmented by infantry.

"The attack will be limited to three days from a given date, which will be notified."

This condition was an undoubted advantage to the defence, as the attack can generally choose its own time, thus causing the defence to be always on the alert, probably for a much longer period than three days.

"The chief objects of these operations are to determine—

"*(a.)* The best means of protecting the mines (including defence by guard-boats) against a sustained attempt to force them by a squadron.

"*(b.)* The value of torpedo boats to the defence, and the best methods of manœuvring them.

"*(c.)* The most suitable organization for the whole of the defensive operations."

I should like to draw attention specially to that word *organization*, which is at the root of the whole matter, and in which we are at present lamentably deficient.

"It is specially to be noted that the operations are to be regarded in no sense as a trial of skill between the forces engaged, but only as a practical experiment with the object of gaining information on the above points.

"In order to avoid loss of time and destruction of stores, it is to be understood that the large ships of the squadron are not to attempt to pass the mine-field until they consider that a practical breach has been made."

It is very unlikely that the large ships of a squadron would in any case attempt to pass through till a breach had been made, at least it is quite contrary to our present ideas of the method of attack.

"The attack will consist of a fully equipped squadron.

"The defence, of—

"1. A naval flotilla, consisting of six torpedo boats and six guard-boats. The guard-boats should be fast steamboats, if possible not less than 45 feet in length.

"2. A complete system of submarine mines and obstructions.

"3. The guns mounted in Stack Rock and South Hook Forts, and in other positions which may be considered desirable for the defence. A fort on the south side of the channel will be represented by a field battery posted there." (See *Plate* I.)

"The personnel recommended for the defence consists of a naval force sufficient to man the guard and torpedo boats, including a certain number of naval artillery volunteers, who will also assist in the other operations of the defence, and—

1 Field battery of Royal Artillery.
2 Garrison batteries do.
2 Companies Royal Engineers (submarine miners).
2 Companies Engineer Volunteers (submarine miners).
1 Battalion of Infantry.

Chief umpires, umpires, and assistant umpires in large numbers were duly appointed, and their duties defined, but it is quite unnecessary here to enter into these matters.

A proposal was made to modify the "General Idea," and assume an introductory artillery action to have taken place, in which the ironclad squadron should have silenced the heavy guns of the forts bearing on them. The chief umpires, however, considered that this would introduce too much of the imagination element, and the "General Idea" as originally issued was allowed to stand. A certain amount of unreality on the part of the attack was necessarily involved, as the fleet would not have anchored, as it did, within effective range of heavily armed forts without having previously reduced the defensive fire.

The following general regulations for the conduct of the experiments were issued by the operations committee.

"1. The experience should be gained at the smallest expenditure of material; officers in charge of boats are to avoid any risk of damage by running into one and another."

This was a very necessary warning. As far as I know there was only one collision, and that was between two of the defence torpedo boats. Considering the number of boats in the mine-field, the pace at which they went, and the confusion caused by alternate darkness and brilliant light, it seems a perfect marvel that there were not more accidents.

"2. The operations of the attack will be limited to breaking through booms and obstructions, countermining, removing mines, destroying cables and putting the naval defences out of action; but to avoid complication, neither guns, infantry, nor electric lights will be put out of action."

This naturally told considerably in favour of the defence, more especially I think in the matter of electric light.

The means at the disposal of the defence were as follows.—

South Hook Fort $\left\{\begin{array}{l}\text{fifteen 7-inch R.M.L.}\\ \text{six 9-inch R.M.L.}\end{array}\right\}$ in open batteries.

Stack Rock $\left\{\begin{array}{l}\text{sixteen 10-inch R.M.L.}\\ \text{seven 9-inch R.M.L.}\end{array}\right\}$ in casemates.

A field battery of six 9-pounder guns on the south shore; these guns were credited with the power of 40-pounders.

There were two electric light stations at South Hook, each capable of showing one powerful light or two of reduced power. (See *Plate* II.) The generators were the service Victoria dynamos, driven by 10-horse power engines. No. I. electric light, on the nights of the 16th and 17th August, was at a point to the west of South Hook Fort, about 60 feet above high water. On the night of the 18th it was removed to a point about 20 feet lower. No. II. was about midway between the 7-inch and 9-inch batteries, and about 90 feet above high water. This was the best site available, but it was too high for efficiency at the shorter ranges, as will be explained later. There was also an electric light station in a temporary shed, just outside Stack Rock Fort, about 10 feet above high water. The generator was an old Siemens' dynamo, driven by a 9-horse power engine, all in very indifferent order.

The submarine defences are shown in *Plate* II.

They consisted of—

1. Forty electro-contact mines, in ten groups of four each, on the fork system, viz., III., IV., V., VI., VII., VIII., IX., X., XI., XIII. These mines were arranged to be from 18 to 23 feet below high water spring tides, the deeper mines being to the front.

The maximum rise and fall of tide in Milford Haven is about 23 feet, which makes it an exceptionally difficult place for submarine mining, mines which are at an efficient depth at high water being awash at low, and therefore comparatively easily destroyed. Spring tides were in force at the time of the experiments, which of course told against the defence.

2. Sixteen counterpoise electro-contact mines, in four groups of four mines each, on the fork system, viz., I., II., XII., XIV. This counterpoise system is the invention of Major Ruck; the mine rises and falls with the tide, and so should always be at the same distance from the surface, a very great advantage where the rise and fall of tide is appreciable, which it is almost everywhere. The mines in this case were arranged to be nine feet under, and as far as could be seen the system on the whole worked very well, considering it was in the experimental stage. The gear employed was in my opinion too heavy, thereby considerably increasing the labour of laying out the mines. I now understand that Major Ruck finds he can work with very much lighter gear, in which case I think there is a great field for his system, as the attack which mines have most to fear is that of gun boats which draw very little water.

3. Twelve counterpoise electro-contact mines, in six pairs, representing boat mines and arranged to be always five feet below the surface, viz., mines 100 to 111. The ordinary service mines were used, as we have at present no satisfactory form of boat mines. The mines forming a pair were 60 feet apart, and connected together by coir rope.

There were also twelve experimental boat mines laid out on the counterpoise system in front of the boom; unfortunately, they went wrong, so no further reference need be made to them.

4. Twelve 500-lbs. observation mines, fired by Watkins' depression position finder, viz., Group C and D. The position finders were mounted in observing stations near South Hook Fort.

5. Two lines of four 250-lbs. mines near Stack Rock, viz., Group F. These were merely to block the passage reserved for the retreat of the defence guard and torpedo boats.

There were thus altogether 100 mines of sorts laid out.

Prior to the attack the junction box buoys were removed from the outer mine-field. In the inner mine-field, however, it was considered that creeping and sweeping would be quite impracticable under fire of the reserved guns on Stack Rock, and as the buoys facilitate the eventful recovery of stores, they were allowed to remain. Further remarks will be made on this subject.

Each mine was fitted with a blowing charge, which in the case of the floating mines was fixed four feet below the mine, so as to be beyond risk of accident at all times of tide. These blowing charges gave a lot of trouble, and were eventually found almost useless. The object is, of course, to give an immediate and unmistakable indication that a mine has fired, without at the same time giving any risk of accident. The charges we used consisted of 1-oz. of guncotton, with a detonator, lightly packed in a cast iron box. This was found to give excellent results during cold-blooded experiments, but during the attack the Navy fired numbers of explosive creeps, consisting of, I believe, two lbs. of guncotton, and it seems it was very difficult to decide, when an explosion was felt, whether it was a mine near or a creep at a distance. The sub-umpire, of course, always gave his boat the benefit of the doubt, and I believe there is no single record of a boat having retired out of action on account of firing a mine.

The boom I think I need not enlarge upon. It was a failure, and we need not perpetuate failures unless we can thereby learn lessons, and in this case I see no useful lesson to be learnt.

A wire entanglement, supported by buoys, was laid out some 250 yards in front of the boom. It might, I think, have been very useful, had it not been broken by the ordinary traffic prior to the commencement of the operations.

Chains and weighted cables were laid out on the bottom to protect the electric cables from creeping. They were more extensively laid in the outer than in the inner mine-field, because, as already explained, we considered creeping would be impracticable so close under the rear guns of Stack.

The defensive force afloat consisted of H.M.S. *Valorous*, *Tay*, *Avon*, and *Forester*, all manned by Royal Naval Artillery Volunteers.

Four second class torpedo boats, 86 feet in length, and one of 65 feet. They were all credited with the rank of first class boats.

Six 37-feet steam pinnaces, considered equivalent to steamboats of 45 feet and upwards.

These boats unfortunately could not rise to the occasion, and add a few knots to their speed, so the rank was chiefly honorary.

The *Valorous* and the gunboats were anchored outside the eastern extremity of the mine-field.

The attacking force consisted of the Channel Squadron.

H.M.S. *Minotaur*, *Iron Duke*, *Sultan*, *Monarch*, *Agincourt*, *Hecla*, *(torpedo depôt)*; and the gunboats, *Seahorse*, *Spray*, *Medway*, and *Medina*.

Five first class torpedo boats.

Seven second class torpedo boats.

Also four countermining launches had been specially prepared at Portsmouth, and sent round to join the squadron.

Preliminary Operations.

With a view to gaining experience as to the value of torpedo boats to the defence, it was arranged that there should be preliminary operations during the approach of the attack, and prior to the fleet anchoring for systematic attack; these operations to conclude after the leading ship has passed the line between Watchouse Point and East Blockhouse Point, and all casualties to be subsequently annulled.

These preliminary operations came off about noon on the 16th August, the weather being very unfavourable, with a strong westerly wind.

The torpedo boats of the attack came in advance of the squadron, and having ascertained the position of the torpedo boats of the defence, they withdrew out of range. Four of the defence torpedo boats then stood out to meet the squadron, and five similar boats of the attack advanced. These latter manœuvred so as to intercept the retreat of the defence boats, which being also under fire of the ironclads were judged out of action.

The attacking force then took up position as shown on *Plate* I., the *Hecla*, an unarmoured torpedo depôt ship, anchoring within about 2,300 yards of Stack, and 2,600 yards of South Hook. Stack at once opened fire, and the chief umpires notified to the

Admiral that unless the *Hecla* was moved beyond effective range of the forts she would be considered out of action. His reply was instructive. "It is not my intention to move the *Hecla* from where she is now. Properly speaking, the whole of the artillery, infantry, and machine guns of the defence should now be out of action from fire of the ship's guns. I regard the *Hecla* as a ship of the squadron." Evidently the Admiral did not see why the committee should have the monopoly of making assumptions. He subsequently explained to the chief umpire that he was obliged to anchor the *Hecla* close to the ironclads, owing to the boisterousness of the weather, and had she been anchored at the distance at which in actual warfare she would undoubtedly have been placed, it would have been impossible to get out the boats and stores necessary for countermining.

It seems clear, therefore, that preparation for countermining can only be carried on *in harbour* in fair weather, so we may reasonably assume that it can rarely, if ever, be carried out at sea.

Here we have one great advantage of submarine mines. *Time* is an all important factor in warfare. The great object of mines is to prevent an enemy rushing the defences under cover of darkness, smoke, or fog, and if mines can make it necessary for a powerful fleet to lay siege to a harbour for some days, it will, I think, be admitted that they have played a great part.

The chief umpires did not wish to stop the operations, which would have been the practical result of putting the "*Hecla*" out of action, so they desisted from further action. The Admiral however, hoisted the signal for suspension of hostilities, waiting for the matter to be settled. This signal was not seen by the defence, who were consequently on the *qui vive* all the afternoon and night of the 16th, in fact our torpedo boats made some most successful attacks on the ironclads at anchor, but they were treated with silent contempt.

During the suspension of hostilities it should be noted that the ships of the squadron were busily engaged rigging their torpedo nets and preparing their boats for service. In any case, I believe, they could not have done any countermining on the night of the 16th, as it was too rough to prepare the boats for that service.

General Plan of Attack.

The following was the general plan of attack laid down by the Admiral commanding.

1. The principal operations will consist of clearing floating obstructions, creeping, and opening up a passage by countermining in the defended channel.

2. The clearing of the channel is divided into sections (see *Plate* III.) and the clearing of each section is allotted to one ship. The commander of each ship will be in charge of the operations carried out in the section allotted to his ship. The Gunnery Lieutenants will be entrusted with the destruction of the boom.

3. The boats for clearing obstructions will first advance, and when a section is reported clear, countermining boats will proceed; after which the *Iron Duke* representing the fleet will advance.

4. In all probability this work will be carried out at night. The intention is to divide the operations that they may be continuous, and thereby leave the defenders as little rest as possible; with this in view the work is so divided that only two ship's companies will be employed at the same time, but the whole of the force enumerated for the attack is to be ready to advance at any moment after the operations commence, and will be called up in the previous detailed order.

5. Instructions will be given to the officers in charge of boats, but as it is quite impossible to anticipate all that may be met with, it is expected that each officer will act as he may deem necessary to clear the obstructions in the directions given in the orders issued.

Detailed instructions followed which it is unnecessary to give here.

Outline Scheme of Defence.

The general instructions for the defence issued by the General Officer commanding were as follows:—

The six torpedo boats will work by reliefs, these being always on duty as vedette boats well out to sea.

They will give notice of the approach of a hostile fleet, one returning at once to report strength, etc., the others keeping well in advance of the enemy.

Land signal parties will be established at St. Anne's Head and Great Castle Head. There will also be permanent signal stations at South Hook, Stack, Hubberston defensible barracks, and at the battery on the south shore.

The torpedo boats will attack the ships of the squadron when entering the harbour as found practicable. They will afterwards retire behind the mine-field and attack any ship which may pass through; they will also take every opportunity of attacking disabled ships.

Guard-boats will attack countermining gunboats with outrigger torpedoes, machine guns, etc. ; they will also endeavour to cut tow ropes, and generally hamper countermining operations.

On being driven back on the mine-field the guard-boats will retire through the north channel close to Stack Rock, and take up position behind the boom. The commander will take the earliest opportunity of signalling "mine-field clear," when the firing battery will be laid on the boat mines.

The main object of the defence is to keep the large mines intact until ships of the squadron try to pass through. As long, therefore, as countermining boats are in the mine-field, the firing battery will never be laid on any but boat and observation mines. Observation mines will be fired against countermining boats and gun boats.

The electric light on Stack Rock, when in use, will throw a fixed beam across the front of the boom.

The west light in South Hook will in the first instance turn a full power fixed beam across the front of the advanced mine-field, to give notice of the approach of the enemy. It will then be used to follow the progress of the attack.

Both east and west lights can be split into two lights of reduced power.

The east light in South Hook will illuminate the main mine-field behind the boom, and will follow the progress of the attack.

Guns will open fire and keep a continuous fire on all vessels or boats which can be clearly distinguished, and which are within effective range. Such fire to be maintained until the vessels or boats are put out of action.

The field battery, representing a fort, will take up position under cover, on the south shore opposite the advanced mine-field. It will co-operate with the guns of the forts in their fire on countermining gun boats, etc.

The infantry will direct their fire more particularly on the vessels or boats within the beam of an electric light, and salvo firing will be used, as far as possible, both by artillery and infantry.

During the whole of the operations, it will be the duty of the guard-boats to keep continually removing, as opportunity offers, the buoys or marks laid down by countermining boats to show the open channel. Also the submarine miners will be ready with spare mines to fill up gaps in the defence.

Should the boom be forced, the guard-boats will retire firing behind the main mine-field.

The electric light must never be kept on vessels or boats of the defence.

The operations practically commenced about 7.50 p.m. on the 17th August, the six defence guard-boats proceeding out to defend the advance mine-field. They took up position in front of the boat mines, but this brought them within 1,200 yards of the squadron, which had anchored much nearer than they should have done under the assumed condition of the guns of Stack and South Hook being unsilenced. The unreality of the thing at once became apparent, and the defence guard-boats were all put out of action in the first quarter of an hour. The opportunity of learning the value of guard-boats was therefore practically lost, although it so happened they did not know they were out of action, and continued to enjoy the fun for some hours afterwards.

About 8.50 p.m. the defence torpedo boats proceeded out to annoy the fleet at anchor. All the ships were protected by netting except the *Hecla*, which was put out of action.

Meanwhile, electric lights of attack and defence were all at work, and the heavy guns of the squadron commenced firing, mainly, I believe, to make a thick smoke over the mine-field, the wind being favourable.

About 9.30 p.m. the torpedo boats of the attack advanced under cover of smoke, and engaged the defence guard-boats (which should really have been out of action). The guard-boats, being met by a superior force, retired, and gave the signal "mine-field clear," when the firing battery was put on the boat mines, *i.e.*, these mines were arranged for automatic firing when struck.

At 10 o'clock the creeping boats commenced their work, and continued all through the night. A number of these boats were at work, but they did absolutely no damage in the advanced mine-field, probably on account of the chains and dummy cables which had been laid.

Charges were also fixed to the boom and fired, several boats being put out of action; firing meanwhile became general, and smoke began to tell on the electric lights.

About 10.15 p.m. the defence torpedo boats having returned for fresh torpedoes, again sallied out. They passed through the attacking boats, which signalled their approach to the squadron by blowing steam whistle, and showing red light.

Several electro-contact mines were bumped and signalled, but the firing battery was not connected.

At 10.30 p.m. an event occurred which is worth recording. Group 100–103 signalled, and two mines fired. Subsequent reports show that at the same time the Admiral in his barge experienced a severe concussion, supposed to be due to No. 101.

About 10.50 p.m. the first line of countermines was run by the *Iron Duke's* boats, but it was found to be a blocked ground. Second lines were then run and fired by the *Minotaur*.

At 11.10 p.m. the defence torpedo boats went out a third time to attack the squadron, but the only result was the loss of one of their number.

At 11.40 p.m. one of the defence torpedo boats was blown up by No. 106 mine. This clearly shows the necessity of a very thorough organization, and understanding of the exact areas over which the defence flotilla can manœuvre in safety.

At 11.50 p.m. a line of countermines was run and fired by the *Minotaur*.

At midnight the *Seahorse* and *Tees* advanced, and the firing battery was put on all mines in the advanced field. In order to screen the advance of the gun boats the attack directed their electric lights on Stack and South Hook, with very dazzling effect.

The *Seahorse* apparently had orders to ram the boom, and accordingly she scorned all orders from umpire until she had accomplished her mission. She was out of action, first by artillery; second, by No 62 observation mine; third, by "B" torpedo boat, but "B" should have been out of action at the time. You will see that things were already getting rather mixed.

The gun boat *Tees* was put out of action by artillery, and retired before reaching the boom.

At 12.35 a.m. a line of countermines was successfully run and fired by the *Agincourt*. A second line was run at 12.50 a.m., but the boat was ruled out of action before firing. Meanwhile, at 12.20 a.m. No. 43 mine signalled and fired, very possibly by one of the *Agincourt* boats in the act of laying countermines.

At 1.4 a.m. the firing battery was taken off all except the boat mines.

At 1.10 a.m. the *Monarch* laid a line of countermines, but they were rigged foul, and missed fire. The operations then ceased for the night.

The above remarks only give the leading features of the attack, which was carried out with much energy, a very large number of boats being employed.

It should, I think, be mentioned that in some cases it was found difficult to induce boats to obey the ruling of the umpire, and retire out of action; they would merely retire into darkness, and come to the front again as soon as the eagle eye of the umpire was removed. Recently at the United Service Institution this was very aptly described by General Schaw, as "that indomitable perseverance" which never knew when it was beaten. No doubt such perseverance is an excellent thing in war, but in this case it did not conduce to the success of our peace manœuvres.

On the 18th August, at 1.40 p.m., the *Iron Duke*, representing the leading ship of the squadron, passed up to the end of the countermined channel, and anchored about 700 yards from the boom. Her countermining boats then laid out and fired six countermines, so as to give her room to swing in safety.

At 3.30 p.m. a steam cutter towed up two countermining launches to the *Iron Duke*, and on the way signalled a mine in XII. group. The firing battery was not on, as the defence was quite in the dark as to what was going on, and merely watched the proceedings with interest. It subsequently transpired that the passage of the *Iron Duke* was in theory carried out at night.

Shortly after 8 p.m. the attack was renewed.

The first event of interest was a gun-boat of the attack being put out of action by artillery fire at 8.48 p.m.

At 9 p.m. a torpedo boat fired a Whitehead torpedo at the *Iron Duke*, at a range of 300 yards. As the *Iron Duke* had no nets rigged, she was probably out of action. I take the word "probably" from the chief umpire's report, but think "possibly" would be preferable.

Creeping meanwhile went on merrily, and group cables II. and VI. were cut by a boat which should have been out of action.

At 9.5 p.m. two gunboats of the attack advanced beyond the boom, and the firing battery was put on the mines in the inner field for three minutes. During that time Nos. 28 and 31 mines fired, presumably struck by the gunboats.

The mine-field was by this time much obscured by smoke from the *Iron Duke*, the wind being most favourable.

About 9.15 p.m. a countermining launch missed the gap in the boom, stuck fast, and had to be abandoned. This appears to be the only record of the unlucky boom having scored a success.

At 9.30 p.m. the *Agincourt* laid a line of countermines across the boom, the boat used having previously been put out of action.

Between 9.30 p.m. and 10.10 p.m. three group cables were cut viz., I., III., and VIII. In the case of III., and VIII., however, the boats had been previously ruled out of action, and the boat cutting III. is also supposed to have been blown up while so doing.

About 10 o'clock multiple cable "C" was cut.

At 10.13 p.m. the *Monarch* ran and fired a line of countermines.

At 10.18 p.m. the *Hecla* did the same, but the boat used should have been out of action.

At 10.25 p.m. the *Minotaur* did the same with a boat previously out of action.

At 11 o'clock the *Sultan* did the same, and the boat was ruled out of action before firing.

At 11.5 p.m. the operations concluded.

Results.

The results of the operations may be summed up as follows.

On the night of the 17th a channel, broad enough for the passage of ironclads, was cleared to within 400 yards of the boom. The channel so cleared was then occupied by the squadron, represented by the *Iron Duke* as the leading ship.

On the night of the 18th this channel was continued through the remainder of the submarine mining defences.

The above results assume that a 500-lb. countermine can destroy one of the latest pattern submarine mines at a distance of 30 yards.

A portion of the channel was 120 yards wide, but the greater part was only 60 yards.

Further, it is doubtful if the channel through groups XI. and XII., in the advanced mine-field, would really have been cleared, as No. 43 mine in the centre, and two mines adjacent to it were fired while the countermines were being actually laid.

In the rear mine-field two of the lines of countermines were laid and fired by boats which should previously have been out of action; also, many other boats which should have been out of action assisted materially in the countermining operations, which would otherwise not have been successfully accomplished.

It is estimated that countermines destroyed three electro-contact and one boat mine in the advanced field, and one electro-contact mine in the main mine-field.

Five group cables and one multiple cable were cut, either by explosive creeps or by axe. This destroyed or rendered ineffective 15 electro-contact and five observation mines, in addition to those destroyed by countermines. Three of the five group cables, however, were cut by boats previously ruled out of action, and the damage to another group was ruled inoperative, as the boat was blown up by one of the mines in the group while in the act of cutting the cable.

The boom was breached in four places by explosive charges, and also by the passage of the *Seahorse*. Two of the boats which fired charges were subsequently declared to have been out of action before the charges were fixed, also the *Seahorse* was out of action before she reached the boom. None of the boats succeeded in reaching the boom without being clearly seen.

The whole of the defence flotilla, with the exception of one torpedo boat, was put out of action.

The casualties of the attack, as estimated by the chief umpires, were as follows :—

Iron Duke, *Hecla*, *Seahorse*, three gunboats, eleven steamboats, five torpedo boats, twenty launches, cutters, &c., and eight repetitions of casualties.

In these results I think too much value has been given to artillery fire.

It should be noted that no further countermining operations could have been carried out, as the whole of the material had been expended.

Before reviewing the experiments the chief umpires point out that their value was sensibly impaired by want of adherence, as far as was practicable, to the conditions of real warfare ; thus :—

1. The preparations of the defence were carried out under the observation of some vessels of the squadron for several days previous to the arrival of the fleet. The attack thus gained important information, presumably unattainable on service. Even after the commencement of hostilities the *Seahorse* steamed through the channel assumed to be blocked, without flying the flag of a neutral, and thereby drew the fire of the battery at Angle.

2. On the 16th August, the first day of the proceedings, the necessary precautions which a hostile squadron would take in the presence of an enemy were ignored. None of the ships were protected by their torpedo nets until the afternoon of the 17th.

3. The *Hecla*, an unarmoured torpedo depôt ship, was anchored in the first line, within easy range of the forts. Even assuming the heavy guns of the forts bearing on the squadron to have been silenced, and that only field artillery and quick firing guns were left to the defence, the work of a torpedo depôt ship could not have been carried out in the exposed position which she occupied.

4. Some countermine boats were sent round from Portsmouth to Milford Haven, and prepared there before the arrival of the fleet; further, a large quantity of countermine circuits were prepared at Pembroke Dock, and sent out to the fleet after the commencement of hostilities, when the weather had moderated sufficiently to allow of this being done. Thus, the port to be attacked was treated in some respects as a base of offensive operations, and its resources made available for the attack, and the difficulties connected with the question of transport and preparation for such undertakings were thereby evaded.

5. The fleet was not in a position to commence the attack until the evening of the 17th, on account both of stress of weather and the non-arrival of countermine stores, which were expected from Pembroke Dock. During this time, however, the ships were actively engaged in the necessary preparations, although the white ensign was flying on board the flagship all the time; this signal for the suspension of hostilities being intended solely in the event of "unforeseen circumstances" arising on either side.

6. On the night of the 18th the artillery fire of Stack Rock was silent during the greater part of the operations, both on those faces bearing on the squadron as well as on those bearing on the eastern mine-field, which were not exposed to the fire of ships. The absence of fire from so many guns immediately adjacent to the mine-field on which the operations were concentrated, gave a character of unreality to the whole night's proceedings. Having said so much, the chief umpires record their opinion that this largely favoured the *defence*, by relieving it from smoke which was found to interfere so much with the efficiency of the electric lights. I must respectfully differ from this opinion. The fact was the wind was so very favourable to the attack, and they managed their smoke so admirably, that it was most difficult to see the mine-field from South Hook, the range being considerable. Officers, however, on Stack report that everything could be clearly seen, and an occasional salvo from the guns of Stack bearing on the eastern mine-field would, I think, have materially assisted the defence. Had the most suitable guns for the purpose been available, viz., quick firing and machine guns, the effect of smoke would have been very materially reduced. I am quite unable to explain the silence of Stack on the night of the 18th. At the time I understood the chief umpire to have put Stack Fort out of action. This, however, was not the case, and the guns bearing on the eastern mine-field could hardly have

been silenced from the front. The submarine mining defence depended greatly on these guns for protection against creeping and countermining; in fact, these operations seem hardly practicable within such short range of quick firing and machine guns.

7. On the 17th and 18th, boats either previously or subsequently adjudged to have been put out of action continued to afford material assistance to the attack, and doubtless without that assistance the operations would not have been successfully carried out in the time or with the material available. On the other hand, some boats of the defence, under similar circumstances, hampered the operations of the attack after they should have been out of action.

8. One of the gun boats of the squadron, while endeavouring to cover the advance of boats by the smoke of her guns, entered several hundred yards on the north side of the blocked water, and thus obtained an unauthorized advantage.

9. The electric lights of the defence were not worked under service conditions, in so far that the western station at South Hook was not protected in any way, the engine, dynamo, and projectors being in the open on ground sloping towards the fleet. The projectors at the other stations were also exposed.

Having summed up generally the results of the operations, the action of the different arms of attack and defence will now be considered.

Defence Torpedo Boats.

The preliminary operations gave little useful information regarding the use of torpedo boats for defensive purposes. This was due to a certain extent to the unfavourable weather on the 16th, but mainly to the fact that although credited with the rank of first class boats, the defence boats, being really second class, were unable to compete with those of the attack in speed and manœuvring power.

The defence torpedo boats, during the attack on the night of the 17th, succeeded in getting within easy reach of the ships, which received no warning of their approach.

Their subsequent attacks, however, after the fleet was fully protected, were of no apparent value. They would have been better employed in the rear of the boom, to resist the passage of attacking vessels or boats.

Defence Guard-Boats.

The defence guard-boats were very small, and quite unsuited to their purpose. They were given honorary rank which was of little assistance. Owing to the proximity of the fleet, as already explained, the guard-boats were all put out of action in the first half-hour, so little positive information was obtained as to their value. Their absence, however, on the second night told very clearly against the defence, and it was amply proved that they would have been most valuable against creeping and countermining attacks if kept in reserve behind the beams of electric light. The portions of the mine-field over which they can manœuvre in safety should be very clearly defined.

Mine-field.

The attack was undoubtedly much hampered by the supposition of shores, where in reality there was deep water, and they were thereby prevented from creeping close in shore, out of the electric light and out of the tide. The theoretical shore line also was not clearly defined, and some of the countermines were laid in forbidden water and the work had to be done twice.

The multiple cables, being in some cases laid entirely on the blocked ground, the attack lost the opportunity of destroying several groups of mines with one creep.

The junction box buoys not being removed in the inner mine-field gave the attacking boats undue facilities for finding and cutting cables. These buoys were not removed, as creeping in the main mine-field under the guns of Stack was considered practically impossible.

There was inadequate provision for the protection of mines and obstructions from passing traffic, and they suffered considerable injury prior to the commencement of hostilities. In time of war the proper regulation of traffic is a most important consideration.

The advanced mine-field was well protected by chain and old cable laid on the bottom, and although a large number of explosive creeps were fired, there is no record of any damage having been done. In the inner mine-field the protection was inadequate, and much damage was done by creeps; whether or not the boats should have been previously out of action is hardly worth enquiring. Even a chance of injury should be guarded against, especially when the protection is so easily afforded. Most of the cables were grappled from *behind*, so obstructions should evidently be laid in rear as well as in front.

The passive obstructions were of little hindrance to passing boats: this was to a certain extent due to the damage done by the ordinary traffic prior to the operations. The boom, it must be confessed, was practically a failure, as it only caused the destruction of one countermining boat. The wire rope obstruction might, I think, have been of considerable use, but a very large gap was torn in it by a passing vessel on the night of the 16th.

Electric Light.

The electric lights were at first worked as follows:—

A powerful fixed beam was thrown over the front of the advanced mine-field.

A fixed beam was thrown from Stack across the front of the boom.

The other projectors were used as search lights, and all were used in the same manner as the attack progressed.

The lights were of course much hampered by smoke, and when the beams crossed those of the attack an illuminated screen was formed at the intersection, more or less opaque according to the atmosphere. At one time during the attack the *Monarch* and *Hecla* both directed their lights on Stack Fort, which appeared to us to stand out like a white sheet. I was subsequently informed by the captain of the *Monarch* that he was quite unable to see the Fort, but laid his projector by bearings. This was no doubt on account of the South Hook beams crossing that of the *Monarch*.

The lights gave the idea of being worked without method, and without concert between them and the guns. The beams were moved by jerks through large arcs, due to the want of satisfactory gearing, and also to the fact that the operator at the projector could not see the object, but moved by verbal orders given from a distance.

Everybody now seems to agree that where artillery is working in conjunction with moveable lights, the officer commanding the guns should also control the lights. To meet the other difficulty of the operator being unable to see the object, efforts are being made to work the projectors automatically from a distance by means of stretched wires, and there seems every prospect of the problem being satisfactorily solved. The operator will then stand where he can obtain a good view, and will bring the light to bear on any point he may wish.

The best sites available were selected for the lights, but those at

South Hook were all too high for short ranges, more especially the eastern one, which was about ninety feet above high water. The incessent vertical, as well as horizontal, movement thereby rendered necessary, considerably added to the difficulty of picking up and following objects, and moreover the areas illuminated were small. The lights were subdivided as the attack progressed, but the projectors in each pair thus formed were so close together that they were liable to simultaneous obscuration by smoke, not to mention destruction by the same projectile.

For an ideal defence there should undoubtedly have been electric lights on the south shore, and it was unfortunate it could not have been so arranged for these experiments. Much valuable information might have been gained as to the use of artillery on one side in conjunction with lights on the other.

The proper protection of electric light emplacements was not considered, but it is an important matter. Designs for new forts will include such emplacements, but in the existing forts the best has to be made of a bad job, and the lights will in most cases have to be placed outside, and will require adequate protection.

The electric lights of the attack were used with much success. One light formed a partial screen by being thrown across the northern margin of the defended area upon Stack Rock. The rest were directed on the artillery of the defences on both sides, in such a manner that none of them illuminated or crossed the mine-field. The result was that the gunners were considerably dazzled, and prevented from laying their guns in the direction of the light, although there was less difficulty in laying in other directions.

The lights were also occasionally flashed up and down, which was decidedly confusing. Some of the gun boats and torpedo boats of the attack used their lights on the night of the 18th, from the advanced position which they had taken up.

Artillery.

The defence artillery was much undermanned, and the smoke and dazzling effect of the hostile lights caused the fire to be decidedly intermittent. At the same time, the rules laid down for the conduct of the operations credited the artillery with considerable execution, and I think the results in this respect should be somewhat discounted.

The guns were fired by salvoes in order to allow intervals for the smoke to lift. This gave the attack an opening of which they were not slow to take advantage. Decoy boats were sent in advance of the countermining boats to draw the lights and also the fire of the defence, and after each salvo the countermining boat could generally reckon on a lull. These decoy boats would be far from comfortable billets in war, and it is very questionable if such tactics could be extensively followed with any great success. Moreover, with a proper armament of quick firing and machine guns, instead of the heavy guns used at Milford Haven, the fire would be much accelerated, and the smoke nuisance much diminished.

As already explained, the guns on Stack Rock were unaccountably silent on the night of the 18th August, and thus one of the essential elements of the experiments was wanting. The want of concert between the guns and electric lights has also been alluded to, pointing to the necessity of the gunners having control of the moveable lights.

The artillery of the attack took up suitable positions for covering the mine-field with smoke, and the wind being exceptionally favourable, their object was successfully accomplished. The gun-boats were afterwards employed for the same purpose from more advanced positions. It does not seem clear for what purpose the *Seahorse* and *Tees* advanced across the mine-field to certain and speedy destruction.

Countermining.

In the absence of information on the subject, the chief umpires have assumed in their report that all countermines were correctly laid and successfully fired, the latter I think being somewhat doubtful. The countermining operations were carried out with great energy and rapidity, but the main portion of the passage was only cleared by one line, representing a theoretical width of sixty yards. It has hitherto been considered necessary to lay a double line, in order to clear a passage for the advance of a fleet, and this was the system laid down in the original scheme, the efficiency of a single line for the purpose not being proved.

The attack was definitely informed that the submarine mining defence would not commence west of a given line, and would not be more than 3,000 yards deep; it seems, however, that only sufficient countermining stores could be collected to lay a double line the exact length given, and thus the failure of the first line necessitated a curtailment. Evidently, depth of defence is an important point, and it is now receiving attention; also the attack should have no clue as to where mines may begin and where they may end.

Recent experiments have shown the present countermine boats to be very vulnerable to the fire of machine guns and rifles, and with a well defended mine-field there is no doubt countermining would be a most difficult operation. The calm water and time necessary to fit out these boats is also, to my mind, a strong point in favour of the defence.

Means of Communication.

It is most essential that there should be a well-organized system of communication between the various branches of the defence, and during the experiments the insufficiency in this respect was very apparent.

Visual signalling, for various reasons, cannot always be carried on, and electrical communication is necessary at all events between the more important positions. A reliable system of communication between stations on shore and the torpedo and guard-boats is indispensable; also, the defence boats must be clearly distinguishable from those of the attack.

The guns and electric lights which work together, also the observing stations and electric lights, must have means of communicating with each other.

We will now consider what lessons have been learnt from these experiments, and how far they may be a guide for the future.

I shall consider first how far they bear on our general system of submarine mining, as that is probably the most interesting point to us.

It has already been stated that *time* is an all-important factor, and that submarine mines are of great value if they can delay the enemy.

It is equally important that we should be able to lay out our submarine mining defences in the shortest possible time. We are far from perfection yet, but much has been and is being done in this direction. One of the chief impediments is the British public, which has the strongest aversion to suffering the smallest inconvenience in time of peace, however much it might facilitate defence in time of war.

Nobody will, I think, deny that defence would be greatly facilitated if main cables and obstructions to creeping could be kept permanently laid out, and from a store point of view there is every reason in favour of such a course. It would, however, entail the reservation of certain waters in which vessels would be denied anchorage, and would doubtless be considered a great hardship. However, it is to be hoped that it may come to pass.

Our ground mines are now kept loaded, and probably we shall shortly be able to do the same with the electro-contact mines. If, further, a satisfactory system of dormant mines, (*i.e.*, mines kept at the bottom, and only released and made buoyant when required) can be devised, there is no reason why the greater part of the submarine mining defences should not be laid out as soon as affairs become critical, without waiting for a declaration of war. In any case, it is essential that everything should be in readiness to lay at all events *some* mines within forty-eight hours' notice, and thus develop a moral if not a material effect.

The proper regulation of the port traffic is most important, and that should be thoroughly organized in time of peace. It would be an excellent plan to put a harbour occasionally "in commission" for a short time, during which the traffic would be worked as in war.

The Milford experiments clearly proved the advantage of having a mine defence as *deep* as possible. You have heard how the attacking squadron could not muster sufficient countermining stores, even after being definitely informed that the defence would not be more than 3,000 yards deep. If, therefore, with the same number of mines, the defence can be so arranged that the enemy cannot know, within say 5,000 yards, where he may encounter mines, it is evident that the defence has been considerably strengthened only at the expense of some additional cable.

Further, in order to minimize the effect of a countermining attack, it is evidently desirable so to arrange mines that no single countermine can ever destroy more than *one*, even with the firing battery arranged for automatic firing. With this in view it is now thought that mines should not as a rule be laid nearer each other than 100 yards; the previously accepted distance having been 200 feet. By such an arrangement the defence will have the power of keeping the firing battery connected for automatic firing during countermining operations, which will no doubt add to the already considerable difficulties in the way of such operations.

In addition to submarine mines we have now got a valuable auxiliary in the Brennan torpedo. It is to be hoped this torpedo may now figure as far as possible in all our schemes of defence. It has begun well by passing safely through the House of Commons, in spite of the opposition of Mr. Labouchere and Sir William Crossman, late Inspector of Submarine Defences.

The first point laid down by the operations committee as requiring consideration was—

(*a*). "The best means of protecting the mines, including defence by guard-boats, against a sustained attempt to force them by a squadron."

It may be assumed that an enemy will rarely, if ever, attempt to force an entrance to a harbour defended by guns and submarine mines, unless under cover of darkness, smoke, or fog. With smoke or fog, electric lights will be of little or no use, and we must be prepared for the worst of these eventualities. An active defence on the water becomes, therefore, an absolute necessity, and as the defence can hardly hope to equal the attack in the number of boats available, the guard-boats should be of a type superior to what can be carried by the largest man-of-war. They should be handy, of light draught, high speed, and armed with quick firing and machine guns, rifles, and any other offensive weapons they can carry. Doubtless in many harbours there are tugs and other craft capable of making passable guard boats, but don't let us therefore lie on our oars and think it will all come right if war should unfortunately break out. These boats require to be fitted out for the purpose, and the necessary guns and stores should be kept in readiness at each station. Last, but by no means least, the personnel should be thoroughly organized and trained in time of peace for the duties they will have to perform in time of war; duties which require no small amount of training if they are to be efficiently performed.

Speaking generally, the guard-boats should have well defined areas over which they can operate, and such areas should be absolutely forbidden to the guns and electric lights of the defence, except under certain clearly defined conditions. For instance, at the commencement of the attack the guard-boats would probably take up position in rear of the most advanced mines, and behind all beams of electric light. When driven back by a superior force of the enemy they would retire through a previously arranged and well defined channel, and take up position in rear of the main obstructions. Such retirement should be notified by pre-arranged signal to all concerned, and the artillery and electric lights and mines of the defence will be free to operate on the area thus vacated. Should the obstructions be forced, the same course would again be followed, the guard-boats probably taking up position in rear of all submarine mines.

The attack will probably have a large number of electric lights, and in order to compete with them those of the defence should be as numerous as possible. For reasons already given, the lowest sites available should be selected, and where practicable they should be on both sides of the defended channel.

The operator at the light being unable to see the object on which the beam is directed, it is necessary to provide some means of working the projector from a distance. As already stated, satisfactory progress has been made in this direction. Further, a more powerful light being required at the longer ranges, when of course the projector is least liable to injury, a counterpoise arrangement is being tried, which enables the projector to appear above the parapet and give a powerful light at the long ranges, and to be replaced at the shorter ranges by a reflector giving a reduced light. This reflector is designed to be quickly replaceable in case of injury.

The action of the lights would probably be somewhat as follows :—

In the first instance, a powerful fixed beam would be thrown across the front of the advanced mine-field. This would mark the outer limit of the field of action of the guard-boats, which would lie in the dark, and be consequently in a good position to make a telling attack on any hostile boats crossing the beam of light.

In front of this fixed beam powerful search lights would work in concert with the guns of the defence commanding the outer waters.

The guard-boats having been driven back to their second position, a fixed beam would again be provided to light up the water to their front; in fact, the same system would be followed all through, the lights following the progress of the attack.

The electric light emplacements for the defence of the inner mine-field should be so placed that they will not be exposed to fire from the front.

It must be evident that the efficient working of artillery, submarine mines, electric lights and guard-boats, requires most careful organization and much practice.

Artillery.

Heavy guns of course form the primary armament of regular works commanding a channel of approach.

Against the boat attacks, however, which presumably will precede the advance of men-of-war, a much more effective defence can be provided by quick firing and machine guns. Such guns should be largely provided, both ashore and on the guard-boats, and should bear over the whole mine-field and also protect the cables when brought ashore.

Special batteries for such guns should be provided, and those for the defence of the inner mine-field should be so placed that they may not be exposed to fire from the front. The defence of the inner mine-field should thus remain intact, although the front guns may be silenced.

Smoke, which so impeded the defence during the experiments, would have had considerable less effect had quick firing and machine guns been in use instead of the heavy guns of the forts which fired over the mine-field. Smokeless powder may possibly be introduced into the service, and still further benefit the defence.

Obstructions.

The word "boom" has come to stink in my nostrils, as it seems generally to be considered the most important part of the defence instead of being quite in the second rank. A boom to be efficient requires the expenditure of much labour and material, which I consider might in most cases be turned to better account. At the same time, in narrow entrances, if good booms can be constructed, there is no doubt they may materially assist the defence. In such cases the boom or booms should be well under artillery fire, should be lighted up in front by fixed beams, and there should always be guard-boat protection in rear to prevent charges being fixed and fired, or other means employed for making a gap.

Any obstructions which can be devised should be laid out in waters where the defence guard-boats will not operate. Nets and coir rope, floated near the surface, have been found useful in fouling propellers, and wire rope entanglements supported by buoys might be of much service in delaying attacking boats under fire.

Boat mines containing small charges should be laid in front of the obstructions, and also, if available, in the advanced mine-field, beyond the action of the defence guard-boats. They should further be used in the shallow water on either side of the defended channel, and should protect the main cables when brought ashore.

Should booms form part of the defence, they could with advantage be made active as well as passive by having boat mines attached at intervals.

Boat mines should obviously be near the surface at all times of tide, and consequently the counterpoise system seems peculiarly applicable to them. The mines being small, all the gear used would be correspondingly light, and there seems no reason why a satisfactory system should not be devised.

A large quantity of chain and old cable should be laid on the bottom, both in front and rear of groups of mines, to protect the electric cables from creeping. Dummy cables should also as far as possible be laid all over the defended channel, even where there may be no mines, to deceive the enemy and cause him to expend explosive creeps to no purpose.

During an attack it will always be a difficult matter to replace in the same positions mines which have been fired or rendered unserviceable, because it entails raising junction boxes and doing boat work in the mine-field. It appears a preferable plan to make all necessary arrangement for laying rows of mines in rear of all those originally laid. Such mines could be kept all ready on board the laying-out vessels, and when a gap in the defence is reported, the earliest opportunity should be taken of laying those mines which will as nearly as possible remedy the fault. The cables might be taken direct to shore, by which means all boat work in the mine-field would be avoided.

(*b*). The value of torpedo boats to the defence, and the best methods of manœuvring them.

The value of torpedo boats to the defence naturally depends greatly on the nature of the harbour to be defended, also on the number of boats of a similar nature to which they may be opposed.

The first duty of the torpedo boats would be to obtain information as to the movements of the attack when at a distance, and to harass the fleet while beyond effective fire of guns and beyond the reach of mines. They should also occupy any available sheltered places in advance of the mine defence where they may be concealed, and whence they may take every opportunity of attacking the enemy's ships and opposing their advance. When once the hostile fleet has taken up position for systematic attack, the torpedo boats would probably be withdrawn, except for night attacks.

(*c*). The most suitable organization for the whole of the defensive operations.

Here we have indeed a large field for discussion, and there is no blinking the fact that at present our organization is lamentably defective.

The question of guard-boats has hitherto fallen between two stools, viz., the Admiralty and the War office. One of these stools seems likely to be withdrawn, and it is devoutly to be hoped that the guard-boats may be able to sit securely on the other. Then we have artillery, submarine mines, and electric lights, all in a happy state of chaos as far as organization is concerned. Who can name the officer who would command all these elements in case of war at any single harbour in the United Kingdom? And yet the proper defence of our harbours is by no means unimportant, and unpleasant visits from hostile cruisers would probably be among the first incidents of war with a naval power. If one thing was proved more clearly than another by the Milford Haven experiments, it was the necessity of organization and combined training of all the elements forming the defence, and it is all important that the officer in command should have a thorough knowledge of the means at his disposal. Such knowledge cannot be obtained in a day or a week.

There is much discussion going on in high places at present as to whether or not the Royal Engineers are the proper people to be in charge of submarine mining defence. Some say it should be handed over to the navy, some to the artillery, and it has become quite a convenient peg on which to hang inconvenient questions. They are all "postponed until the general question of submarine mining has been settled." Moreover, the general question, instead of being discussed with a view to perfecting our system of national defence is too frequently argued in a strictly partizan spirit, from which I fear we, as a corps, are by no means free.

Mr. Goschen recently made an excellent remark in allusion to the attitude of the Opposition when national difficulties are encountered by the Government of the day. His words were: "It sometimes appears to me that the exultation of the partizan exceeds the regret of the patriot," and many of us might take those words to heart.

The question should be fairly and intelligently considered, and the more this is done the more I am convinced it will become clear that it would be most difficult for any other branch of the service to take over submarine mining work.

It may, however, be decided in haste that this work is to be handed over to others, in which case it will infallibly be repented of at leisure. Whoever they may be they will have many difficulties to overcome, and it is to be hoped we will not look on with the exultation of the partizan, but give every assistance in our power towards the improvement of our national defence.

But believe me, it is not merely the small question who is to have charge of submarine mines. The real question, which can no longer be avoided, is, who is to have charge of guns, submarine mines, electric lights, and floating defence? The opinion is gaining ground, and will continue to gain ground, that coast defence will not be satisfactory until all these elements are combined in one body. Call this body by whatever name seems most conducive to the best results, and least likely to produce petty jealousy and opposition—only let us have some form of coast defence corps to try and bring order out of chaos. With such a corps we could have a body of men in each harbour, working under one head, thoroughly trained in the combined working of all the elements of the defence. It need not necessarily follow that the officer commanding the coast corps in any harbour should also command the whole defensive force in time of war, when infantry will be largely employed. He will, however, command those portions which require the most careful organization and training in time of peace, and having been responsible for such organization and training, who can doubt that he will utilise the forces at his disposal to infinitely better effect in time of war than in the present state of divided responsibility, or we might almost say absence of all responsibility.

F. R. H.

PAPER V.

THE LYDD EXPERIMENTS OF 1886.

By Major G. S. Clarke, C.M.G., R.E.

The experiments of 1886 possess less than average interest. For reasons which will be noticed hereafter, some of the points with regard to which information appears to have been sought, have little or no connection with the requirements of war, and the results obtained cannot, therefore, be said to add greatly to our stock of useful knowledge, or provide us with new data.

The principal subjects of experiment were :—

I. The effect of employing flattened exterior slopes for the parapets of field redoubts subjected to the fire of field guns.

II. The resistance of parallels and approaches, of improved sections, in sandy soil, to the fire of medium guns.

III. The resistance to artillery fire offered by parapets of average earth for comparison with previous results obtained against similar parapets of light sandy soil.

IV. The liability of the sunken fence forming the permanent obstacle of Twydall redoubt, to be destroyed or breached by artillery fire.

V. The value of the fire of field guns against troops occupying a hasty field redoubt without overhead cover.

VI. The effect of the fire of field guns against wire entanglements placed in the shallow ditches of field redoubts.

VII. The possibility of using the fire of field guns to clear the ground of land torpedoes.

VIII. The value of "slight extemporized overhead cover" against rifle fire at extreme ranges.

IX. The use of light steel plates as overhead cover against high angle shrapnel fire.

X. The utility of balloons for observing and directing artillery fire, and their liability to be hit.

I.—Breaching Parapets of Field Redoubts.

Stiff Soil.

Target.—12-foot parapet of stiff soil; height, 7 feet; exterior slope, 1 in $2\frac{1}{2}$.

(*a*). *Gun.*—12-pr. B.L.

Projectile.—Steel common shell.

Range.—2,500 yards.

Twenty-five rounds were fired, yielding only four hits in the parapet itself, and two hits in the escarp. The hits were much distributed, and cannot be said to have produced any effect whatever. The deepest single crater was 2ft. 6in.

Range.—1,200 yards.

Twenty-five rounds were fired, giving 12 hits. Excluding two rather wild rounds, the hits were well in line, and the parapet was trenched through to an average breadth of about 6ft., and depth of about 3 feet. The deepest single crater was 3 feet.

(*b*). *Gun.*—20-pr. B.L.

Range.—2,500 yards.

Twenty-five rounds fired, giving 12 hits, so placed as to produce no real effect whatever. Parapet nowhere trenched through. Greatest depth of crater, 3 feet. The extreme hits were 30 feet apart. One round fell 800 yards short.

Range.—1,200 yards.

Twenty-five rounds fired, giving 18 hits, distributed over about 15 feet length of parapet. Effect practically *nil*, the depth of trench scarcely averaging 1 foot. Deepest crater, 2 feet 6 inches.

Target.—14-foot parapet, clay; height, 7 feet; exterior slope, 1 in $2\frac{1}{2}$.

(*c*). *Gun.*—25-pr. R.M.L.

Range.—2,500 yards.

Eleven rounds fired, giving 4 hits, all dispersed, and producing no real damage whatever. Deepest crater, 2 feet 3 inches. Four rounds subsequently fired at this section giving 2 hits.

Range.—1,200 yards.

Twenty-five rounds fired, giving 15 hits. Parapet not trenched through in a straight line. Depth on line of best effect averaged less than 1 foot. Deepest crater, 3 feet.

Light Soil.

Target.—12-foot parapet, sandy loam ; height, 7 feet ; exterior slope 1 in $2\frac{1}{2}$.

(*d*). *Gun.*—12-pr. B.L.

Range.—2,500 yards.

Twenty-five rounds fired, giving 8 hits, well distributed. Effect *nil.* Deepest crater, 1 foot.

Range.—1,200 yards.

Twenty-five rounds fired, giving 17 hits. Parapet trenched through, but not in a straight line. Average depth about 1 foot 6 inches. Deepest crater, 2 feet.

(*e*). *Gun.*—20-pr. B.L.

Range.—2,500 yards.

Twenty-five rounds fired, giving 9 hits. Parapet nowhere trenched through. Deepest crater, 1 foot 6 inches.

Range.—1,200 yards.

Twenty-five rounds fired, giving 18 hits well placed. Parapet trenched not quite up to crest. Average depth about 1 foot 6 inches. Deepest crater, 1 foot 6 inches.

Target.—14-foot parapet ; height, 7 feet ; exterior slope 1 in $2\frac{1}{2}$.

(*f*). *Gun.*—25-pr. R.M.L.

Range.—2,500 yards.

Twenty-five rounds fired, giving 1 hit. Crater, 1 foot deep.

Range.—1,200 yards.

Twenty-five rounds fired, giving 13 hits. Parapet trenched through. Average depth about 2 feet. Deepest crater 2 feet 6 inches.

REMARKS.

Altogether 286 rounds were fired at parapets 12 feet and 14 feet thick, with what precise object it is not easy to determine. It was generally admitted that guns of such natures were unable to seriously damage moderate parapets, and the very idea of breaching a field redoubt appears to be based on a totally wrong conception. Breaching has been commonly employed as a means of breaking down a material obstacle, and thereby creating means of access to a position otherwise unapproachable. But the parapet of a field redoubt is an obstacle in no sense of the word. Almost anybody can run up a short slope of 1 in $2\frac{1}{2}$, and what conceivable advantage would be gained by cutting a few shallow irregular trenches here and there in the faces of a redoubt to be attacked—trenches, perhaps, 18 inches deep ? If the defender has an obstacle, it will be outside his parapet, and will not be touched. If he has not, his cover is practically as good as it was before, and unless he has been sitting *on* his parapet during the artillery practice, waiting to be killed, he will—as the Turks did—offer just as much resistance to assault as if the artillery had kept their limbers full.

It seems worth while to estimate roughly the amount of shooting required to cut down a parapet appreciably, premising that at 2,500 yards it is not the slightest use to employ the fire of any of the above guns for this object. The best breaching result was apparently that obtained at 1,200 yards by the 12-pr. B.L. gun against a clay parapet. The trench cut in the superior slope was about six feet broad at the top and three feet deep. Considering that the earth thrown up from one crater fills up another, so that the cutting of a second parallel trench would go far to obliterate the first, it is impossible to allow an effective breadth of more than three feet for each trench.

Thus for 20 yards of breach, 500 shells would be required *at target practice*, where the services of a range party marking and signalling back the position of each hit were available. To multiply the above result by three for the disturbing conditions of war appears a moderate correction. Hence, *to reduce by three feet the height of a clay parapet 12 feet thick and 20 yards long, by shell fire from the 12-pr. B.L. gun at 1,200 yards, 1,500 rounds would be required*, or about the whole of the ammunition carried by two field batteries.

Judging from the Lydd results, about 3,000 rounds would be required to produce the same effect in a sand parapet. What greater waste of force could ingenuity devise ?

Regarded as comparative trials of guns against parapets, these series were inevitably unsatisfactory, since the distribution of rounds, on which alone breaching effect depends, varied considerably.

The advantages of flat slopes needed no further confirmation, and as there are no previous trials by the side of which these can be placed, it is not easy to see how this experiment fulfilled its stated object. Sand again proved a superiority of resisting power which no one has questioned.

II.—Trial of Improved Sections of Parallels.

(*a*). *Target.*—Portion of a 2nd parallel, sandy soil ; height at crest, 4 feet ; parapet *en glacis* 24 feet thick at ground line.

Range.—1,200 yards.

Gun.—5-inch B.L.

Projectile.—Steel common shell.

Ten rounds fired, giving 3 hits exactly in line. Parapet trenched through to average depth of about 2 feet. Deepest crater 2 feet 9 inches.

(*b*). *Target.*— Portion of 2nd parallel, sandy soil; dimensions as before, but interior slope revetted with gabions surmounted by two layers of sand bags.

Four rounds were fired, giving 3 hits not in line. Parallel not trenched; gabions not disturbed; but sandbags displaced in two places, the craters extending to the crest. Deepest crater, 2 feet.

(*c*). *Target.*—Portion of an approach; section same as that of 1st parallel. Fire directed at angle of 50 degrees to line of crest.

Four rounds fired, giving 3 hits dispersed. Approach not trenched. Deepest crater, 2 feet 6 inches.

Gun.—12-pr. B.L.

Projectile.—Steel common shell.

(*d*). *Target.*—2nd parallel, section as above.

Range.—800 yards.

Ten rounds fired, giving 5 hits; no trench formed. Deepest crater, 1 foot 3 inches.

(*e*). *Target.*—1st parallel; section as above.

Range.—1,200 yards.

Five rounds fired; no hit.

(*f*). *Target.*—Approach; section as above.

Range.—750 yards. Fire directed at an angle of 50 degrees to crest line.

Five rounds fired, giving 2 hits. Craters 1 foot 9 inches deep.

(*g*). *Target.*—1st parallel; section as above.

Range.—1,200 yards.

Ten rounds fired, giving 4 hits, of which 2 were in line. Parallel not trenched through. Deepest crater, 2 feet.

(*h*). *Target.*—Approach; section as above.

Range.—800 yards. Fire directed to an angle of 50 degrees to crest line.

Six rounds fired, giving 6 hits, closely grouped. Approach not trenched through. Deepest crater (at crest) 2 feet.

Remarks.

It is not easy to see the use of the above series. Parapets *en glacis*, whether for parallels or approaches, would necessarily be preferable, not merely as resisting shell action better, but as constituting less visible targets. Presumably because this proposition was self-evident, the report makes no allusion to any possible superiority of the "improved sections" as deduced from these experiments, but contents itself with generalities as to the uselessness of such firing. "It seems improbable that the besieged would deem it worth their while to expend ammunition largely for the purpose indicated." But this, too, was already sufficiently evident, as was pointed out in 1884.*

The best result obtained was the cutting down of the crest for two feet over a length of three or four feet, six feet of cover being still left in the parallel itself. Of the 54 rounds fired, only four could possibly have injured men who happened to be standing in the trench behind the point where the hits occurred. The rest were simply thrown away.

"Breaching parallels and approaches" is not one of the "operations of war," and to keep down rifle fire from a parallel—a quite distinct object—common shell would only be used in the absence of shrapnel.

III.—Resistance to Howitzer Fire of Parapets of Average Earth, for Comparison with that of Light Soil.

Target.—Parapet of average earth, 30 feet thick; exterior slope, 15 degrees.

Range.—1,200 yards.

Gun.—8-inch R.M.L. 70-cwt. howitzer.

Projectile.—Common shell.

Twenty-nine rounds were fired, giving 22 hits, the remaining rounds breaking up in the gun. The parapet was trenched completely through, to an average depth of about 4 feet 6 inches, by 13 hits; and about 6 feet at the conclusion of the practice. The average top breadth of the trench was about 14 feet, and the revetment of the interior slope was destroyed for a length of five gabions.

Remarks.

The above results may be compared with those obtained by the same howitzer in 1884 and 1885 against clay and sandy loam parapets respectively. The number of rounds from the 8-inch howitzer

* *Professional Papers*, Vol. X., Paper VII.

required to trench a 30-foot parapet with a 15-degree exterior slope is—

Material.	No. of Rounds.	Year of Experiment
Clay	13	1884
Sandy Loam	21	1885
Average soil	13	1886

From this it would appear that average soil offers no greater resistance than clay ; but experiments on this small scale do not permit of perfect comparison. The shooting of the howitzer in 1886 was almost perfect as to line. The depth of the trench cut by the 13 rounds in clay in 1884 was somewhat deeper, though the breadth was less than that obtained by the same number of rounds last year. It seems clear, therefore, that average soil ranks between clay and sandy loam—a result which might have been anticipated with some confidence. The practical value of a "breach" of this description has not been explained.

IV.—Attack on Sunken Fence of Twydall Redoubt.

Target.—Section of glacis and ditch with iron fencing (see *Fig.* 1).

(*a*). *Range.*—1,500 yards.

Gun.—12-pr. B.L.

Projectile.—Steel common shell ; angle of descent 2° 30′.

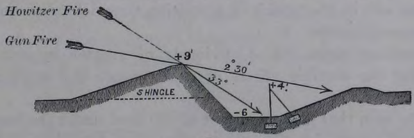


Fig. 1.

The line of fire was arranged to make 15 degrees with the line of the fence.

Twenty rounds were fired, producing no effect whatever. One shell only struck crest of glacis, and is naïvely reported to have "knocked a couple of pebbles off crest of glacis."

(*b*). *Range.*—2,210 yards.

Gun.—8-inch R.M.L. 70-cwt. howitzer.

Projectile.—Steel common shell ; bursting charge, 26lbs. Angle of descent 33 degrees.

The line of fire was at right angles to the line of the fence.

Twenty rounds were fired, of which only one struck the railing, tearing away two bars and creating a gap two feet wide, and bursting in the slope beyond, damaging the concrete foundation for a length of five feet. One round passed through the same hole, doing no damage. Only three rounds struck the glacis itself.

Remarks.

The fact that a deep trench could not be dug on this site without reaching water necessitated the throwing up of a shingle glacis, nine feet high, in order to procure the relative heights of the top of the railing and the covering mass.

In the 12-pounder series (*a*) it was intended to fire 50 rounds ; but, with the angle of descent available, it was impossible to reach the fence, and previous experiments had abundantly shown that to attempt to breach the protecting glacis with this gun was perfectly hopeless. This being eventually realized, the practice was stopped.

The employment of common shell from field guns against such a work as Twydall redoubt, even at the moderate range of 1,500 yards, may now, it is presumed, be abandoned as futile.*

By a concentrated and well directed shrapnel fire the defenders could, probably, be compelled to take cover ; but since such a fire must cease long before the assaulting infantry could approach the work, it may, perhaps, be ultimately admitted that field guns can render little or no aid in the attack of a position thus defended and garrisoned by steady troops.

The howitzer series (*b*) is obviously of greater importance, as representing the possible effects of the heaviest high-angle gun of our siege train.

It will be seen that one round out of 20 fired under the beneficent conditions of target practice was so effective as to make a hole sufficiently large for men to pass in single file.

The position of an unfortunate assaulting party packed on the wrong side of the railing, under the full fire of the work, and endeavouring to struggle one after another through holes of this description, merely in order to emerge on a full array of entanglements beyond, may perhaps be imagined.

* The experimental officer remarks, "The hits only made insignificant scoops, some could hardly be traced."

It is stated that at the siege of Strasburg it was possible from the advanced trenches to single out, by the colour of the *debris*, rounds which struck the scarp wall and to signal them to the breaching batteries. This would hardly be the case at Twydall, where a siege battery might shoot for a week in ignorance as to whether the fence was being injured.

It is remarkable that in spite of the large bursting charge, so little result was produced by the single effective hit. Had the projectile struck the upper horizontal rail, the effect would have been greater. Better results would probably have been obtained by a shell bursting two or three feet short of the fence; but this, with a percussion fuze, would involve a greater angle of descent, and consequently less accuracy; while time fuzes can by no means be relied upon for such a delicate operation.

Better high-angle siege guns than our 8-inch howitzer will, doubtless, be produced. Oblique fire will add to searching power without an increase to the angle of descent. High explosives will give more effective shell action. Setting against these developments of the future the vast difference between Lydd target practice and siege conditions, it will generally be admitted that the sunken fence has extremely little to fear, even from the siege train of the attack.

In addition to the above experiments, 200 rounds of Martini-Henry ammunition were fired at the fence at a range of 44 yards, in order to estimate the damage to be expected from the fire of the defenders. The result merely went to show that it is desirable to turn the edge of the V-shaped bars inwards, and to strengthen the attachment of the railings to the standards. This being done, there is no danger of any weakening whatever of the fence by rifle and machine gun fire from the work.

V.—The Employment of Shrapnel Fire against Troops Occupying a Hasty Field Redoubt without Overhead Cover.

Target.—Portion of redoubt in sandy loam, with dummies placed as shown in *Plate* I.

Range.—2,500 yards.

Gun.—12-pr. B.L.

Projectile.—Steel shrapnel; angle of descent, 5° 10′.

Fifty-six rounds were fired, yielding the following hits on dummies.

Front trench	...	19
Rear "	...	34*

REMARKS.

This experiment is in all respects unfortunate and misleading. The position in which the dummies were stationed was naturally of the first importance, and under no conceivable circumstances would the garrison of a redoubt under fire have occupied the positions arbitrarily chosen (see *Plate* I).

Why *stand* at all in the inner trenches? Above all, why stand as far away as possible from the protecting mass, as the hapless dummies in rows *a*, *b*, *c*, and *d*, were made to do? Why might not rows *a* and *b* place themselves close behind the traverse, presumably made for their protection, and from which they will require, say, one second more time to reach the gorge banquette? Why dawdle at *e*, an obviously hot corner? Finally, why is the gorge banquette manned and the front parapet deserted, save for one dummy, who seems to have strolled there to look about him after the distribution had been made. By this unfortunate distribution, all the main conditions of the problem were vitiated, and the results are worthless so far as practical deductions are concerned. If an experiment of this description had been made in Russia before 1877, and had been misread, it would go far to explain the slaughter at Plevna.

It is scarcely necessary to state that the proper course for the garrison of a redoubt of this nature, under such a fire, is to *sit* in the bottom of the trench as near to the protecting mass, whether parapet or traverse, as possible. A few sentries crouching down on the banquette, and looking over at intervals, will suffice for a look-out. Moreover, if a work of this class is to be attacked in rear, shrapnel fire will have to be brought to a timely end, or it will become an effective ally of the defenders. Thus, the gorge parapet will usually take care of itself, and be manned only when the artillery fire ceases. The positions arbitrarily selected for the fated garrison of the redoubt, and their natural positions, have been both shown in *Plate* I. The opening angles of shells burst in exceptionally favourable positions are indicated.

This experiment should, apparently, be tried again, with the dummies occupying the latter positions.

* Or 48 (?). The lesser total is taken for the results of the firing.

VI. The Effect of Shrapnel Fire from Field Guns against Wire Entanglements placed in the Shallow Ditches of Field Redoubts.

Target.—Entanglement in shallow ditch of field redoubt, (*Plate* I).
Range.—2,500 yards.
Gun.—12-pr. B.L.
Projectile.—Steel common shell. Angle of descent 5° 10′.

The experiment was carried on simultaneously with V., above.

In all, 56 rounds were fired.

The German entanglement suffered no damage. One upright of the low entanglement was cut through.

Remarks.

There could have been no reason to suppose that wire entanglements would suffer appreciably from shrapnel fire, and the experiment possesses little interest. If it were ever considered worth while to fire at a shallow invisible belt of entanglement, common shell with a percussion fuze would naturally be employed; but, that there would be any real probability of thus reducing the efficiency of such an obstacle, cannot for a moment be admitted.

The value of entanglements will some day be amply demonstrated, and it is sufficient at present to remember that such an obstacle has never yet been passed under fire. The elaborate so-called "German entanglement," which seems to have found favour, appears to be altogether superfluous. It is a luxury which time and unlimited supplies of wire would alone justify. Far simpler arrangements will suffice for all the purposes of war, and it may be questioned whether, as against men, this intricate net-work is really a more efficient obstacle than the earlier forms borrowed from America; since clearly the measure of destructibility depends rather on the pickets then the interlacement. As against dogs, and possibly rabbits, the superiority of the German entanglement is freely admitted.

VII. The Use of Field Guns to Clear the Ground of Land Torpedoes.

Target.—16 land torpedoes, of which seven were placed in the ditch of a field redoubt, and nine in the open in front of the ditch, the latter being distributed over an area of 26 yards by 24 yards, (see *Plate* II.).
Ranges.—1,200 and 2,100 yards.
Gun.—12-pr. B.L.

Projectiles.—Steel common shell and steel shrapnel.

The land torpedoes were of four types.

1. Mechanical mines fired by a trigger, connected to a trap consisting of a triangular frame, sides 12 inches long, covered with rabbit wire netting; the charge being placed in a box sunk in the ground, and the trap hidden by brushwood. Four of these mines were laid in part of the ditch. (*Plate* II.).

2. Fortress mines, electric, five in number, laid on glacis.

3. Land mines, electric, four in number, laid in ditch.

Both of the above are fired by bringing pressure on a disc four inches in diameter.

4. Tripping mines, electric, three laid in ditch and fired by a tripping wire running along the ditch 1 foot 6 inches above the bottom, and 4 feet from the front.

The following rounds were fired:—

26 common shell 25 shrapnel	1,200 yards.
25 common shell 23 shrapnel	2,100 yards.

At 1,200 yards, No. 3 land mine was fired by a common shell striking the contact disc.

At 2,100 yards, No. 14 mechanical mine was hit by a shrapnel bullet and put out of action, the safety pin being knocked out.

No. 8 tripping mine was fired by a common shell, which burst in the escarp about 18 feet beyond it, and threw back *debris* on the tripping wire.

No. 15 mechanical mine was fired by a shrapnel bullet, which cut the trigger lanyard.

Remarks.

The concussion of a shell bursting close at hand would certainly not suffice to make contact in the case of an electric bell, and there could have been no reason to expect any better result in the case of the electro-contact mines. However, the question was happily disposed of by the fact that a 12-pr. shell burst within 3 feet, and an 8-inch howitzer shell within 4 feet of such a mine.

The tripping mine, fired by *debris* thrown back by a burst shell, was probably set a little too fine.

For the rest, it is clear that the mines will be fired if they are hit in the proper place—a previously evident proposition. The probabilities, therefore, are amenable to mathematical treatment.

The mines in the ditch appear to have been laid *under* the entanglement—an arrangement which would hardly be adopted in the field when it is undesirable that the efficiency of one form of obstacle should be demonstrated by destroying another.

VIII. The Use of Slight Overhead Cover against Rifle Fire at Extreme Range.

Target.—Deal planks, three inches, one and a-half inches, and one inch thick, supported by uprights, and placed in the front and rear trenches of the redoubt. (*Plate* I.).

Gun.—One-barrel Gardiner. Angle of descent of bullets about 10°.

Six hundred and eighty-five rounds were fired at 2,000 yards, after which it became evident that the angle of descent was not sufficient to reach the target. The bullets, however, appeared to have very little energy, being unable to penetrate a gabion band struck at 50°.

The range being increased to 2,530 yards, giving an angle of descent of about 15°, 240 rounds were fired, without any hit being obtained "on account of imperfect communication with the range party,"—a difficulty apt to occur on service, where there would be, unfortunately, no range party.

Finally, 550 rounds were fired, giving

3 hits on 3-inch planks.
6 „ $1\frac{1}{2}$-inch planks.
3 „ 1-inch planks.

each hit made a slight cut about $\frac{1}{8}$-inch deep.

Remarks.

Considering the known velocities of the bullets, there was no reason to expect any better result. It may now be asserted with safety that $\frac{1}{2}$-inch deal planking will provide ample overhead cover against rifle bullets fired at 2,500 yards. If long range rifle fire is likely to be employed by the attack, its effects can thus readily be guarded against. This description of cover, if provided at all in hasty redoubts with interior trenches, would be needed as a protection against weather rather than bullets; but for rough shelters (such as the Plevna huts) built in rear of works of defence, it is satisfactory to know that excessively moderate measures will suffice against rifle fire.

IX. The Employment of Light Steel Plates as Overhead Cover against High Angle Shrapnel Fire.

Target.—Gun portion of sunken battery protected by steel plates 1-inch, $\frac{3}{4}$-inch, $\frac{1}{2}$-inch, $\frac{1}{4}$-inch thick.

Range.—1,600 yards.

Gun.—8-inch, R.M.L. 70-cwt. howitzer.

Projectile.—Steel shrapnel. Angle of descent 22° 20′.

Thirteen rounds fired, six dummies hit. One blind shell struck a $\frac{3}{4}$-inch plate, fracturing it, and bringing it and the adjoining plates down on the detachment. The body of another shell struck a $\frac{1}{4}$-inch plate, doubling it up. Portion of the body of a third shell struck another $\frac{1}{4}$-inch plate, indenting it deeply. Many bullet hits were obtained on the plates, merely splashing them.

Range.—2,400 yards. Angle of descent 30° 30′

Thirty rounds fired, giving 66 bullet hits on the plates, and one on the dummy gun. No effect whatever.

Remarks.

The experiment shows that $\frac{1}{4}$-inch steel plates give complete security against shrapnel bullets from the 8-inch howitzer, and that the same plates are not penetrated even by the body of the shell at 1,600 yards, using a $3\frac{1}{2}$-lb. charge. On the other hand, a blind shell under the same conditions fractured a $\frac{3}{4}$-inch plate.

The plates appear to have been merely supported, and not being tied back to the parapet in any way, were easily knocked down upon the gun detachment. Steel plates $\frac{1}{2}$-inch thick, properly stayed, would doubtless suffice as a protection against the largest splinters, but might succumb to blind shrapnel or to common shell. It is worth noting in connection with this that the $1\frac{1}{2}$-inch steel dish of the Eastbourne cupola, struck by a blind shell at an angle of 46° 30′, with a velocity of about 575 f.s. was merely indented.

On the whole, it appears that extemporised cover of this class may occasionally be employed with advantage, since in this experiment all effect at the 2,400 yards range was thus prevented.

X. The Employment of Balloons for Observing and Directing Artillery Fire.

A considerable number of observations were made at ranges of 2,500, 3,300, and 4,600 yards, from a captive balloon, at altitudes varying from 800 to 1,800 feet.

The experiments were by no means complete or exhaustive; but the results clearly showed that great advantages in directing artillery fire can be thus obtained.

To test the liability of a captive balloon to be brought down by artillery fire, 17 rounds of steel shrapnel were fired from the 12-pounder at a range of about 3,100 yards, without result.

REMARKS.

Balloons, as observing stations, will probably be largely used in future sieges. Their value for purposes of reconnaissance has long been admitted. Their use for directing artillery fire is no longer open to question. The balance of advantage thus obtained should certainly lie with the defence; since there appears to be no restriction, other than that of wind and weather, to the use of balloons in fortresses. The practice at the balloon was inconclusive, since the 15-sec. sensitive fuze employed was tried for the first time in the 12-pounder gun. The range was, however, considerably shorter than is necessary, and the difficulty of obtaining a hit was much increased by a simple expedient adopted by Major Elsdale of keeping the balloon in movement. There is no reason whatever why this plan could not be adopted under service conditions, and it appears to have had the effect of completely checkmating the range finders.

MISCELLANEOUS.

A few other experiments were tried, but call for little remark.

Rifle and machine-gun fire was employed at ranges of 600 and 1,000 yards against a mirror reflecting the beam of the electric light. Altogether 950 rounds were fired, giving four hits on the mirror, by which the light reflected was not perceptibly affected. Since, however, "shadow laying" was, unfortunately, not adopted, the small result obtained is possibly misleading.

Excellent practice was made by the 8-inch howitzer, at 2,400 yards, at the familiar sealed pattern field magazine, 18 hits being obtained in 60 rounds. A direct action *delay* fuze was employed; but, since all the shells with one exception burst on graze, the magazine remained uninjured. Nearly the whole of the 60 rounds would have fallen on the deck of a moderate sized vessel lying end on to the howitzer. The shooting obtained by Scott's and French's sights was practically the same.

The 0·6-inch wall-piece gave fresh evidence of its irrepressible vitality. With a steel bullet, it is at present unable to penetrate a sap roller of coarse brushwood at 150 yards!

London, 15th August, 1887. G. S. C.

PAPER VI.

REPORT ON THE BLOWING UP OF THE WRECK "GONDOLA."

By Lieut. J. Pring, C.Bn., R.E.

Proceeded to Holy Island on the 4th January, 1887.

I found on a more accurate survey of the wreck than I previously had been able to make, that to place charges on the starboard side, as well as the port, would be little or no use, as a sandbank had formed on her starboard side up to within three feet of her bulwarks. I therefore decided to lay down eight charges of 50 lbs.—seven on her starboard bow, as shown on *Plate* I., *Figs.* 1 and 2. This sketch shows the position of the wreck when the charges were laid down.

The charges were fired at almost high water, and had a depth of 30 feet of water over them.

The column of water thrown up was not very high—not above 14 feet.

The effect of these charges was, that the vessel appeared to have been lifted bodily and cut through her length, close to the sand, the two charges in the bows cutting her through and letting the bow drop down from being the highest part to the lowest. The decks abaft the mainmast were blown up, but the cross girders remained intact, which appeared to have kept the port side from falling away, also giving the wreck a much greater list to port.

I placed two charges, one of 50 lbs. near the mizzen chains, and one of 25lbs. near the stump of the mainmast, as shown in *Plate* I.

Figs. 3 and 4. This cut all the girders abaft the mainmast, and allowed the port side to fall over, taking away part of the starboard side, pumps, and stump of mainmast, and shook her starboard side very much, which allowed the sand to get away, as shown in *Plate* II., *Fig.* 1. I then placed one 50-lbs. and one 25-lbs. charge, as shown in *Plate* II., *Fig.* 1, in a hole in the deck near the deckhouse, and one in the hatchway ; pushed them as far as possible under the deck, and fired ; but they did but little damage. These last sets of charges had about 12 feet of water over them when fired. The wreck was then as shown in *Plate* II., *Fig.* 2.

I placed four charges, as shown in *Plate* II., *Fig.* 3, getting one into the place where the bows had parted, and three outside on the starboard side, at intervals of 20 feet.

The column of water thrown up was very peculiar ; one column of water was perfectly light and rose straight up in the air, and after a quite perceptible pause a large column of water, quite black, shot out from the left base of the first column, forming a shape, thus, V. The effect of these charges was that they blew away the bow and the remainder of the port side, as shown in *Plate* II., *Fig.* 4.

I laid down four 50-lbs. charges on the starboard side, at a depth at low tide of about 10 feet, and fired at half tide with about 18 feet of water. Directly after the explosion I took soundings, and the portion of wreck to which the charges were fixed appeared to have been blown away.

I did not wait for the next tide to inspect the work done, as this would have delayed me for another day if the weather had been favourable, and left for the Tyne at 12.15, 21st January, 1887.

The charges mentioned in the foregoing report as 50 lbs. and 25 lbs. actually contained 57 lbs. and 27 lbs. of guncotton.

The following method was adopted in fixing and arranging the charges to the side of the vessel. Cable used—unarmoured telegraph.

The charges had angle-pieces of wood, fixed to prevent them getting chafed, and were connected up in continuous circuit.

The charges were connected to each other by 2-inch rope, which was somewhat shorter than the intermediate cable to prevent any strain being brought on it.

Each charge was weighted and lowered down to its proper position, and secured to the side of the vessel by large iron staples. This latter work was done by the diver, who signalled in turn as each charge was made secure.

List of Stores supplied to, and for maintenance of, Submarine Mining Vessel, "Burgoyne," employed in connection with blowing up wreck of "Gondola" off Holy Island, during the Month of January, 1887.

Description of Article.		Number or Quantity.	Remarks.
Bricks, bath	No.	4	Supplied from S.M. store
Cotton waste, coloured ...	lbs.	60	
Cloth, emery, Fine ...	sheets.	9	
Cloth, emery, Middling ...	,,	17	
Candles	lbs.	4	Bought from Contractor.
Fenders, cork, large ...	No.	2	
Line, fine, ratlin	lbs.	31	
Mats, coir	No.	3	
Soap, soft	lbs.	28	
Soap, yellow	,,	15	
Soda	,,	38	
Oil, olive	gals.	12	
Oil, colza	,,	8	
Oil, engelberth	,,	3	
Oil, paraffin	,,	2	
Twine, sail	lbs.	1	
Wick	,,	1	
Coals (steam, north country)	tons.	15	Supplied from S.M. store.
Section V.			
Cases, guncotton, dry, $2\frac{1}{4}$ lbs., empty	No.	20	
Detonators, electric, No. 12 ...	,,	20	
Guncotton, dry, charges, priming L. & S. M., $2\frac{1}{4}$ lbs.	,,	20	
Guncotton, wet slabs, $6\frac{1}{8}'' \times 6\frac{1}{8}'' \times 1\frac{3}{4}''$	lbs.	1080	
Section VI.			
Cotton waste, white ...	lbs.	28	
Section VII.			
Bags, guncotton, 50 lbs. ...	No.	18	
Bags, guncotton, 25 ,, ...	,,	2	
Clamps, universal ...	,,	20	
Cable, electric, unarmoured, telgph.	yds.	250	
Plates, earth, jointers, S.M. ...	No.	1	Lost accidently.
Shackles, attachment, chain, $\frac{5}{8}''$	,,	1	Lost with anchor & chain.

J. PRING, Lieut., C.Bn., R.E.,
O. C. Tyne Section, C. Bn., R.E.

Clifford Fort, North Shields,
15th February, 1887.

PAPER VII.

STEEL.

By Ewing Matheson, Esq., C.E.

LECTURE I.

The whole subject of steel has been in a transition state for the last thirty years, the Bessemer inventions and those that have grown out of them having revolutionised the ideas formerly prevailing. So rapid has been the growth of knowledge in regard to the manufacture, qualities, and use of steel, that conclusions drawn at any time during this period from previous experience are liable to serious alteration. Without going so far as to speak of information available twenty years ago as obsolete, it may certainly be deemed incomplete, and needs qualification from subsequent experience, and it is to be hoped that points which are still uncertain to-day may be elucidated in the early future.

Such a succession of changes need, however, cause no anxiety. It is no small matter to alter the usage of centuries, and the beginning of the steel age as the outcome of the iron age of the past must needs be attended by certain dislocations of old practice. In dividing the subject into two lectures, I propose as the first, to-night, to deal with steel in regard to its composition and modes of manufacture and tests; and in the second, to-morrow, with the qualities and uses of steel.

To engineers who have to deal with materials provided for them, and are never likely to be called upon to produce the materials, it might appear unnecessary to speak of the methods of manufacturing steel, and therefore to deal only with the means and advantages of employing it; but its behaviour when in use depends so closely on the incidents of making that the two cannot be wholly dissociated. Moreover, the economical considerations that determine the choice between iron and steel in this country can only be weighed by those who have a full knowledge of the manufacture. It has often been attempted to define what is meant by the name "steel." Undoubtedly it is iron in a certain form, and before the time of the Bessemer inventions the capacity for being tempered was the main distinguishing characteristic between steel and iron. Steel is stronger and harder than iron, but these are matters of degree only; and no art could give to a sword made of iron the capacity which tempered steel has of springing back to its original form after having been bent double, or give a serviceable edge to a knife or tool for cutting hard metals.

One of the differences between iron and steel is the amount of carbon it possesses—steel in this respect coming between cast iron and wrought iron. There is also less foreign substance in steel, which contains 99 per cent. of metallic iron, while cast iron contains only about 90 per cent. There are other constituents which may determine the quality of the steel, or which may hinder its manufacture, of which I shall speak presently; but the amount of carbon is the essential difference. Cast iron contains from 2 to 4 per cent. of carbon, wrought iron from 0·012 to 0·3 per cent., and what may be termed—for want of a better designation—steel proper, has any proportion of carbon between 0·2 and 1·5 per cent. What is called mild steel, or ingot iron, contains from 0·05 to 0·18 per cent., chemically, much resembling wrought iron.

The original material from which steel is made is cast iron, and the earlier processes of manufacture, commencing with the iron ore, are common to all methods of making steel; but the stage where the treatment begins to differ varies with the particular system of manufacture adopted, as will presently be seen. As it is desirable to show clearly not only how steel is made, but the difference between it and iron, the manufacture of the latter may be briefly summarised.

Iron ore contains from 30 to 60 per cent. of metallic iron, most of which can be extracted. The poorer kinds will not repay carriage, and depend on contiguous fuel, as they must be smelted near the mine. The manufacture of cast iron consists, as is well known, in smelting the ore, in a blast furnace. The ore is in the form of oxide of iron, but during the process of combustion the oxygen is removed from the ore, which becomes carburetted, or charged with carbon, the iron so charged falling to the bottom of the furnace, and it is then run out into cast or pig iron, containing practically all the iron and phosphorus that may be in the ore, silicon to the extent of from 0·25 to 3 per cent., and some of the manganese and sulphur. Almost all the iron in England is made by the hot-blast, which extracts the maximum quantity of iron from the ore, but a few cold-blast furnaces are still at work for the highest class iron. As we all know, cast iron, while hard, strong against compression, and not devoid of elasticity, has, as compared with wrought iron, little tensile strength, no ductility, cannot be welded, and is liable to break when subjected to sudden shocks or blows. The greater the amount of carbon, the more fusible is the metal; after the carbon is expelled the metal no longer melts when subjected to a white heat, but becomes pasty and malleable, and in this condition has the valuable property of welding. Wrought iron is therefore decarburized cast iron, and differs from it in its mechanical structure. The decarburizing of the iron is performed by what is known as the puddling process, which also removes almost all the silicon, phosphorous, manganese and sulphur. A few cwts. of pig iron are placed in small furnaces accessible by doors to the workmen, who stir up and manipulate the white-hot pasty metal and add a small amount of oxide of iron. The carbon is oxidized, and escapes as carbonic oxide gas, which burns away in flame. The other impurities are oxidized and pass into the slag. The pasty lumps of iron are taken from the furnace to squeezers, which rid them partially of cinder; they are then pounded under heavy tilt or steam hammers and rolled into bars. These puddled bars, as they are called, are not yet serviceable as bar iron, as they are rough, not yet sufficiently homogeneous, and do not possess the tensile strength and toughness which further working will give them. Most English pig iron contains from ½ to 3 per cent. of phosphorous, and if any considerable quantity of this were left in the wrought iron, it would be cold short, or brittle when cold. But the process of puddling, when properly performed, eliminates, as just stated, most of this, namely, from 80 to 90 per cent. of what was in the cast iron. The manufacture of puddled bars forms a distinct stage in the process of making wrought iron, the bars being sometimes sold to those who continue the process, but generally the finishing is done at the same ironworks. Puddling is one of the severest forms of manual labour, and one of the indirect benefits of the steel inventions is that this labour is being superseded, there being in this country now about 3,000 less puddling furnaces than in 1865. The bars are sheared into lengths of one or two feet, bound up in a bundle or pile, and being again brought to a welding heat, are again pounded by hammers into homogeneous lumps or blooms, which are then passed many times through flat rolls to make them into plates, or through grooved rolls for angle, ⊤, or the numerous other shapes of bar which are needed. The more the iron is worked the better it is; sometimes scrap iron is mixed up in the pile, and for high quality iron the pile consists of nothing but scrap iron. The iron when thoroughly rolled in this manner really consists of numerous pieces welded together by squeezing, the iron becoming fibrous, and stronger in the direction in which it has been rolled than across it. The real substance of the iron may be seen by subjecting a piece to the action of acid, or by examining a fragment, such as a piece of chain, which has lain long in the sea. The cinder, or other foreign substances, which were in and between the iron have disappeared, and the sinewy fibre of the iron is revealed. The rolled iron has a tensile strength with the grain—that is, in the direction in which it has been rolled—of 20 to 25 tons, and across the grain of 16 to 18 tons, and may be beaten, twisted, welded, and otherwise dealt with.

At Lowmoor, at Farnley, and a few other works in the neighbourhood of Leeds, a peculiar iron is made known as best Yorkshire iron, and it may be referred to here as it comes into close competition with steel. It is made from ironstone remarkably free from deleterious constituents; it is smelted with coal very pure and free from sulphur in a cold-blast furnace which leaves in the dross all but the best of the metallic iron; it is again melted in small open-hearth fires, by which process the iron is still further refined; and then, by puddling, followed by elaborate hammering and rolling, plates and bars of the highest quality are produced. This iron, while having only the same tensile strength as the best iron rolled from scrap, is remarkably ductile and tough; it is used for boiler plates, which have to be subjected to severe bendings, and in the shape of bars is used for the drawhooks and drawbars of railway carriages, for the best rivets, and for the most important smith's work. This iron costs double the price of ordinary iron, but is still preferred to steel by many engineers for boiler plates; while for smith's work there is as yet hardly any attempt to supersede it by steel.

Although the subject of this lecture is Steel, I have ventured to occupy your time thus far in describing the manufacture and difference between cast and wrought iron, though these are either well known to you or fully described in text books. But it is necessary, or at any rate convenient, in this way to lead up to the subject of steel, as I desire to accentuate the differences between it and iron.

Steel was made up till about the year 1860 by adding to wrought iron a certain quantity of carbon, by heating bars of malleable iron (by preference high quality Swedish bar iron) in contact with powdered charcoal until the iron acquired a sufficient amount of carbon. The product is known as *blistered* steel from the appearance it presents, and it is then either made into *shear* steel by further processes, by piling together pieces of it and hammering it, as in making wrought iron blooms; or is made into *cast* steel, by re-melting in crucibles and running it at a certain temperature into a mould of the desired form. It is from cast steel that chisels and other cutting tools are made. The quality of crucible steel is infinitely varied according to the purpose for which it is required, and there are still inherited secrets at Sheffield in regard to the mixing, melting, and other processes. The hardness of the steel depends on the amount of carbon it contains, very hard steel for cutting tools having ten or twelve parts per 1,000, and soft ductile steel as little as five parts of carbon per 1,000. It is not, however, my purpose to-night to deal with crucible steel, about which there is nothing of interest that cannot be found in various metallurgical text books. It is to be noted then that up till about 1860 the transformation of iron into steel, whereby its tensile strength was about doubled, and other valuable properties imparted to it, could only be effected by first converting it into wrought iron by a laborious process of puddling, and then in small quantities converting it into steel. When malleable iron was selling at £8 per ton, steel cost £60, and upwards. This high price forbade its use for the many structural purposes for which wrought iron was employed, but many attempts had been made before that date by Mushet and others to simplify the processes of steel making, by regulating the amount of carbon added to wrought iron.

In 1856 Bessemer took out his first patents for transforming crude iron into malleable iron or steel, by forcing a blast of air into molten cast iron until the continued contact with the oxygen in the blast burnt out enough of the carbon and silicon to leave just enough carbon to make steel of it, or by entirely removing the carbon to leave it in a condition of malleable iron. When the first of these conditions was reached the molten metal was poured into an ingot mould, and was then available as steel. There were found, however, to be certain difficulties in making steel in this way. To rid the iron of just so much carbon, and no more, requires skilful and continued testing; and further, it was found that as the larger part of the manganese, if there be any in the iron, is burnt away in converting the steel made from it, unless the original iron contained a considerable amount of manganese so as to leave enough, it was not forgeable, and was liable to crack when rolled or hammered. There is plenty of iron in the world containing enough manganese, but there does not happen to be much of it in English iron, or in the iron of those countries having suitable coal and other advantages. For unless the pig iron contains enough manganese to leave from 1 to 3 parts per 1,000 in the metal after it has been subjected to the Bessemer blast, the steel will not be ductile or forgeable. For these reasons it is only in a few places that the iron is sufficiently manganiferous for the original or "direct" Bessemer process to be used in this way, and indeed the quantity so made is too small to need consideration. The Bessemer steel of the world, and six million tons or more of it are produced annually in Europe and America, is now made by blowing out *all*, or practically all, the carbon from molten cast iron, and then giving back to it, as I shall presently describe, a sufficient amount of carbon and manganese to produce a steel of the desired grade.

Naturally during the earlier years of steel making continued improvements were made in the details of the apparatus employed and in the process itself, but the following is a description of what is taking place every day in the Bessemer steel works of the world—works in each of which from 1,000 to 4,000 tons of ingots are produced per week with a routine of regularity now oft repeated, but from its simplicity and beauty never likely to become dull or uninteresting.

In most cases pig iron is melted in cupolas of the ordinary type, and then run into the converter vessel; but in a few instances, in England and elsewhere, this process of melting is saved, the product of the first smelting in the blast furnace being run direct into the converter, or conveyed thither in large vessels or ladles, instead of being first run into pig iron, which has to be re-melted. This simplification has not been so universally adopted as was expected, because it is not always possible to maintain such perfect regularity in the first melted iron as in the second. Pig iron run from the same melting of a blast furnace not being all alike, it is convenient to select for the second melting pigs of a suitable kind. The molten metal, however, whether from the blast furnace or the cupola, runs into the Bessemer converter, which is of the form shown in *Fig.* 1, *Plate* I. This vessel is of wrought iron with a suitable lining, and is of a capacity to hold from four to ten tons. The vessel having been turned to a convenient angle to receive the molten iron, and then again tilted up so that the flames and gases pouring out of the nozzle shall be discharged upwards, the blast is then turned on, and enters the converter by numerous tuyere holes in the bottom, *Figs.* 1 and 2, *Plate* I. The blast is a powerful one as compared with the pressure in the blast of a smelting furnace, the former being equal to a pressure of twenty to thirty pounds per square inch, the latter to about four pounds per inch. The blast is maintained for a period of from six to twenty minutes, according to the composition of the metal, and the intensity of the blast, and during its continuance a stream of sparks and blazing gases, like the most brilliant fireworks, pours out of the nozzle. All this time the metal is in a state of violent ebullition, and the carbon in the form of gas is being consumed. Suddenly the flame becomes duller, the carbon and silicon having been consumed, and the experienced workman, at this the proper moment, stops the blast. The metal is now entirely decarburetted, and if poured at this stage into a mould, it would, if it had enough manganese in it, be of a strength and character like wrought iron, but more ductile and without its fibre. But the object is to produce steel, and therefore a little molten spiegeleisen, or ferro manganese, containing carbon and rich in manganese, is added, and at once becomes mixed with the still bubbling metal, which is now steel, and is at once poured into a series of ingot moulds. The adding of the carbon and manganese is important, and interesting enough to require further explanation.

I stated above that a certain proportion of manganese was necessary to ensure toughness and forgeability in the steel. Iron ore rich in manganese (and some of it is so rich as to be considered as manganese ore with more or less iron in it) is found in various parts of the world. The richest kind contains as much as 70 per cent. of manganese and has a high value for various chemical purposes; but the lower grades, at any rate manganiferous iron ores having between 10 and 50 per cent. of manganese, are used for making spiegeleisen and ferro manganese. The two terms are somewhat misleading. The first, spiegeleisen (a German name given because of its bright, glassy appearance), contains about 4 per cent. of carbon, from 10 to 30 per cent. of manganese, and little else besides but iron. Ferro manganese is merely a richer or more concentrated combination of manganese, the latter ranging from 30 up to 70 and even 80 per cent. There are many makers of spiegeleisen, and some steel works make their own supply, but the richer ferro manganese requires special skill and experience to make it, and there are only about half-a-dozen manufacturers of it in Europe. The spiegeleisen is generally added in a molten condition, being melted in a small furnace close to the converter, and having been weighed, either before or after melting, is poured into the converter as just described. If ferro manganese is used it is inserted cold or only red hot. The quantity of metal in the converter and its chemical composition being exactly known, as well as that of the spiegeleisen or ferro manganese, the quantity of concentrated carbon and manganese necessary to qualify the whole can be accurately calculated. So skilful has the manipulation become that steel ingots with any prescribed percentage of carbon are made to order to afford the ductility or hardness suitable to the purpose in view, and with very trifling variation. Steel made by the Bessemer process for rails and wheel tires has from 0·3 to 0·5 per cent. of carbon. But for what is called mild steel, such as is used for boiler plates or other purposes, when ductility rather than extreme strength is needed, the quantity of carbon in the steel ranges only from 0·10 to 0·18 per cent.

Having thus briefly described the Bessemer process, without attempting to enter into the more minute chemical differences of the steel, or the mechanical details of the apparatus, I will now turn to the other modern system of converting iron into steel. As steel stands, in regard to carbon, between cast iron, which has so much, and wrought iron, which has so little, it is not surprising that attempts have been made to produce steel by mixing the two, and during the last 100 years various methods of doing this were tried. Owing, however, to the small chemical knowledge, and to the difficulty of constructing furnaces to smelt considerable quantities at a high temperature, none of these attempts were successful, and even in a few cases where steel was so made the results were less advantageous than those of carbonizing wrought iron in a crucible, as already described. So matters remained till the time of the Bessemer inventions. But contemporaneously with these the brothers William and Frederick Siemens, German scientists naturalised in this country, were conducting experiments with a view of treating metals in reverberatory gas furnaces instead of by the direct application of coal fuel. Their studies were not exclusively directed towards steel making, but generally towards an economy in fuel, and its more equable application to all metallurgical purposes when intense heat was required.

In 1861 the Siemens brothers took out their earliest patents for their plan of constructing reverberatory furnaces, and pointed out their suitability for steel making; but their patents for what is now generally known as the open-hearth process were obtained some years later. This process utilizes two main ideas: one, that steel can be best made by the decarburization of cast iron by the admixture of iron in a malleable state; and secondly, that by using an inflammable mixture of heated gas and heated air as fuel, a great economy can be obtained as compared with the direct use of coal or coke in contact with the metal.

The first part of the apparatus is a gas producer, which may be at a considerable distance from the steel making furnaces. The gas is made, not in horizontal retorts, as is usual at an ordinary gas works for illuminating gas, but in vertical furnaces, of which numerous kinds have been devised, of which the following (taken from Percy's *Metallurgy*) may be taken as an example.

The gas-producer consists essentially of a fire-grate, on which a thick layer of fuel is maintained, so that the combustible part of the fuel is converted mainly into carbonic oxide, hydrogen, and hydro-carbons, which are carried forward through suitably arranged flues to the furnaces where they are burnt.

The gas-producers are constructed, partly of fire-bricks and partly of ordinary bricks, preferably in blocks of four each, and are built below the surface of the ground, so that the roofs of the producers are on a level with the surface.

A block of four gas producers is shown in vertical sections, longitudinal and transverse, in *Plate* II.,* which the following description of the reference letters will explain:—

a a. Covered hoppers for charging the grate with fuel: they should always be kept filled: the covers prevent the escape of gas from the producers during charging.

b b. Weighted levers attached to flaps which form the bottoms of the hoppers.

c c. Inclined planes, made of cast iron plates covered with fire-bricks, upon which the fuel falls, and along which it descends: the inclination of the planes and the arrangement of the grates and fire-bars are varied, according to the nature of the fuel used; that shown in the 'section at A B' and in the

* I am indebted to my friend Mr. C. W. Siemens for the drawings from which the accompanying lithographs are taken, and for much of the information upon which this description is founded.

'section at E F' is intended for caking, and that in the 'section at C D' and in the 'section at G H' for non-caking coal.

d d. Horizontal flat bars laid in steps so as to form a grate.

e e. The fire-bars.

f. A pipe for supplying water to the space below the fire-bars, where it evaporates; the steam thus produced passes through the fuel in admixture with air, which in this case has free access to the space below the fire-bars. When water is used in this manner in working two producers which face one another, the water may be conveyed from one producer to the other, by means of a channel, *u*, communicating between the two.

g. A steam-blast which may be used instead of the water supplied by the pipe *f*: by means of the blast a mixture of steam and air is blown into the producer.

h. A hole in the side of the producer through which the steam blast enters it.

i i. Shutters at the back of the grate, which is enclosed, when the steam-blast is used, to prevent the escape of the blast.

k k. Holes in the arched roof of the producers, fitted with covers and small stoppers, for testing the gas by allowing it to escape and lighting it, and for admitting iron bars to loosen the fuel and detach clinker.

l l. Flues through which the gas passes off from the separate producers.

m. The uptake, constructed of second quality fire-bricks braced with iron rods, into which the separate flues from the four producers open.

n. The cooling-tube of wrought-iron, 20 feet or more in length, and falling 6 inches from the uptake end to permit of any condensed liquids running off at the lower end.

o. The downtake, also of wrought-iron, opening into the 'main gas-flue to furnaces.'

p. The tar well.

r. A damper for cutting off the block of four producers from the main gas-flue.

s s. Dampers at the top of the flues, *l l*, for isolating each separate producer.

t t. Doors, which are kept closed by their own weight, for obtaining access to the uptake and cooling tube when required for cleaning.

The mixture of gases on leaving the producers has a temperature varying between 300° and 430° C., and this initial heat is made available for producing a *plenum* of pressure. The heated gases are made to rise about 20 feet through the uptake, *m*, and are then cooled in the wrought-iron tube, *n*, to about 100° C. (whereby they gain about 50 or 60 per cent. in density), or to a still lower temperature: this gives a preponderating weight to the descending column in *o*, urging it forward to the furnace; thus, too, an excess of pressure (of from one to two-tenths of an inch of water) over that of the atmosphere is maintained in the main gas-flue, whereby indraughts of air are prevented, which would tend to produce explosive mixtures in the flues. The cooling of the gases is not a waste of heat, as there is no gain in sending them hot to the regenerators; for at whatever temperature the gases may enter them, their final temperature just before combustion is always nearly the same as that of the hottest part of the regenerators.

Mr. W. Hackney, who has had great experience in the management of regenerative gas-furnaces, informs me that at the Landore Works some of the cooling tubes are several hundred feet long, and that the furnaces are found to work better, the greater the length of the cooling tubes; since the gases become more thoroughly cooled, and consequently a greater *plenum* of pressure is produced, and a larger proportion of the aqueous vapour which the gases contain is condensed.

An excess of pressure in the gas-flues might also be obtained by placing the producers at a lower level than the furnaces, but this is rarely practicable; moreover, unless the gases were cooled, they would pass through the reversing valves at a temperature too high for the convenient working of the valves.

The action of the gas-producer in working is as follows:—the fuel descending slowly on the solid portion, *c*, of the inclined plane, becomes heated and parts with its volatile constituents—hydrocarbons, water, ammonia, and some carbonic acid—which are the same as would be evolved in a gas-retort. There now remains from 60 to 70 per cent. of carbonaceous matter, inclusive of ash, to be utilized: this is accomplished by the slow current of air entering through the grate, *d*, which produces a regular combustion immediately upon the grate. The carbonic acid formed passing through a layer of incandescent fuel takes up another equivalent of carbon, forming carbonic oxide, which passes off to the furnace. For every cubic foot of combustible carbonic oxide thus produced, 2 cubic feet of incombustible nitrogen pass also through the grate, tending greatly to diminish the heating power of the gas. But not all the carbonaceous portion of the fuel is volatilized on such disadvantageous terms; for either the water below the fire-bars, or the steam-blast, *g*, supplies steam, each cubic foot of which in traversing the layer of heated fuel becomes decomposed into a mixture consisting of one cubic foot of hydrogen and nearly an equal volume of carbonic oxide with a small amount of carbonic acid. Thus one cubic foot of steam yields as much inflammable gas as five cubic feet of air; but the one operation is dependent on the other, inasmuch as the passage of air through the fire is attended with the evolution of heat, whereas the production of inflammable gases from steam by decomposition is attended by the consumption of heat; and further, the necessity for the maintenance of a strong red-heat, which is required to convert carbonic acid into carbonic oxide by contact with carbon, limits the quantity of steam which can be used.

Since the supply of air to the grate depends upon the withdrawal of the gases evolved from the producer, the production of gas is entirely regulated by the demand. By means of the dampers, *s*, the production of gas may be arrested completely for some hours, without deranging the producer, which will begin work again as soon as the communication with the furnaces is re-established. The gas, however, is of a more uniform quality when there is a continuous demand for it; and for this reason, as well as to be able to supply an extra amount of gas to any furnace requiring it, it is best to supply several furnaces from one set of producers, and to keep the latter constantly at work.

It is necessary to remark that the cost of the gas is very different to that of the gas used for lighting purposes. Instead of the special cannel, or other coal of high illuminating power, coal is chosen for its calorific qualities, and this is cheaply obtained in the districts where steel is made. Further, there is little of the expense of purifying and distribution necessary with illuminating gas, and there are no intermediate profits to be paid by the user. While, therefore, the selling price of the illuminating gas in this country ranges from 2s. to 5s. per 1,000 cubic feet, the gas for steel making costs only from two to five pence.

There are various shapes of open hearth furnaces, but the illustration on *Plate* III. may be taken as a general type.

The general arrangement of the furnace is described by Dr. Percy as follows:—There are four regenerators, of which two, intended for the passage of air, are larger than the other two, for the passage of gas. The regenerators are placed below the reheating chamber, and are worked in pairs consisting of one larger and one smaller regenerator. Each pair communicates with one end of the reheating chamber.

In front of the furnace is a pit, which is covered over with cast-iron plates, supported at intervals by brick arches : there is a grating in the plates for the admission of air to the pit. In the pit are two sets of valves for regulating the supply and directing the flow of gas and of air, respectively, into the reheating chamber, through each pair of regenerators alternately. From the reheating chamber the products of combustion pass through and heat the pair of regenerators which, at the time, are not in use for the admission of gas and air. When this pair of regenerators has become heated by the passage of the products of combustion, the direction of the currents is reversed, and the gas and air are passed through the heated pair of regenerators and enter, at a high temperature, the reheating chamber where combustion takes place.

A gas reheating furnace is shown in vertical sections, longitudinal and transverse, in *Plate* III., to which the following description of the reference letters applies :—

a a'. Two regenerators, through each of which the air for combustion of the producer gas, and a portion of the heated products of combustion, pass alternately. They are fire-brick chambers, filled with walls of fire-bricks built crosswise, all the bottom courses or rows being parallel to one another, with small spaces between each two courses, the second series of courses being set in a similar manner but at right angles to the first, the third at right angles to the second, and so alternately to the top : by which means a large surface is exposed for absorbing or yielding heat, from or to gases passing through the regenerator.

b b'. Two similar regenerators, through each of which the producer gas and the remaining portion of the products of combustion pass alternately.

c. The chamber for reheating the iron or steel forgings.

d d. Ports in the two end walls of the reheating chamber, communicating, by means of flues, with the two regenerators, *b* and *b'*.

d d' Similar ports, communicating with the two regenerators, *a* and *a'*.

e. A pipe in connection with a flue leading from the main gas-flue (*Plate* III.) to the regulating valve, *f*. There is a short branch pipe leading from this flue to the surface of the ground, with a stopper in the cover to it, for testing the gas, to ascertain that it burns steadily, before it is admitted to the regenerators; otherwise an explosion would be liable to occur, either from an explosive mixture being turned into the furnace, or from the gases admitted being too poor to burn well, and consequently going out and re-igniting with an explosion.

f. The valve for regulating the supply of gas to the reheating furnace.

f'. A similar valve for regulating the supply of air, which is admitted through a grating in the pit plates, as above mentioned.

g. The reversing valve for turning the current of gas into the regenerators, *b* and *b'*, alternately.

g'. A similar valve, for turning the current of air into the regenerators, *a* and *a'*, alternately.

h h. Flues leading from the valve, *g*, to the regenerators, *b* and *b'*, and *vice versâ*.

h' h' Flues leading from the valve, *g'*, to the regenerators, *a* and *a'* and *vice versâ*.

k. The chimney-flue, which is placed in communication with the regenerators, *a* and *b*, and with *a'* and *b'*, alternately: the valve, *g*, regulating the communication with *b* and *b'*, and the valve, *g'*, with *a* and *a'*.

l. The main flue, leading from the chimney-flues of several furnaces to the chimney.

m. The furnace-damper, near the entrance to the chimney-flue, *k*. By means of this damper the pressure in the furnace is regulated, so as to draw the flame away from the working door when necessary. Close to the damper small buttresses, so inclined as nearly to meet at the bottom, are built against the side walls of the chimney-flue in order to contract the lower part of the flue at this point, by which means the draught through the furnace can be regulated by the damper with considerable precision.

n. Screw standard for raising and lowering the damper, *m*.

o o'. Screw standards in connection with systems of levers, shown in the 'section at G H,' for adjusting the valves, *f* and *f'*.

p p′. Levers for reversing the valves, *g* and *g′*. These valves should be reversed nearly but not quite at the same moment.

r r. Doorways, leading from the pit in front of the furnace into the separate regenerators. These doorways are filled in with two thicknesses of brickwork, the inner one of fire-brick, and the intervening space is filled with sand to render it air-tight.

It will be seen that the air enters the reheating chamber *above* the gas; from its greater specific gravity it sinks through the latter, so that a perfect mixture is formed and complete combustion ensues. The products of combustion are stated to become reduced in temperature from 1400° C. on entering the regenerators to 150° C. on leaving them.

The flame of the furnace may be made oxidizing or neutral at will by means of the valves, *f* and *f′*, which regulate the proportion of gas and air admitted to the reheating chamber, *c*; also, by means of the furnace damper, *m*, the balance of pressure between the reheating chamber and the external atmosphere may be varied as required: the best results, however, are obtained when there is a slight excess of pressure in the furnace above that of the external air. Thus the whole working of the furnace is completely under the control of the workman, who, by taking proper advantage of the means at his disposal, can prevent the iron from being burnt, and so effect an important economy in addition to the saving in fuel. Experience has proved that 3 cwt. of small coal are required to heat a ton of steel ingots, and 6 cwt. of the same fuel to heat a ton of iron, to the forging point, or about half the consumption of an ordinary furnace doing the same amount of work.

A very high temperature can be attained in the regenerative gas-furnace, owing to its power of accumulating heat, without resorting to cutting flames or an intense draught. There are, however, two causes which limit the accumulation of heat: one is the fusibility of the materials composing the bed, sides, and roof of the furnace; the other is the attainment of the temperature, at which combustion of the fuel altogether ceases to take place, owing to the interference of dissociation. The phenomenon of dissociation has been previously referred to; its further consideration is beyond the scope of this work.

The great accumulative power of the regenerative gas-furnace is well shown in the furnace for the melting of steel in crucibles: by its means 24 pots, each containing 56 lbs., make 5 charges of "mild steel"* in the 24 hours with a consumption of 25 cwt. of small coal per ton of steel, including that used for the pot-annealing stoves; whereas in the old furnaces $2\frac{1}{2}$ to 3 tons of coke are required to melt a ton of steel in similar crucibles.

A still greater saving of fuel has been effected with these furnaces in Mr. C. W. Siemens' process for the production of steel from pig-iron and ore in the open-hearth regenerative gas-furnace. In this process 6 tons of pig metal are completely decarburized by ore, and after the addition of ferro-manganese or *spiegeleisen* the charge is run into ingot-moulds. A ton of mild steel is thus produced with a consumption of 14 cwt. of coal. This great economy is mainly due to the power of accumulating heat possessed by these furnaces.†

* This term is applied to steel approaching to wrought-iron in composition.

† A description of this process, which has been carried out on a large scale at the works of the Landore Siemens' Steel Company, near Swansea, is contained in a paper read by Mr. Siemens before the Chemical Society of London in March, 1873.

Mr. Siemens has favoured me with the following information regarding the application of the regenerative gas-furnaces to the manufacture of glass :—"In the manufacture of glass a very notable saving of fuel has been effected.

"The first glass-pot regenerative gas-furnace was erected by Messrs. Lloyd and Summerfield at Birmingham in 1861 ; and at the meeting of the Institute of Mechanical Engineers at Birmingham, in 1862, Dr. Lloyd stated that the average expenditure of fuel in the year was 35 tons per week in the old furnaces, and 16 to 17 tons in the new : this furnace, which is used for making flint-glass, is still in satisfactory operation.

"For some time past Messrs. Siemens have directed their attention to the melting of glass in open tanks, so as to dispense with the use of glass pots entirely ; these proving a success at the works of Messrs. Powell, Bristol, and elsewhere, the next step was to render the process of glass manufacture continuous, so as to save the time wasted in melting the materials. These improvements culminated in the 'continuous-working tank furnace.' This furnace consists of an oblong basin, with an arched roof, and is divided into two unequal compartments, which freely communicate below a bridge ; at the end of the larger compartment is the charging door, and along its sides are the gas and air ports of the regenerators; the combustion of the heated air and gas taking place here, a zone of intense heat is formed, in which complete fusion takes place, the molten glass flows under the bridge to the smaller compartment, or 'working end,' where are placed the doors through which the workmen gather the glass for blowing : thus the materials are continuously charged in at one end whilst the glass is being constantly removed from the other.

"The results obtained by the above-mentioned furnaces are exceedingly important. At Aniche, in the north of France, an 8-pot regenerative gas-furnace consumes $2\frac{1}{2}$ kilogrammes of coal per kilogramme of manufactured glass Several of the continuous-working tank furnaces are in operation at Mr. Frederick Siemens' glassworks at Dresden, where the details of the arrangements have been chiefly worked out. At Decize, in Belgium, a continuous-working tank furnace requires only $1\frac{1}{3}$ kilogrammes of coal per kilogramme of finished window glass, whereas an ordinary Belgium coal furnace consumes $4\frac{1}{2}$ kilogrammes of coal in doing the same amount of work."

The process of steel making in the furnace is, as I have already mentioned, the combining together cast iron, which has too much carbon, with malleable iron, or steel; but there are variations in the process depending a good deal on what material is most conveniently available. The various modifications may be broadly divided into two, namely, the Siemens-Martin (Martin was a Frenchman and co-inventor), known as the pig iron and scrap process; and the second, the Siemens proper, known as the pig iron and ore process. The first of these, the pig iron and scrap, is used mainly in France. The beginning of the operation is making a fluid bath by melting the pig iron, and then adding malleable iron or steel scrap in the proportions of about 80 of scrap to 20 of pig iron. This mixture boils till the carbon is oxidized, and then it is run off into ladles, and the ferro manganese added. This process occupies about six hours.

With the pig iron and ore process the above proportions are reversed, about 80 per cent. of pig iron and 20 per cent. of scrap being mixed, and after this is well melted, hematite ore is added to oxidize the silicon and carbon in the bath, until the samples show that the proper quantity has been arrived at. This plan occupies about ten hours, and is preferable in England where hematite ore can be cheaply procured and where scrap is dear. At each operation of the open-hearth process from eight to fifteen tons of steel are produced, the weekly out-put by the pig iron and scrap process being about 200 tons, and by the pig iron and ore process about 120 tons.

One noticeable difference between the Bessemer and the open-hearth process is, that while the former occupies only about twenty minutes, the latter takes from six to ten hours. During the last hour of this longer period numerous samples can be taken to ascertain the quality of the bath, and if the process has been pushed a little far it can be brought back by adding a little cold cast iron. These facilities for testing and adjustment render the open-hearth process preferable in the opinion of many engineers to the Bessemer process for steel of very exact composition, such as is needed for springs and fine tools.

Basic Steel.—I have now described in a summary, but I hope for the purpose sufficient, manner the three great classes of steel—crucible, Bessemer, and open-hearth. The first of these, the crucible steel, needs no further attention from the point of view of this lecture; but in regard to the other two there is one important point not yet touched upon, and I have left it till now because it is common both to the Bessemer and the open-hearth processes. In describing how the amount of carbon made the difference between iron and steel, I mentioned that there were other ingredients which affected the quality. I have already referred to manganese. The other ingredients are phosphorous, silicon, and sulphur. The two last may be dismissed shortly, as this is not a chemical lecture. Little more than a trace of silicon remains in good steel, and any excess would render the steel too hard and brittle. Sulphur, if in excess, makes iron or steel red short—that is to say, brittle when hot.

The phosphorous, however, is a more serious enemy, and exercises so vital an influence on the whole steel manufacture of the world, as to need special attention in any consideration of the subject. When Bessemer had proved the correctness of his theory as to the decarburizing by an air blast, he found that he could not get tough steel because of the phosphorous, which was not eliminated as in the process of puddling. It was found that good steel must not contain more than 0·1 per cent.; with more than this it is too brittle, or cold short. As nine-tenths of the iron ore in Europe contains more phosphorous than would leave this maximum, and as, further, none of the phosphorous in the ore is removed either by the smelting or the converting, only certain descriptions, found in limited quantities, are fit for making steel by either the Bessemer or open-hearth processes just described. To Great Britain the subject is very serious, for although the Bessemer inventions were a great benefit to mankind, and to the users of steel here as elsewhere, the supremacy of this, the chief iron producing country of the world, was seriously damaged when it was found that none of the ore in Derbyshire, Staffordshire, Yorkshire, Lincolnshire, Northamptonshire, or Scotland was suitable for steel. The pig iron made in enormous quantities in the Cleveland district in North Yorkshire contains 1½ per cent. of phosphorous, Scotch iron contains about 1 per cent., Staffordshire pig from 1 to 2½ per cent. and Northamptonshire pig iron 1½ per cent. The rich hematite ores on the coast of Cumberland and North Lancashire, in the neighbourhood of Whitehaven and Barrow-in-Furness, are alone pure enough for steel making, and about three million tons per annum of this Bessemer ore, as it is called, have been mined during recent years. The pig iron made direct from it is worth about 10s. to 15s. per ton more than the ordinary English pig iron. Most of the Bessemer ore is sent direct to the steel works, where it is smelted and then converted, but a good deal is also made into pig iron by those who do nothing else, and this Bessemer pig is sold to steel makers in England, the Continent, and the United States. The quantity of ore which, from the small percentage of phosphorous it contains, may be called the non-phosphoric ore in the Barrow district is, however, quite insufficient; vast quantities have therefore to be imported from countries where it abounds, Spain, the island of Elba, and the north coast of Africa being the chief sources of supply. About three million tons were imported last year. As in England, so in America, most of the iron ore mined has too much phosphorous, and the significance of this is apparent when it is known that to the United States, a country abounding in iron, not less than a million tons of non-phosphoric iron ore were last year exported from Europe.

I have referred to these statistics to lead up to the description of a modified process of steel making, with which, doubtless, many of you are acquainted, and which is known as the Basic system of making steel from phosphoric iron. Although the ores imported from Spain and elsewhere are good in quality, and practically inexhaustible in quantity (though they are becoming dearer as the mining proceeds), and owing to the contiguity of the mines to the sea and low freights are delivered at English ports, where coal abounds for smelting, as cheaply as the Barrow ore, still it is a serious matter for this country to be dependent for its steel manufacture on a limited quantity of high-priced English ore and on a supply of foreign ore, which might be stopped or curtailed in time of war. The attention of metallurgists and chemists was therefore early directed to the discovery of a process by which ordinary English ores might be utilised ; and especially is this important in the inland coal and iron districts, where the manufacture of iron and steel is well understood, but where, owing to the burden of railway carriage, the imported ore would not be available.

In the years 1877 to 1880 patents were taken out by Sidney G. Thomas and Percy C. Gilchrist for a particular method of dephosphorizing iron, which has proved so successful as to entirely change the aspect of affairs just related. The essential part of the new process is the addition of some cwts. of lime per ton of pig converted, and the lining of the converter or furnace with a specially prepared form of lime. The process is described by the patentees in a paper read before the Society of Arts in 1882, as follows :—

"The Bessemer vessel is lined with magnesian lime, which has been previously subjected to an intense white heat, and so brought to a condition of density, tenacity, and hardness, as far as possible removed from the condition of the material generally known as well-burnt lime, and more closely resembling granite, or flint. Before the metal, which may be either melted pig iron or iron employed direct from the blast furnace without intervening re-melting, is run into the converter, from 15 to 18 per cent. of its weight of common well-burnt lime is thrown into the vessel. The metal is then introduced, and the charge is blown in the usual way to a point at which the ordinary Bessemer operation is stopped—that is, till the disappearance of the carbon, as indicated by the drop of the flame. The dephosphorizing process requires, however, to be continued for a further 100 to 300 seconds; this period of so-called after-blow, which would be prejudicial both to quality and yield in the ordinary process, being with phosphoric iron, under conditions permitting of the removal of phosphorous, that in which the great bulk of the phosphorous—down, indeed, to its last traces—is removed. The termination of the operation is shown by a peculiar change in the flame, and checked by a sample of the metal being rapidly taken from the turned-down converter, flattened under the hammer, quenched, and broken so as to indicate by its fracture whether the purification is complete. A practised eye can immediately tell whether or no this is the case. If the metal requires further purification, this is effected by a few seconds further blowing.

"The operation is thus, as will be seen, but little different from the ordinary Bessemer process, the differences that have been indicated, viz., the lime lining, the lime addition, and the after-blow, are, however, sufficient not only to enable the whole of the phosphorous, which would otherwise be untouched, to be completely removed, but further, the silicon, of which inconvenient and even dangerous quantities are occasionally left in the regular Bessemer process, is entirely eliminated, while at least 60 per cent. of any sulphur which may have been present in the pig is also expelled. It is found, too, that the once formidable phosphorous is of most substantial assistance in securing, by its combustion, the intense heat necessary for obtaining a successful blow and hot metal."

The old methods, where the converter or furnace is lined with ganister, *i.e.*, silica, is briefly called the acid-Bessemer, or acid-open-hearth. The new method is called Basic-Bessemer, or Basic-open-hearth, from the fact that the lining and matter added are basic materials. So far as the supply of Barrow ore extends, and so long as imported ore is cheap, the ordinary method of making steel will continue to be used as well as the Basic system, but the latter will be employed for converting ordinary English pig iron, having from $\frac{1}{2}$ to $2\frac{1}{2}$ per cent. of phosphorous. The extra cost of making steel in this way is about 6s. to 7s. per ton, which is saved in the cheapness of the phosphoric pig iron. The Thomas-Gilchrist invention was at first confined to the Bessemer converter, but since 1881 it has been applied with equal success to the open-hearth system of steel making in the Siemens and other analogous furnaces, and at the present time is so applied in England, France, Belgium, and Russia. It has been found that the Basic process of steel making is most successful in regard to mild steel, and for the extremely low-carbon steel, sometimes now called ingot-iron. While, however, the tensile strength of such low-carbon steel is only from 24 to 28 tons per square inch, as compared with the 28 to 50 tons of steel proper, yet the mild steel is not only stronger than wrought iron, which has only from 20 to 24 tons, but it is greatly superior in regard to ductility and elasticity, as will be further described in my second lecture.

Just as the Bessemer inventions inaugurated a new industry, and by reducing the cost of steel to one-eighth of its previous amount has saved annually millions of tons of coal and millions of money, so the invention of the Basic system has rendered available to the world whole districts of iron otherwise useless for the purpose of steel making. Even in Great Britain, where the Cumberland pure ores are at hand, and where Spanish ore is so cheaply imported—even in Great Britain, 260,000 tons of steel were made in 1886 by the Basic system ; in Germany nearly 900,000 tons were so made in the same twelve months ; the total in Europe being 1,300,000 tons. But outside Europe the future benefit of the combined Bessemer and Basic systems is incalculable. In America, in the states of Virginia and Alabama alone there is an abundance of coal and iron close to the surface of the ground, but still unworked, which probably equals the whole supply in these islands, and yet up to the present time hardly any non-phosphoric ore has been found, so that steel can only be made there by the Basic process. The same may be said of India, China, and Japan. In all these great countries the era of steel making from native materials is rapidly approaching, and to those who may be called upon to investigate their resources, and to render them available, much will depend upon these minute and subtle constituent differences.

The steel from the converter vessel, or from the open-hearth, having been poured into a series of ingot moulds placed in readiness, these solid ingots are ready to be hammered or to be rolled into rails, plates, bars, or other forms of steel between rollers as shown in *Fig.* 3, *Plate* I. If a casting only is wanted, the metal, instead of being run into an ingot mould, can be cast into any desired form. So far as the chemical composition is concerned, the process of steel making is completed, and the metal might forthwith be forged into a spring, a sword, or a knife, but the casting itself is not yet mechanically perfect —that is to say, if it were cast into a rail or plate, it would not be sufficiently tough. Steel has a far higher melting point than cast iron; it loses its fluidity earlier, and consequently risks of unsoundness, which in a slight degree attend all iron founding, are increased in steel. The metal solidifies rapidly, and not only becomes porous, or honeycombed in thick parts, but where there are great inequalities of thickness, thin parts having cooled first are liable to be strained by the further contraction of the thicker and still heated parts. I shall refer later on to the subject of steel castings; but dealing with the process of making steel into malleable forms, it is sought to close any porousness in the ingot by hammering and rolling it. Whatever may be done to an ingot in this direction, the original top end of the ingot, which was the more open and spongy part of it, is never as good as the lower part, and this continues through the intermediate process of the bloom to the rail which is rolled from it, and some portion—generally between six inches and eighteen inches, known as a "crop end"—has to be cut off as scrap. It has been attempted to remedy this by compressing the steel while still in a molten or semi-molten condition in the ingot mould. I saw this done at one of the largest steel works in America six years ago, and I believe it is still done there.

Compressing Steel by Steam.

A small steam-chest, A (*Plate* I., *Fig.* 4) supplied with steam from an adjacent boiler, is attached to the base of the crane X, which lifts the ingot moulds E, and from this chest hangs about six nozzles or branches, each with a few feet of rubber tubing, B. Directly an ingot mould has been filled with steel, a loose iron cap, D (*Plate* I., *Figs.* 4 *and* 5), having a $1\frac{1}{4}$ inch iron pipe, C. attached to it, is placed on the top of the mould and wedged down by a key or cotter, F. The iron pipe having meanwhile been coupled on to one of the rubber tubes, steam of about 85 lb. pressure is then admitted for about 40 seconds, and, pressing on to and permeating the molten mass, squeezes it down about 9 inches in a length of 6 feet 6 inches, the gases escaping at the bottom of the mould through slots or chases made there for the purpose. Porousness of ingot is almost entirely overcome, the degree to which the steel is solidified being ascertained by comparing a broken ingot with one which has not been compressed, and the improvement in quality remains till the rail is finished, a section of certain dimensions weighing more than if made of uncompressed steel. These results are as given to me by the inventors, but whether the advantages claimed of improving the quality were obtained appear doubtful as the plan has not been genenally adopted. Compression by rolling is the universal method. Sometimes the ingot, while still red hot from the mould, is placed in a furnace, or "soaking pit," as it is called, so as to retain, increase, or equalise its high temperature ; but sometimes the ingots are allowed to get cold, and are re-heated when wanted. They are first either hammered, or compressed between huge rollers, or passed through rough or corrugated rollers to be cogged, as it is called, the original form of the ingot being reduced in thickness and elongated. In the more modern rail mills the reduction of the ingot is performed in the early passages through the pair of rail rolls (*Plate* I., *Fig.* 3). The percussion of heavy steam hammers is by some steel makers and engineers considered much better than compression by rolls, and the hammering is sometimes specified as a condition of purchase. The ingot, after being hammered or squeezed, is known as a bloom. If, as is sometimes the case, it is too big for its ultimate purpose, the bloom is cut into lengths, each of which is rolled down into the rail, plate, or bar required. Throughout these processes, while it is sought to compress the steel and squeeze together any bubble-holes or coarse crystals, it is to be noted that the original homogenity of the cast ingot is retained. There is no piling together of separate pieces and squeezing and welding them together, as in making wrought iron, and for almost every purpose this is advantageous, but for some purposes loss of fibre is inconvenient.

At the beginning of this lecture I remarked that engineers might deem it outside their province to investigate very closely methods of producing the materials which they used, and that they might consider there was enough to be done in applying them. But I would say that an exception should, at any rate, be made in regard to steel. No one is in a position to appreciate the resources of this country, whether in the building of ships or bridges, or in the construction of railways, guns, or forts, who has not visited a modern steel works. They are of necessity large in extent and capacity, for the processes of manufacture can only be carried on cheaply on a large scale and in buildings which remind one of the Crystal Palace in their extent, but illuminated with the flames and sparks of the converter, and alive with the roar of the blast, with vessels teeming with molten metal, and huge masses of red hot steel being conveyed from one stage of manufacture to another, so that one is almost more reminded of some infernal pandemonium than of an industrial undertaking.

Apart from the metallurgical processes, the application of machinery to the movements of the materials and apparatus are of the largest and most modern kind. It is hardly too much to say that the Bessemer inventions could never have attained their present success had it not been for the aid afforded by hydraulic appliances, on the principle first introduced for other purposes by Sir William Armstrong. You are doubtless familiar with the principle of the hydraulic accumulator, and the transmission of power to cranes and dock gates, as in Chatham and other dockyards. In almost all steel works the entire apparatus is worked in this way. Upon a platform are arranged a series of levers, somewhat like those in a railway signal box. One or two workmen operate these levers, and by one, lower the converter to receive the molten iron; by a second, tilt it back to receive the blast; and again by a third, lower it to pour out the steel. Next, by the movement of another lever, huge ladles, or cauldrons, are brought to receive the stream of metal, and to take it in turn to the numerous ingot moulds. Then, when all the metal is cast, the red hot ingots are—still by hydraulic force—lifted from the moulds and laid upon wagons, to be taken to the reheating furnace, or the rolling mills. Locomotives, much smaller than those on the narrow gauge railway in Chatham Dockyard, are sometimes employed to haul these ingots; while in some steel works, when the smelted ore from the blast furnace is converted directly into steel without the intermediate casting into pig iron, larger locomotives will arrive from the blast furnace with ladles full of molten metal. In the after-processes, also, the application of automatic machinery is most ingenious and interesting. The blooms are moved to and fro at the rolling mills by hydraulic force, and having passed through the lower rolls, are lifted to the upper pair of three high rolls, so as to repass without the reversing of the rolls, as necessary in the less modern two-roller machines, and when, as in a rail mill, the rail is completely rolled, it is automatically straightened, and sawn into exact lengths.

One circumstance peculiar to steel making, amongst all manufacturing processes, is the similar nature of the methods in different countries. Steel making of the kind here described is so modern that the various methods have been almost simultaneously applied in the principal steel-producing countries. If England is ahead to-day in one part of the apparatus or process, the United States will be ahead to-morrow in another, and each invention is immediately available to all.

Five years ago I visited eight out of the then ten steel works of the United States, and had it not been for the numerous negro workmen, might have thought myself at Sheffield, or Barrow, or Workington. During this present year probably two million tons of steel rails will be made in the United States, and although the quantity here will be somewhat less, our greater production of ship and bridge steel will probably give as great tonnage as in America. So on the Continent of Europe—Krupp in Germany, Creusot in France, Cockerill in Belgium, and on a lesser scale at the steel works of Austria, Russia, Italy, and even of Spain, the same sequence of operations may be seen, changing in a few hours crude iron ore, brought direct from the mines, into the finest steel, with a less consumption of fuel, a greater simplicity of method, and at a cost considerably less than that for which the commonest wrought iron can be produced.

Steel Casting.

The production of cheap steel by the Bessemer process soon extended the use of steel castings to many purposes where strength and toughness are desired, and where, because of the shape, the rolling or forging from wrought iron or steel is difficult or impossible.

In ordinary cast iron a tensile strength of more than eight tons per square inch cannot be relied on, and owing to their very slight capacity of elongation, such castings are liable to fracture from sudden shocks. Steel castings direct from the converter will, however, have a tensile strength of twenty-eight tons, a limit of elasticity of thirteen to fifteen tons, and an elongation before fracture of twenty per cent. in two inches, and even when the steel has been hardened to a breaking strength of forty tons, the two-inch test pieces will elongate fifteen per cent before fracture. There are, however, difficulties in the way of casting steel, which limit its use and increase its cost. Owing to the removal of the carbon from the original cast iron, it is not so easy in steel as in iron to keep the metal in a fluid state during the process of casting. If, for instance, pigs of steel were melted in an ordinary foundry cupola, the heat would not be sufficient to retain the metal in a molten condition ; at the bottom of the cupola the steel would become pasty, and would run too sluggishly to fill a mould properly. The higher melting point of steel requires the blast of a Bessemer converter, or the intense heat of a reverberating furnace or crucible, to keep it fluid enough, and the metal has to be used quickly before the fluidity is too much reduced, and the sand moulds must be specially prepared to withstand the great heat. The gases in the molten metal prevent the metal solidifying, and unless there be free vent for their escape, bubbles or air holes in the heart of the casting will give it an open or honeycombed appearance when fractured.

In iron founding it is usual to cast what is termed a "head" to the metal, which can be cut off when it has served its temporary purpose of imposing a weight or hydraulic pressure on the molten metal in the lower part of the casting. This is also done in the casting of steel, but the rapid solidification of molten steel reduces greatly the advantage obtained. Steel may be rendered more fluid by an increase of silicon in the metal, but as this reduces the ductility of the castings, it can only be adopted when this quality is not of great importance. Indeed, if strength and ductility be assured, a user will do well in not objecting to trifling specks in the castings, which would be wanting in iron. The risks of unsoundness and hollow places of a honeycomb appearance are greatest in thick castings. To prevent this, endeavours have been made to compress the castings while in a molten or semi-molten condition. I have already described the manner in which ingots are compressed by steam. In this country the plan of the late Sir Joseph Whitworth, of applying hydraulic pressure, has been successfully used with cylindrical castings when great strength is required ; such castings, for instance, as are used for the hollow shafts of screw propellers, or for the compressed air cases in torpedo boats, where a concentrated pressure is needed ; also for the cylinders of baling presses, subjected to a working hydraulic pressure on the rams or pistons of 6,000 lbs. per square inch.

These plans of compressing steel are not easy of application to the various shapes that engineers require, and the skill of the founder is exercised to obtain, first, such a chemical mixture of the metal as will give the maximum fluidity with the necessary strength ; then to so shape the patterns, contrive the moulds, regulate the heat and manipulate the metal, as to obtain sound castings. The art of doing this has been brought far towards perfection, but the skill is as yet in but few hands.

In connection with this it may be mentioned that Bessemer converters on a small scale, say for making about one ton of steel at a time, may be added at moderate expense to the ordinary plant of an iron foundry, so that there is likely to grow up a wider experience of casting steel.

Although I have given precedence to this mention of steel castings, it is in rolled steel that the greatest advantages are to be found, and it is with these that my lecture to-morrow is chiefly concerned. In concluding the present lecture, I will briefly touch on the question of *testing* steel.

Testing.

The superiority of steel over iron depends, as will have been seen, on many minute points, both in the chemical composition of the materials and the mode of treatment; and as, moreover, there is little or nothing in the mere outside appearance of the metal when made, to denote its character, it is necessary to prove its quality by testing. This is more requisite in steel than in iron, because the possible differences are greater and the causes more subtle. In the case of iron, if a strength equal to twenty-four tons breaking strain be prescribed, with a certain amount of elasticity, the mere appearance of a fracture will show that it has been badly puddled and rolled, giving a very fair idea of quality; and even if inferior iron be substituted, such iron will stand three-fourths, or more, of the prescribed strain; but if steel be badly made, it may be so deficient in strength and elasticity as, if the mistake be undetected, to involve disaster in the use made of it. The risk must not, however, be over-estimated. At all steel works constant tests are being made to ensure the due course of manufacture. All the materials—coke, limestone, and iron ore—are analysed before entering the blast furnace, and the pig iron and fuel are similarly examined by the steel maker before he attempts to use them. A sample is taken from every charge of the Bessemer, or other converter, and is tested by bending or hammering, so as to show that there is the ductility due to its desired character of steel. As certain qualities are prescribed within narrow limits by the purchaser, the maker of steel has to assure himself of these qualities to avoid loss by the steel being rejected.

I shall presently allude to the testing of rails, and the users of other forms of steel—the boiler maker and bridge builder, or ship builder—all have means of testing to ascertain the character of the material before they expend labour upon it. But all these testings are performed as a subsidiary process by those whose main occupation is something else, and whose appliances are often of a rude kind, and who, having a direct pecuniary interest in the result, cannot expect that their testings will be accepted without question. Public testing laboratories have, therefore, been established, in which impartial persons examine the samples presented to them, and, without knowing what the specified qualities are, simply report on the facts disclosed, and leave the parties interested—the engineer, manufacturer, or others—to make their own deductions. Some months ago a very able and interesting paper was read before the Institute of Civil Engineers by Professor Kennedy, on "Engineering Laboratories," and to that paper, with the discussions upon it, fully reported in the volume of Proceedings about to be issued, I would refer you for a fuller account of the apparatus and methods than I can give you here. The first laboratory of a public nature was that established in London by Mr. Kirkaldy, about thirty years ago, and his was followed by that of Professor Kennedy, at University College, in 1878, and probably nine-tenths of the public tests of iron and steel used in the rolling stock, bridges, and roofs of the English, Colonial, and Indian railways during the last five years, have been made at one or other of these places. For Government work there are testing machines at Woolwich Arsenal, here, also, at Chatham, and one has been recently established at Cooper's Hill Engineering College, where the testing for the Indian State railways is now carried on. The machine used by Mr. Kirkaldy has a nominal force of one million pounds, or four hundred and forty tons; but I believe two hundred tons is seldom exceeded. Professor Kennedy's machine is less powerful, only giving fifty tons, but this has proved enough for the purpose. These machines can be used either for tensile or compressive strains, applied longitudinally or transversely to the samples, and there are special appliances for measuring torsional strains. The samples presented for testing must, of course, be of such moderate size as will allow of fracture by the power of the machines. For convenience, and to allow of easy comparisons between different samples, certain sizes of test pieces are cut out of the plate or bar. A usual form and size of test piece is shown in *Fig.* 4, *Plate* IV. The wide ends form a convenient grip for the machine, and the part where the fracture is to take place is generally from one inch to two inches wide, according to thickness. If cut out of rails or tires, round pieces, half-an-inch to one inch in diameter (*Fig.* 7, *Plate* IV.) are substituted. When broken, these pieces seem elongated, as in *Fig.* 8, *Plate* IV. Some engineers still use what is known as the old Woolwich test piece, having a sectional area of one-quarter of a square inch. In specifying the quality of rolled steel, three things are generally prescribed: first, the tension that the metal must bear before fracture; second, to show the ductility, the percentage of elongation before fracture; and third, the reduction in sectional area at the point of fracture. The strain is very gradually applied, and sometimes after the metal has stretched a certain distance the strain is relaxed, to ascertain if the test piece will return. The limit of elasticity is very high in steel, a medium quality capable of withstanding thirty tons before fracture showing permanent set only at seventeen to eighteen tons. In regard to the tensile test, the piece operated upon may be of any convenient length, but in prescribing the percentage of elongation before fracture, it is necessary to specify also the length of the test piece, for when the strain comes on the steel, the softest place yields first, and the sectional area being there diminished, the increasing strain tells there the most, and the bar breaks at that point before the rest of the piece has an opportunity of stretching. Therefore, as the most of the stretch occurs at one place, it bears a higher proportion to the whole length in a short piece than in a long piece. If, therefore, a piece five inches long between the shoulders elongates thirty per cent. before fracture, a piece of the same steel ten inches long would probably not stretch more than twenty-four per cent.; while, on the other hand, a piece two inches long would stretch forty-five per cent. For further particulars on this point I would refer you to a paper on the form of test pieces in vol. lxxvi. of the *Proceedings of the Institute of Civil Engineers*, The greater the tensile strength the harder the steel; so that a certain maximum of strain is specified, according to the purpose in view.

I shall refer in my next lecture to the special qualities deemed suitable to rails, tires, boilers, and bridges, and also to what may be called the workshop tests, or actual manipulations of the steel, which are prescribed to confirm or correct the conclusions derived from the laboratory tests. In some cases engineers not only specify the mechanical tests which are to be borne, but stipulate by what process the steel is to be made, and also the chemical constituents of the steel, especially as to the percentage of carbon. The expediency of this is, however, very doubtful, and eminent engineers hold different opinions about it. There are variations in the practice of steel makers, whose materials—ore, pig iron, fuel, etc., vary, and it gives them freer scope if only the results are sufficiently defined, and each maker left to get it as he deems best. But while the testing pieces cut out of the actual rail, plate, or bar may reveal to those conversant with the matter almost as fully as a chemical test the percentage of carbon and the freedom from phosphorous, this is not the case when partly manufactured steel is purchased, such as blooms and billets, and for these the amount of carbon and phosphorous are prescribed, and in many cases, generally in purchases from abroad, an analysis, signed by a responsible chemist, has to accompany the invoice of the seller. Sometimes the purchaser prescribes the system of manufacture —he may demand crucible steel for tires, or open-hearth steel for boiler plates ; or, while allowing steel made in the Bessemer converter, may stipulate for the use of non-phosphoric ore, and so exclude the Basic process. While, however, for the majority of cases it may be unnecessary for the purchaser to investigate the chemical constitution of the steel if the mechanical tests prove satisfactory, it might be of considerable service if from time to time the broken test pieces were analysed by the chemist, so as to obtain a series of records of what minute variations in the analysis were associated with certain mechanical results.

There is still another process of investigation which is likely to be adopted in the examination of steel, namely, that by the microscope. There are still circumstances in regard to steel not thoroughly understood, and among them is the change of structure which occurs, not only by what is known as the fatigue of metal from oft repeated strains, but to the curious recovery, or at any rate change, after a period of rest. Bauschinger, the eminent German scientist, is at present the authority by whom investigations of this sort are most likely to be made.

LECTURE II.

HAVING in my first lecture described the manufacture of steel, particularly in regard to the differences between steel and wrought iron, we have now to consider how the character of this steel renders it available to engineers for various purposes, and the advantages it affords. Steel has a tensile resistance of from twenty-five to fifty tons per square inch, as compared with twenty to twenty-four tons in iron. As Dr. Siemens summarised it, "Steel was almost the hardest substance in nature if treated in a certain way; treated in another way, it was the most elastic of metals, if not the most elastic substance in nature; and treated in another way it was nearly the most ductile of metals. It was decidedly the strongest substance in nature." The wide range of quality possessed by steel is, as we have seen, chiefly determined by the percentage of carbon it possesses, and this can be adjusted with great precision in the course of manufacture. Both in tension and compression steel possesses the valuable quality of a high elastic limit, owing to which severe and repeated strains can be imposed without undue risk in straining. The homogenity of steel is an advantage in many respects, as compared with the composite character of wrought iron, which is made up of numerous pieces welded together. The method of manufacture by which the steel is produced in the most simple way, by casting into an ingot, increases greatly the size and weight of pieces which can be manufactured at moderate cost, unlike iron produced from small lumps puddled in a furnace by hand labour, and laboriously welded together by powerful and costly machinery.

The drawbacks to the use of steel, which in the earlier days of its manufacture deterred many engineers from trusting it, even in the face of its manifest good qualities, have rapidly disappeared with the experience of the last ten years, and when the immense advance in this short period is taken into account, it can hardly be doubted that the objections and uncertainties which still remain in regard to a few of the uses it has been put to will also speedily vanish. In England, on the Continent, and the United States, a powerful alliance of scientists, manufacturers, and engineers is at work, the first class by minute investigations, and the others by practical experiment and use, to further improve the modes of making, and the proper manipulation of the steel when made; and although in this advance the leading nations, England, Germany, France, and the United States, are advancing by parallel paths, each profiting by the skill of the others, it is satisfactory to Englishmen to remember that not only the Bessemer invention, but also those of Siemens were accomplished in this country; and, further, that the improved methods devised by Whitworth and the Basic system, which renders available the iron ore of the world, nine-tenths of which seemed at first to be useless for steel, are also due to Englishmen.

Steel rails had been used for some years before steel was generally adopted for boilers, ships, and bridges. This was partly due to the cost of steel for these latter purposes, because till the quantity required became large, economy in manufacture could not be obtained. This, however, was not the only reason, for while steel plates and bars were being tried for various purposes, the new material had not fully gained the confidence of engineers. Accidents, to which no certain causes could be assigned, occurred from time to time, and deterred prudent people from adopting steel till the more venturesome had further proved its trustworthiness. In vain did the steel makers submit their steel to tests, and show that with all the advantage of forty tons per inch breaking tensile strength, the steel had a greater ductility and a much higher limit of elasticity than iron. The test pieces might endure the strain put on them, but larger pieces broke in a curious way. Plates lying on the ground before being used were found to have cracked right across in the night, and boilers made of steel which had been tested most satisfactorily cracked in an ominous manner. Although these accidents were not numerous, probably no more in proportion to the amount made than was occurring in iron, they were alarming because they were unaccountable. It became very evident that steel behaves differently to wrought iron, and the new material was loudly decried. It gradually became apparent, however, that if certain simple precautions were taken these accidents might be avoided, and at the present time in steel used for any of the purposes to which it was applied, rails, axles, tires, bridges, ships, and boilers, the percentage of failures is very much less than with iron. I will enumerate some of the peculiar risks of steel, and the manner of avoiding them, as elucidated by the experience and discussions of the last five years.

The quality of steel depends to a large extent on the amount of work that has been bestowed upon it. As was explained in my first lecture, steel in the ingot form needs certain processes of squeezing, hammering, and rolling to convert it into ductile and malleable plates and bars. There is always in steel castings a certain coarseness or openness of grain, which, in the case of large ingots of twelve inches to twenty inches thick, gives in the centre of the ingot a honeycomb looking section, more or less permeated with blow holes. The after reduction of the ingot by hammering, squeezing, and rolling solidifies the steel, and so closes together the air holes that only faint black lines occasionally show where they have been. But unless this is sufficiently done by powerful machinery, the original openness of grain is not entirely removed, and small laminations appear in the plate or bar, destroying the homogenity at the places where they occur, and reducing the effective sectional area. The reduction of a fourteen-inch ingot down to a rail or to a plate one inch thick effects this solidification; but if to save labour, or because the machinery is not powerful enough, a slab or ingot five inches thick were cast, the reduction would not be sufficient.

It has been found that if holes are punched in steel plates, the tensile strength of the plates is reduced more than is due to the reduction of sectional area by the holes, but the explanation of this proved simple, and suggested its own cure. The metal round the hole, say $\frac{1}{16}$th or $\frac{1}{12}$th of an inch, becomes so hard and brittle (*Plate* I., *Fig.* 6) from the sudden dislocation of the metal, that when the plate with the punched holes is strained, this hardened metal round the holes does not yield; all the strain, therefore, comes on this annular hard part, and it breaks, the fracture then extending to the surrounding ductile steel. If, however, the hard part be rimered out, or if the ductility be restored by annealing, the original strength is obtained. Consequently, punching, which was at first permitted, and then a few years ago prohibited, is now again allowed in mild steel if this after-riming be performed, or if the plate is annealed. By mild steel I mean a quality having a tensile strength of not more than thirty-one tons per inch. Shearing has the same effect as punching, in hardening the adjacent metal (*Plate* I., *Fig.* 6), and consequently all sheared edges must be planed down from $\frac{1}{16}$th to $\frac{1}{8}$th of an inch to avoid brittleness, and consequent commencement of fractures.

Other operations have also an injurious effect on steel. Steel is more or less plastic when white or red hot, and ductile when cold, according to its carbon character, hard, medium, or mild; but there is a critical temperature somewhere between 500° and 700° Fah., or "blue heat," as it is termed, when it seems to suffer greatly when hammered or bent. The harder the steel the worse it is in this respect. Steel blooms and plates, though made red hot for hammering or rolling, soon lose the intense heat, and if the operations were continued at a blue heat the danger would arise. Most of what were deemed mysterious fractures undoubtedly occurred in steel which had been so severely strained at a blue heat as to acquire self-contained initial strains, so that when subjected afterwards to percussion, or even to sudden fall in temperature, or strainings in course of use, it became fractured. This liability, though it seems to have been known to a few, and though the same circumstances occurred in a less degree in rolled iron, was quite ignored in the modern treatment of steel up till about five years ago. In manipulating steel, the workmen considered that a moderate heating would slightly soften the metal and render it, though not, of course, so plastic as a red heat, at any rate better than cold steel. This erroneous notion occurred both in the steel works in rolling into blooms, rails, or plates, and in the manipulation in bending the plates for rails and boilers. The whole subject was thoroughly elucidated a year ago in a paper by C. E. Stromeyer, read on 26th of January, 1886, before the Institute of Civil Engineers, and in the subsequent discussion by steel makers, chemists, engineers, boiler makers, and others. I refer you to that paper for full information on the subject. The results were fairly summarised by one of the speakers, an experienced steel maker, as follows :—

"1st. Initial strains existing in steel were not eliminated by raising to a blue heat. The heating must be continued to full redness before such strains were got rid of.

"2nd. Steel strained at a blue heat and allowed to cool continued in a state of strain, and was much injured; this injury was much greater than if the steel had been strained while cold.

"3rd. Steel which has been injured by strain at a blue heat was restored to its original condition by raising it to a red heat and allowing it to cool."

Now, ordinary bendings, such as for boilers and ships, are best done cold, and machinery should be increased in power if necessary, in order to do this, rather than facilitate the operation by heating. But while the blue heat may be avoided, steel is liable to peculiar strains when severely squeezed, bent, or hammered cold. In certain kinds of structures, particularly boilers and ships, there are parts which have to be distorted into peculiar shapes, and the particles of the metal become so disarranged as to impose unequal and severe strains upon the outer skin of the plate or bar, which, though they show no sign of it, are subjected to high initial stresses which render the steel liable to fracture if exposed to percussions, or even to strains well within its normal strength. The same liability occurs if one end of a plate be made red hot to allow of bending or welding, while the other end remains cold. As the metal can be restored to its original condition by annealing, the danger disappears when the remedy is applied. Annealing in this regard means the gradual heating of the steel in a furnace to a full red heat, and allowing it to cool slowly. As the steel becomes soft and plastic, the particles subside into a natural condition, and the properties of the metal are restored.

It must not be supposed from the foregoing remarks that there are dangers and liabilities in steel so serious as to render its use questionable, but it is a new material, and the treatment appropriate to it has had to be learnt; this treatment differs in many respects from that suitable to iron, which may also be burnt or damaged by inexperienced workmen; and users have only gradually acquired the proper knowledge of steel; but although the causes for some of its peculiarities are not yet thoroughly understood, especially its peculiar constitution when at blue heat, the facts are now so well known that fewer failures occur than in iron, and workmen who have once got accustomed to it find it easier of treatment.

The principle uses of the steel made by modern processes may, so far as engineers are concerned, be divided into the following classes: *Rails*, *wheel tyres*, *axles*, *bridges*, and *boilers*. Taken in this order, the hard steel comes first. The first great use of steel was for rails. The cost of renewals of a railway, not only in the purchase of new rails, but in the expenses of relaying, were so great, that the promised advantages of steel were very attractive, and as much as £20 per ton was paid for steel at a time when iron rails could be bought for £7. Bessemer himself had asserted that so simple was his process that steel rails would eventually be made more cheaply than the commonest puddled iron. The prediction has now been verified. In 1876 steel rails cost £8 per ton, when iron rails cost £6; but in 1883 the two were alike, at £5; and since that date the manufacture of iron rails has ceased, and last year's first-class steel rails were sold for £3 15s. per ton, a price as low as that of the cheapest wrought iron at the same date and at a time when iron rails would have cost 10s. more than steel.

Hardness against abrasion and crushing are the qualities most useful in rails, and the importance of these qualities has grown during recent years, as locomotives have been made heavier. The advantages afforded by steel came, therefore, at an opportune time, the steel having a tensile strength of forty to fifty tons per inch as against the twenty tons for iron rails; and not only is the steel harder, but it wears away by slow abrasion, while in an iron rail the original laminations of the pile become separated, long strips or ribands peeling off till the rail is rendered dangerous or useless, in one-fourth the time which may be reckoned on for a steel rail.

The engineer desires, therefore, to obtain, and the steel maker strives to produce, a rail that has the maximum hardness without brittleness, and this is found in steel having a tensile strength of thirty-eight to forty-two tons per square inch. To obtain this quality, nearly a half per cent. of carbon is given to the steel, the exact proportion ranging from 0·35 to 0·5. More than this would bring the steel further towards the condition of cast iron than would be prudent. Some engineers specify this carbon proportion; it is, however, generally left to the maker; and the exact proportion is sometimes determined by the climate, the hardest rails not being used in countries liable to extreme cold. A tensile test of small strips is sometimes required to show whether the prescribed maximum or minimum limits are fulfilled, but generally it is the testing of the rail itself that is depended on to prove the quality. As an actual example of what is at present the practice of our leading engineers, I give you the specified tests for a steel rail weighing seventy-one pounds per yard, of which during the last four years about 60,000 tons have been sent to one of the British colonies.

First, it was required that the steel should be made from non-phosphoric ore, thus excluding the Basic steel, described in my first lecture; this condition is not required by many engineers. Then, that the rolling must be completed with the steel at a heat showing red during daylight, thus avoiding the risks of the blue heat. The strength and elasticity of the rail, as a girder, was proved by placing a piece of rail four feet six inches long on bearings three feet six inches apart, and hanging in the centre a weight of twenty-five tons, and no signs of fracture appearing, the load was removed, and not more than three inches permanent set was allowed. The crucial test was that of the falling weight. A piece of rail the same length of four feet six inches was placed on similar bearings three feet six inches apart, and a weight of one ton was allowed to fall from a height of six feet on the centre three times. Under percussion it was specified that the rail should not bend less than three and a half inches, or more than four inches, thus forbidding either excessive ductility or excessive hardness. Then the fall of the weight was doubled to twelve feet, and two blows were given with limits of deflection of eight and a half and ten inches. Rails which showed the slightest sign of fracture under these tests subjected the whole batch rolled from the same lot of ingots, *i.e.*, made in the one operation of the converter, liable to rejection.

It will be evident that rails made to satisfy a rude test of this sort might well withstand the percussion of the heaviest locomotive when laid on sleepers the usual short distance apart. The proper test for rails of other shapes and weights are arrived at partly by calculations, partly by experiment. The hardness of steel rails, so valuable against abrasion, and affording so great a strength as girders between their supports, renders them more liable than mild steel to fracture under certain contingencies. In the earlier days of steel rails, a peculiar risk was discovered. As, perhaps, you are aware, the double-head rail is hardly used at all in the world except in England, India, and some of the British colonies, the Vignoles, or flat-bottomed rail of the kind I have just described, being used on the Continent and in the United States. These rails are held down to cross sleepers by spikes, and as there are no cast iron chairs as in England, it is necessary to hold them against longitudinal movement, or "creeping," which occurs in rails over which trains are constantly passing in one direction. In the case of iron rails this used to be done by cutting one or more slight notches or grooves in the side of the flange (*Fig.* 5, *Plate* IV.), so that the spikes held it from moving forward. It was found the cutting of this groove in a steel rail, though it was slotted and filed out without punching, so as to avoid rough usage, reduced the strength of the rail against a falling weight by one half, and consequently the notching of steel rails has been abandoned, and other means of holding the rail adopted.

The *Steel Tyres* for railway wheels, particularly of locomotives, are obviously exposed to great abrasion, and as their durability depends upon this, their hardness is as necessary as that of rails. In the United States the requisite hardness has till lately been obtained by using solid cast iron wheels made of a specially tough quality of iron, with the tread of the wheel hardened by being cast in what is known as a "chill," or iron mould, and the wheel then annealed to give the necessary toughness. Probably ninety-nine per cent. of American wheels are still so made, although English steel tyres are rapidly coming into use there for locomotives. The making of steel tyres has, in this country, been brought to great perfection, and in no case have the special qualities of steel proved more valuable. About the same hardness is given as in rails, namely, a breaking strength of about forty tons to the square inch. For tropical and other countries, where no extreme frost need be feared, still stronger steel, of a tenacity equal to forty-eight tons, is ventured upon; but there are only two or three makers in the world who can provide this with an absolute certainty of the necessary toughness.

The highest character obtained is, perhaps, that of the tyres made from crucible steel, but the Bessemer tyres are nearly as good. An ingot of suitable shape is hammered when hot into a disc or cheese-like form, and in this is punched a hole. This hole is then enlarged by a taper plug or cylinder being forced through it by hydraulic pressure (*Fig.* 6, *Plate* IV.) Having thus got a hole large enough for the purpose, the ring is then distended to its full diameter by an ingenious machine, having vertical rollers, one inside and one outside the ring. The tyres thus fashioned are tested by letting them fall a considerable height on to a rail, or by being placed on edge and a weight falling on them, a usual test being a weight of one ton falling ten feet, and any greater fall up to thirty feet till the internal diameter is reduced $\frac{1}{6}$th ; that is, for instance, a three-foot tyre to two feet six inches. Out of the same tyre is then cut a test piece, which is subjected to a tensile strain prescribed of from 40 to 48 tons per inch, when an elongation of from 10 to $12\frac{1}{2}$ per cent. in two inches is required.

For *Ships* and *Bridges* much milder steel is used than for rails, the risk of the accidents previously alluded to caused by improper treatment of the steel being thereby greatly lessened. As this was not at first understood, there was a reaction against the new material soon after it was introduced. Advantages afforded by steel were, however, so great in shipbuilding as to induce further trials, and entire success is now assured. In the iron and steel shipbuilding in this country, eighteen per cent. of the vessels built in the year 1880 were of steel. In 1883 this proportion had grown to thirty per cent., and last year, 1886, sixty-eight per cent. were built of steel. When considerable portions of an iron ship are left unsupported by the water, the hull is exposed to peculiar strains, which tend to open the seams and to strain the iron beyond the limit of elasticity. If a vessel is stranded, or in collision, the shocks and indentations will fracture iron plates, and iron ship plates are unfortunately not of high quality. The advantages afforded by ductile steel, where there is a choice between iron and steel, were obvious, and as, moreover, the saving in weight by using thinner, because stronger steel allows more dead weight cargo to be carried, a direct profit is afforded which is wanting in other structures.

By a consensus of opinion among the most eminent engineers, the steel now prescribed for ships is of a kind having a tensile strength between twenty-six and thirty tons per square inch, and for bridges a little higher, namely, from twenty-seven to thirty-two, some engineers giving a latitude within this range of three and others of four tons between the minimum and maximum strength. The steel must have a ductility, as shown by an elongation before fracture, of twenty per cent. in a length of eight inches, and a contraction at the point of fracture of thirty per cent.

Besides the tensile strength, other tests are prescribed. Strips of steel, whether cut lengthwise or crosswise of the plate, bar, or angle bar, heated to a low cherry red and cooled in water, at a temperature of 82° Fahr., must stand bending round a curve of which the diameter is not more than three times the thickness of the piece heated. In addition to this, flat bars must stand bending as in *Fig.* 3, *Plate* IV., and angle bars doubling backwards as shown in *Figs.* 1 and 2, *Plate* IV. Further, it is required that rivet holes must be either drilled or rimered out and sheared edges planed, as already referred to, and that all straightening of bars and plates shall be done by pressure, and not by hammering. The foregoing prescriptions for steel may be deemed satisfactory when I mention that during the last five years not less than 30,000 tons of railway bridges constructed of such steel have each year been sent to India, and that steel shipbuilding has increased in a rapid ratio during the same period.

In order of hardness there is a considerable step downwards in steel used for *Railway Axles*, which are subjected when in use to peculiar strains. The weight of the engine or carriage tends to bend them, however slightly, and as the axles revolve, the strain is the reverse way, bending backwards and forwards. Tests of an analogous kind are therefore prescribed. An axle is placed with its journals resting on solid bearings, and a weight is allowed to fall in the centre so as to bend it. The axle is then turned round to present its now convex side upwards to receive a blow, and a succession of blows bends the axle backwards and forwards. I will give as an example an axle for a standard-gauge wagon, with axle-box bearings six feet three inches apart. A weight of one ton was allowed to fall twenty feet for twenty-three times, with the axle reversed each time, the deflection each time being about three inches; and two blows were given from a height of thirty-five feet, and the axle bent five inches without any sign of fracture. Sometimes with a test of this sort no tensile test is specified, as the strength and toughness are sufficiently proved. The practice differs about the tensile strength deemed suitable, some engineers requiring steel as mild as twenty-six tons tensile strain implies, and others venturing on much harder steel, up to thirty tons.

Next in order to ships, bridges, and axles, come *Boilers*, in regard to the character of steel required, and for this purpose a very mild quality is prescribed, though not all of one grade. For the shells and ends of boilers, where no severe processes of manufacture are needed, steel of from twenty-six to twenty-nine tons, with an elongation of twenty per cent. in eight inches, may be used, so getting the advantage of considerable tensile strength. But for fire-boxes and tubes, which are not in tension, but which have to be flanged, welded, and otherwise dealt with, a milder quality of from twenty-four to twenty-six tons is used, with a ductility shown by an elongation of twenty-five per cent. in eight inches. Such steel can be flanged and welded as easily as the best Yorkshire iron, which in iron boilers has to be used in these parts, and which cost twice the price of ordinary iron, while the steel costs only ten per cent. more. The workmen who once get accustomed to the almost lead-like ductility of the steel are loth to return to iron; but it is fair to add that at this date, 1887, opinions are not unanimous on this point, and many engineers prefer high class iron of the Lowmoor or Farnley kind already described.

So great is the ductility of mild steel that the late Sir W. Siemens used to say that a boiler made of it could not burst, however great the pressure, even if the safety valve were fastened down. The steel would stretch so much before it fractured that the seams and rivet-holes would elongate and cause such leakage as to relieve the pressure. It is doubtful, however, if this relief would be quick enough to save boilers from the sudden shocks which are sometimes the cause of explosions.

The economy of high pressure steam for marine and other engines is now generally recognised. The principle of triple-expansion engines, where the exhaust steam from one cylinder is used as a motive force in another and larger one, can only be applied successfully with a high initial pressure in the boiler. Steel has been used for marine boilers since 1878, and it affords the necessary material for the boilers which are now worked at pressures of from 120 to 170 pounds, while a few years ago 80 pounds in iron boilers was the maximum, as it was almost impossible to make large boilers for higher pressures, because the plates became so thick as to be jointed with difficulty.

When steel is so low in carbon as to endure only twenty-five tons tension, it is, chemically, so nearly like wrought iron, that the very name of steel is denied to it by some metallurgists, and the name of ingot iron, or, in Germany, *fluss-eisen*, is given to it to distinguish it from puddled iron. It is for mild steel of this sort that the Basic method of making (as I have already described) is best adapted ; but Bessemer steel, whether Basic or not, is not generally deemed so certain in quality for boiler plates as the Siemens or open-hearth steel, which is generally prescribed for high-class boilers.

One of the most important points in smithing steel is to avoid hard and unequal strains, either by irregular heating or by irregular pressing and hammering. These risks are avoided by bringing the steel to a regular, mellow, red heat throughout its entire thickness and surface, and then operating on it by means of a slowly-moving machine press, whereby the whole surface is attacked simultaneously. The other and, perhaps, still more important point, is the annealing of every piece of steel that has had any tearing or severe bending stress upon it. It is possible that when steel is better known the rules as to annealing may be relaxed, but at present they may be deemed vital.

Regarding the welding of steel, I may mention a new process of heating the steel by gas instead of by an ordinary fire. This plan is adopted, for instance, in the welding of long tubes, the gas flame being conveniently brought to the part required just as the welding hammer is about to fall. There are different methods of joining welded edges together, sometimes by joining bevelled or scarfed edges, as in a lap joint ; and sometimes by inserting what is known as a glut piece of steel, V or round shaped, and hammering it well down. In welding mild steel this glut piece may be with advantage made of Lowmoor or similar high-class iron.

I have now briefly described how the different grades of steel, from the hard steel of forty-eight tons down to the mild steel of twenty-five tons tensile force, are allotted to their special purpose. Of the special steel used for guns, and that which is so prepared and annealed as to give a tensile strength of over fifty tons, I prefer not to speak, as the methods of making and using it are in this country known only at Woolwich, at Armstrong's, and by a few specialists at Sheffield and elsewhere. I would, however, say that the range of quality is higher than that I have mentioned as useful to engineers, far greater strength being obtainable by bestowing more work upon it. Thus steel wire will endure at the rate of ninety to one hundred tons per inch, and piano wire one hundred to one hundred and twenty tons. There are other applications, rather outside those of the engineer, which show the character of steel. The manufacture of tin-plates is one of the great industries of this country—that is to say, sheets of iron coated with tin, as used for utensils, sardine boxes, and such like. To stand the cold stamping and dishing, charcoal-made iron of an expensive kind was formerly used. But mild steel has superseded this, the steel being more ductile and much cheaper. Another use of mild steel is for cold-drawn weldless tubes. For very many years seamless brass and copper tubes were made by drawing them from a solid ring, but it is only in recent years that steel has been so treated. The mode of production resembles, in its earlier stages, that which I described for wheel tyres, a taper plug or mandril being forced through a hole in a disc of steel, *Fig.* 1, *Plate* IV., and the disc elongated and thinned by being forced through dies till it is only one-eighth of an inch thick, but perfect in finish and strength. The back bones and other important parts of tricycles and bicycles are made of weldless steel tubes, and these machines could never have attained their present perfection had it not been for this material. Wood screws as used by carpenters, which were formerly made from charcoal-iron rods, are now almost entirely made from mild steel.

It now remains to state the few cases where steel cannot be substituted for wrought iron. Steel is not used for high-class forgings which have to be welded and then are subjected to sharp tensile shocks. Thus no railway engineer would at present venture to make the draw-bars and hooks of his carriages of steel ; nor is chain with welded links yet to be trusted, although there are few cases where it would be of greater advantage, especially for strong cables. Lowmoor or Farnley iron is preferred for these purposes. Steel is not used in this country for the fire boxes or furnaces of locomotive boilers, copper being almost universally employed. These fire boxes are, from their shape, made of flat, or almost flat, plates, and require numerous stays to withstand the steam pressure. The number of attachments, the excessive range of stress caused by the varying temperatures when working and at rest, all involve risks peculiarly affecting steel. Even on the London and North Western Railway, where steel made at Crewe is used for every possible purpose, the fire-boxes are still made of copper. Steel fire-boxes are used on American railways, but the durability is not equal to copper, and is more dependent on the quality of the water.

Having now described the different grades of rolled steel, from the high carbon hard steel used for tyres and rails down to the low carbon mild steel used for flanging and welding of boiler plates, I will say a few words on some other of the conditions arising from the use of steel, namely, the saving in weight, and consequent increased limit of span in bridges ; the advantages of portability in bridges and other structures ; the effect of cold on steel, and also of rust.

In regard to bridges, it was at first considered by engineers that the greater strength ought to allow such a saving in thickness, and therefore in weight, as would fully repay the higher price per ton. But even now that bridge steel has been so cheapened as to be only about 25s. or 30s. above that of rolled iron, it is found that for spans under one hundred feet no considerable saving in weight can be prudently obtained ; first, because the saving in weight, which the reduced thickness might allow, makes no perceptible saving in the total stress on the parts ; and, secondly, because it is necessary in steel, as in iron, to allow for wasting by rust. In the case of a structure, subject to shocks, as in a railway bridge, the inertia of the heavier weight is an advantage ; the blow given by a heavy train coming upon a bridge may be likened to a hammer on an anvil ; and though a steel anvil two-thirds the weight of an iron anvil might sustain the same dead load, it would not so well absorb the blow. There are incidental savings in the use of steel. For instance, it is easier to get long and heavy pieces in steel than in iron, consequently there is a saving in cover-plates ; but it is beginning to be realised that superiority in quality and greater safety are the advantages to be looked for rather than mere saving in price. To put it shortly : If an extra expenditure of seven per cent. will give a bridge of thirty per cent. higher limit of safety for long spans, it is surely worth the doing ; and, consequently, in short spans engineers are beginning to adopt steel without altering their drawings at all, and without any saving in weight.

In this country the Board of Trade regulations for bridges require that no part of an iron bridge shall be strained by its maximum load more than five tons per square inch. For some time after the introduction of steel they would not recognise it as a superior material, but they have since allowed a strain of six and a half tons per inch, based on the Admiralty quality of twenty-six tons breaking strain. Taking iron at twenty and bridge steel at twenty-eight, this is perhaps all that could be expected. As, however, the parts of bridges are not, as a rule, subjected to such distortions and bendings in the course of manufacture as are ships, nor are they so liable to complicated stresses when in use, a rather higher working strain than six and a half tons might be permitted, and this is granted when circumstances warrant it. There is no reason why harder and stronger steel should not be used for those parts of a bridge which are always in compression, even if such stresses vary considerably with the moving loads or wind pressure. As, however, in the majority of cases it is convenient to have one kind of material only in the same structure, to avoid the accidental using of the hard steel where it is unsuitable, the mild steel is used in all parts, except in such obvious cases as the rollers on the bed plates ; but in a large bridge where the advantage from varying the kind of steel is considerable, or where careful supervision can be exercised, hard steel is also used. A case in point is afforded by the now famous Forth Bridge, of which Mr. Benjamin Baker, with his partner, Sir John Fowler, is the engineer. Mr. Baker has made most careful and elaborate experiments, and is making without hesitation, in parts subject only to compression, hard steel equal to a tension of thirty-seven to forty tons per square inch. Rivet holes are all drilled, and the edges of the plates, when they have been sheared, are planed ; and these precautions being observed, the enormous compression loads that come upon certain parts of the bridge are met with a full margin of safety without an undue weight of material.

Having a certain knowledge of the material employed, and of the maximum stresses to be endured, the factor of safety must be determined by the nature of the stresses. Formerly, in England, at any rate, it was a generally accepted rule that no part of an iron structure should be strained in tension to more than five tons on the inch, the same stress being often allowed in compression also, although the official regulations in some foreign countries allowed less. Having prescribed such limits, with or without any stipulation as to the factor of safety, it was not always modified for different parts of the structure. Indeed, so far as official rules in Great Britain are concerned, this still remains the case, and though a higher strain than five tons is allowed for steel, the engineer is left to do as he likes within the prescribed limit. The experiments of Wöhler, in Germany, on the fatigue of metals due to oft repeated stresses, showed that the range of stress, as well as the maximum stress, was an important circumstance to be considered. Wöhler's experiments were described in some English journals, but had not attracted general notice. So far as I am aware, attention was first publicly drawn to these experiments by Mr. M. Am.

Ende, in his paper on the weight and working strain of girder bridges, in vol. lxiv. of the Institute of Civil Engineers, he having previously designed some bridges on the new basis. Mr. B. Baker, in the discussion of a paper read by me at the same institution in 1882, drew attention to the change of practice among engineers on this point, and also again last year in some notes presented by him to the American Society of Mechanical Engineers. These notes were printed fully in the *Engineer* of January 21st this year, and are well worth perusal, as giving the latest opinion on the subject.

Although a reference to the works of Professor Wöhler, Professor Kennedy, Mr. Baker, and other eminent authorities, will tell you much better and more fully than I can the exact principles involved, it may be convenient in such a lecture as the present, where I am endeavouring to bring the subject up to date, to put these views summarily before you.

Dealing then with this new theory, it is becoming a generally accepted rule among engineers to give a different factor of safety to the various parts of a bridge, according to the range of stress. In *Plate* V., *Fig.* 1, I give a series of diagrams to illustrate this system, the formula shown above the diagram being a pretty fair average of what has been adopted by various eminent engineers, as shown in the papers of the Institute of Civil Engineers, already alluded to. The formula on the diagram gives the appropriate strain, S, for any given range of stress upon this basis, and the results of the formula may be approximately seen on the rectangular diagram by reading off the strain, S, on the bottom line at a point vertically below that in which the diagonal line (for steel or iron respectively) intersects the dotted horizontal line which represents the variation of stress. The constant, A, 5·2 and 4·0 are arbitrarily arrived at. The diagram applies both to iron and steel, the former with a normal maximum strain of 5 tons per inch, and the latter of $6\frac{1}{2}$ tons, these each giving a factor of safety of four, on the basis of iron at 20 tons breaking strength, and steel of 26 tons. We need only deal with the latter. Taking first a case where there is no range of stress, where the strain is uniformly at its maximum, as, for instance, might occur in an aqueduct or bridge carrying a tube always full of water, here a very high stress might be ventured on, namely, 7·8 tons, as will be seen from the formula, taking $\frac{\text{Minimum Force}}{\text{Maximum Force}} = \frac{1}{1}$, or, reading on the diagram at the point below the intersection of the steel line with the top dotted line (the dotted line showing that the strain is always a constant quantity $+1$). The diagram, A, shows that in this case there is no alteration of stress, as that is shown, where present, by a shaded area. The next case is that of a bridge of such a span that the dead weight of its structure causes about half the total stress present when the live load is passing, here the range of stress is shown at B, by the shaded area, and S may be calculated from the formula, or read off from the rectangular diagram at the point below the intersection of the diagonal line and the line marked $+ 0{\cdot}5$, this line signifying that the dead load is only ·5 of the total load. Then comes such a case as that of the cross girders of a bridge, where the strain varies from that caused by the weight of the girders themselves (practically *nil*, and shown as such at C by the dotted line to the maximum of the passing load). In this case it will be seen that S ought not to be more than 5·2 tons. The worst cases of all are those where the strains vary from tensile to compressive; these are shown on D and E. In E, where the strain varies equally, enough material ought to be provided to avoid a greater strain than 2·6 tons per square inch. Such cases as the last are the middle diagonals of a trellis bridge, or part of the flanges of continuous girders.

The harm done in short-span bridges before these circumstances were taken into account, was the more serious because such bridges were for other reasons made too light. It was too frequently the case that a certain constant was adopted for the moving load on bridges, say one and a quarter ton per lineal foot for a single line railway, and it was only as the effect of modern heavy locomotives on bridges began to tell, as it has done of late years, that the different effect on long and short bridges appeared to be realised. On a bridge of 300 feet span, a train, even with two locomotives, would not impose 300 tons weight, and a provision of one ton per lineal foot would be enough; while on a bridge of twenty feet span the whole wheel base of a sixty-ton locomotive would impose three tons per foot. A few years ago the cross girders of a bridge were not unfrequently designed with reference only to the distributed load, and not with due regard to the concentrated load of one pair of wheels on one cross girder. In some locomotives the load on one pair of wheels is as much as sixteen tons.

The result of Wöhler's experiments I have just referred to show that the deterioration of steel, as also of iron, from the fatigue of oft repeated strains, must not be measured only by the number of times the maximum strain is applied, but by the amount of alteration in these strains. The careful laboratory experiments of Professor Kennedy in England, Wöhler and Bauschinger in Germany, and others, go to show that there is little or no harm caused by the greater range of stress, so long as the total stress does not pass the limit of elasticity, and if we were quite sure that the effective material in a structure was as the designers intended, and as it appeared to be, we need have little concern with the range of stress if it were well within the limit of elasticity provided.

But it is now generally recognised that this theoretical margin cannot be reckoned on. There is a weakest point somewhere in every structure, which would give way long before the other parts were strained up to their limits. This defect may arise from various causes. There may be a flaw in some bar which diminishes its effective area; the metal round a rivet hole may have cracked, or some hidden part may have corroded; there may be an initial stress in some part owing to careless heating or working, which, added to the load reckoned on by the designers, may greatly exceed it. From some of these causes there is always a possibility, nay, even a probability, that some portion of the structure may be undergoing strains above the limit of elasticity, and therefore is subject to the ill effect of a wide range of stress.

It was hoped that this branch of the subject would have been dealt with at the last year's meeting of the British Association, and I believe that a committee of the mechanical section is preparing a report for the meeting of this year. There is, of course, the preliminary point to be considered, how far it is desirable to have Government interference at all. English engineers have hitherto been much freer in this respect than those in other countries, and it may be deemed best to leave the full responsibility to those who are intrusted with the safety of the public.

While for most permanent structures, such as boilers, bridges, and roofs, the relative strength and cost are the main points to be considered, the case is different where transport and portability are concerned. For mere conveyance to a distant country, especially where inland carriage is involved, steel affords obvious advantages, and the calculation of cost is entirely altered. For instance, a steel structure which, from its higher price per ton than iron, may cost the same, or even a little more in the country of manufacture, may cost greatly less when £5 per ton has been paid for carriage. For some of the bridges which have been erected in South Africa, it has cost more to convey the pieces inland by bullock wagon than the entire price paid for the bridge at the ship's side in Cape Town. The lightness allowed by steel becomes of much greater importance where portability is an essential item in the use of the structure. From this point of view, the facilities afforded by steel will doubtless encourage invention in regard to military bridges, whether in regard to pier supports, or pontoons, or superstructure. I know one Russian engineer who has spent much trouble in devising bridges composed entirely of steel tubes, ranging from one inch to nine inches in diameter, the larger tubes serving as piles or legs, and the smaller tubes for the bracing into rigid piers, while smaller combinations serve for triangulated girders. The various tubes, when taken to pieces, pack one inside the other for transport in telescope fashion. For structures of this kind, harder, stronger steel than usual could be ventured on, because there would be less risk of hidden flaw, all the parts being subject to constant examination. For carriages of all kinds light steel sheets and bars are now much used; for instance, steel is now used to advantage in the framing of omnibuses, and I have already alluded to bicycles and tricycles. Torpedo boats are another example. The hulls of such vessels are constructed of steel sheets about one-eighth of an inch thick, and serve admirably for every purpose except that of resisting percussion, and even when such vessels run aground, or are in collision, they will bulge rather than break.

The effect of cold on steel, as well as on iron, has been the subject of much controversy. Railway tyres, whether of iron or steel, break oftener in winter than in summer; steel hammers fly asunder when used in frosty weather; and chains which have been exposed out of doors to frost are liable to sudden fracture. Workmen who have much to do with hoisting operations will warm chains before using them. This alleged brittleness of iron and steel during extreme cold has been denied by some scientific men who have experimented by placing bars of iron or steel in ice till they are reduced down to its temperature, and then testing them in tension and compression and by sharp blows, the results being the same as those made at an ordinary temperature. While this was interesting as far as it went, it was really not a true test, for the alteration produced by extreme cold does not take place in the small, simply-shaped pieces, but in large pieces or those of irregular shape and thickness. I have already referred to the initial stresses due to unequal cooling, as when one part only of a plate has been heated; and the abnormal stresses occurring in a casting which, being of varying thickness, has strained some of its parts in shrinking. Such castings often crack spontaneously while lying on the ground. So in the case of railway tyres, whose fracture has often been the cause of disaster, the molecules of metal are probably arranged differently in the rim than in the flat part; the extra shrinkage, produced by cold, may tell differently, and cause such stresses as render the metal liable to fracture under sharp percussion. This risk is the greatest where the metal has been strained during manufacture, and not restored by annealing.

In a chain whose links have been welded, there may be one link strong enough under ordinary circumstances, but which may suffer derangement if exposed to a sharp blow during frost. I cannot give you a scientific reason for this liability, but the microscopic investigation of metals may help to elucidate the matter. Anyhow, I would advise you, if called upon to use a crane on a frosty morning, to thaw the iron chain—that is to say, to bring it to an ordinary temperature, not the dangerous blue heat, notwithstanding what laboratory experiments may tell to the contrary.

As to the difference between steel and wrought iron in this respect, steel castings are, like iron castings, more liable to fracture than rolled iron; and as rolled steel was first cast into an ingot, its later freedom from the liability of a casting would depend upon the amount of work bestowed upon it being done equally.

In regard to the rusting of steel, there has hardly been sufficient experience to warrant very positive conclusions, and the opinions arrived at have been on isolated cases. I have taken some interest in the subject, and believe that steel has the advantage in this respect. The rust upon it is granulated, as in cast iron, and not in flakes, as in wrought iron, and therefore the damp does not get below the flakes, as in wrought iron. The liability to rust depends on minute chemical differences. I have seen one plate pitted with small, cup-shaped rust holes, from which the next plate was free. It is almost certain that these two plates were cut from the same lot of ingots, that is, had been produced by the same operation of the Bessemer converter or other initial process.

E. M.