GENERAL VIEW OF PALMER'S WORKS, AT JARROW-ON-TYNE.

CIVIL AND MECHANICAL ENGINEERING

POPULARLY AND SOCIALLY CONSIDERED

BY

J. W. C. HALDANE, C.E. AND M.E.

SECOND EDITION IMPROVED AND ENLARGED.

WITH TWELVE PLATES

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PREFACE TO THE FIRST EDITION.

The Scientific and general Engineering literature at the present time is of a very extensive and varied character, but however valuable it may be to those who make it a study, the ordinary reader will naturally find such volumes unintelligible and uninteresting. It has, therefore, occurred to the Author—who has had thirty-five years' experience in various branches of the profession—that a brief outline of its history; a description of the inner life of the Works and those connected with them; the system of management in great establishments; and the construction of ships and engines, might prove interesting and instructive to readers of all classes, if treated in a free and unconventional style.

In furtherance of this object, the language employed in this Work has been made as simple and as free from technicalities as possible, while a few of the experiences of private practice, a variety of useful information, and a sprinkling of anecdotes have been added, for the purpose of giving a little animation to the whole.

While endeavouring to impart in a pleasant way as much professional knowledge as possible, the writer has specially dedicated Chapter VI to those numerous people who "wish to know what to do with their boys." It is also hoped that Chapters XXIV, XXV and XXVI, will be instructive to those who desire a glimpse of the secrets of private practice.

The intention has been to try to interest everyone, but the difficulty of doing this is so apparent, that the kind consideration of the generous reader may perhaps be more easily extended to one who has done his best, though conscious of numerous failings.

Many thanks are due to the authors of various books, papers, and perodicals, who have supplied information regarding the early history of Railways, Canals, and Steam Navigation; to Mr. B. H. Thwaite, C.E., for revising the MS.; and to the firms who have sent photographs, &c., from which the Engineering Views have been taken. Reference will also be made to many other sources of knowledge on similar subjects which in the following pages have only been briefly touched upon. It is hoped, therefore, that this volume may not only afford instruction, but prove sufficiently interesting to repay perusal.

J. W. C. H.

LIVERPOOL, *May*, 1887.

PREFACE TO THE SECOND EDITION.

The highly appreciative manner in which the first edition of this Work was received by the press and by the public, has induced the Author to make many improvements and important additions, but without altering in any way the style of writing which has made the book so popular. The text has been carefully revised throughout, and so much fresh information given concerning the latest phases of Engineering, that it is hoped the volume will become even more acceptable than its predecessor.

J. W. C. H.

30 NORTH JOHN STREET,
LIVERPOOL, *September*, 1889.

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CHAPTER I.

STEAM NAVIGATION—CANALS AND RAILWAYS.

First steamer to India—Defects in Machinery—Junius Smith and "British Queen"—First voyage of "Sirius" and "Great Western"—The pioneer Cunarder "Britannia"—Bridgewater Canal—Liverpool and Manchester Railway—Railway Mania—Difficulties of Railway Engineers—Q.C. of the period—Woosung Railway—Japanese Students in England.

THE history and the practice of Engineering are so varied and comprehensive, that it will be rather difficult to compress them into a very small space, nevertheless, their leading events may be touched upon, and their principal features referred to, in the following pages. People generally seem to have a pretty fair knowledge of the legal and medical professions—some of the unamiable may say, "a great deal too much"—but they also possess, so far as can be learned, somewhat limited ideas concerning the education and inner life of the engineer, and for reasons which will afterwards be explained.

It is, indeed, surprising, that while the Arts and Sciences flourished in ancient Greece and Rome, and works in earth, and brick, and stone, attained colossal dimensions, the mechanical branch of engineering was asleep through all those ages, and only wakened up at the beginning of this century with a giant's power, transforming our modes of travel and manufacture, and revolutionising the world in fifty years. It may be mentioned, however, that mechanism of a minute and philosophical description had been developed in a variety of ways during previous centuries, but was chiefly employed in the construction of wonderful clocks, such as those in Strasburg Cathedral and elsewhere, toys of various kinds, and other useless, though, no doubt, ornamental curiosities. All of which led to the great future, when the wheels, and pinions, and shafts, then employed, would be reproduced on a vast scale in mill gearing, and in the innumerable details of powerful steam engines and constructive machinery.

Leaving out of sight for the present the primitive efforts of Mr. Miller of Dalswinton, to introduce miniature steam navigation in the year 1788, and passing over the advent of the "Comet" on the Clyde, in 1812, and also the coasters which subsequently arose, we come down to 1825, when a bold effort was made to steam to India. The merchants in Calcutta had offered a premium of a lac of rupees for the first voyage out and home, averaging seventy days each way, and this at last resulted in the fitting out of the paddle-steamer "Enterprise," of 470 tons, and with engines of 120 horse-power, by Maudslay.

She sailed when completed, but with so many vital defects in her machinery and arrangement that the wonder is she ever arrived. For example, unprotected cylinders, and an equally naked boiler, created such intense heat that the men could not work below in safety. Her entire cargo consisted of coals and stores for an expected run of thirty-five days to the Cape, and in consequence of a quantity of coals in bags having been stowed on the top of the boiler to gain extra space, the ship caught fire. The average speed on the voyage was five knots an hour, and the time occupied amounted to one hundred and fourteen days, forty of which were under sail, and eleven at anchor. In every respect the undertaking was a complete failure. It, however, exposed defects which the engineers were quick to rectify, and her commander, Lieutenant Johnstone, R.N., received £10,000 for his arduous services.

In 1832, an American Doctor of Laws, named Junius Smith, was fifty-four days in crossing by a sailing ship from London to New York, and thirty-two on the return voyage to Plymouth, which was quite too much for him. He, therefore, carefully considered the subject, and at last became convinced that "*any ordinary sea-going steamer could do the distance in fifteen days with ease.*" He then energetically set about organising a company in London for the purpose of building Atlantic steamers, but, like the railway people before him, was considered by many a semi-lunatic. Persevering, however, in spite of all opposition, particularly from the sailing-ship proprietors, and supporting his opinions by many calculations based upon facts, he succeeded in forming a company with a capital of £100,000, which enabled him eventually to build the " British Queen " of 2,400 tons!

The failure of the contractors caused a serious delay, but she was at last completed, and left London on her first voyage in July, 1839, arriving in New York fourteen-and-a-half days afterwards. In the meantime, Dr. Smith's firm had chartered the "Sirius," of 700 tons, for a voyage out and home, and started her from Cork on April 4th, 1838, while another company had specially built the "Great Western," of 1,340 tons, which sailed from Bristol on the 8th, their respective runs being eighteen and fifteen days.

Both vessels arrived in New York the same day, and were received with salvoes of artillery, and the joyous acclamations of vast multitudes on land and water. Their captains and officers were almost deified, and the people ran wild with excitement over the great and long wished-for event. Captain Hoskin took charge of the "Great Western," and Lieutenant Roberts, R.N. — subsequently lost in the "President" — commanded the "Sirius." A passenger in the former contributed a very interesting description of the voyage, and their reception in New York, to *Chambers's Journal* of the period.

The "British Queen's" owners now proceeded with the building of the "Britannia," which was put on the station in 1840, to carry the mails between Liverpool and Boston, &c. The first voyage occupied fourteen days eight hours, and those in the ship received a perfect ovation from the inhabitants on their arrival, and it is said that Mr. Cunard, who crossed in her, had eighteen hundred invitations to dinner sent to him within twenty-four hours afterwards.

Charles Dickens crossed in the "Britannia," and one of the most interesting chapters in his *American Notes*, is occupied with an account of the voyage. A notable event in the history of this pioneer Cunarder was the cutting of a channel, 100 feet wide and 10 miles long, through the ice which filled Boston harbour in 1844, to enable her to sail at the specified time, thus disappointing the hopes of the jealous New Yorkers, who said "Boston was an icebound port in winter." The contract price for the work was 10,000 dollars, but it cost 20,000; numerous tugs, however, kept the ice in future from consolidating, and thus prevented a recurrence of the difficulty. This new era in civilisation, successfully inaugurated by Dr.

Smith, was the forerunner of an immense traffic, and of a wonderful rapidity of communication between the two continents, which has been swiftly developed down to the present time.

The original name of the " Britannia's " firm was now slightly altered to the " British and North American *Royal Mail* Steam Packet Company," but as this grand and impressive title was too ponderous for daily use, it was changed to the " Cunard Line," whose long-sustained fame is before the world, and needs no further comment.

CANALS AND RAILWAYS.

Simultaneous improvements were now made on land, some of which, canals, for example, were of much earlier date than the introduction of steam navigation. In 1760, the roads around and between Manchester and Liverpool were so wretched as to be often impassable, and the trade of Manchester, small as it was, found its way on pack horses to the Severn, down which it was floated to Bristol. The Duke of Bridgewater, who at this time ardently studied engineering under Brindley, proposed connecting the two towns by means of a canal, and soon afterwards began its construction. Want of capital, however, for carrying on the work compelled him to sell off nearly all he possessed ; he borrowed small sums from his tenants, and, as a last resource, mortgaged the Worsley Canal—his first scheme—to a London firm, who gave him sufficient money to enable him to complete the undertaking to Runcorn.

It must be borne in mind that all previous English attempts in canal engineering had simply been to widen out existing ditches and small streams, whereas those just mentioned were cut through solid ground, involving

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It must be borne in mind that all previous English attempts in canal engineering had simply been to widen out existing ditches and small streams, whereas those just mentioned were cut through solid ground, involving careful surveys and difficult and costly works, such as bridges, viaducts, &c. Now that Manchester had a direct outlet to the sea, its trade went up with a bound, and Lancashire manufacturers flourished.

The Bridgewater Canal ultimately brought in a revenue of about £100,000 a year to its proprietors, who became very exacting in many ways. It was frequently blocked by an excess of traffic, and in winter often frozen up, so that goods sometimes occupied as much time in transit as they did in coming by sailing ship from New York. To try to remedy therefore this unendurable evil, the Liverpool merchants held a meeting, with Mr. Joseph Sanders as president, and the result of their discussion was that George Stephenson should be applied to for advice on the subject. Having gained useful experience on the Stockton and Darlington, and previous colliery lines, he immediately proposed a railway. The county of Lancaster was in arms against such an idea ; the landed proprietors, the little villages and towns, and all the country houses too, declared that they would not have their territory desecrated by such an innovation, which was sure to bring with it many serious evils. The unkindest cut, however, came from the canal people, who waged a war of extermination against *all* railways.

The surveyors had a rough time of it, and by the merest chance the bill before Parliament was passed. The line was accordingly commenced, and thus began the Liverpool and Manchester Railway, which, with Stephenson as engineer-in-chief, was successfully opened with great *éclat* on September 15th, 1830, and through the fabulous prosperity which almost at once attended it, set every one on fire for other similar schemes. Hudson, the "Railway King," was deified because he had made

£100,000 in one day, and helped others to be "successful;" but he led many to ruin, and when he fell, it was like Lucifer. A few kind friends saved him from absolute penury, and he often said afterwards that his happiest days were when he sold linen behind his counter in the city of York.

Some idea of the extent of the speculative mania, which existed at this time, may be gathered from the fact that from 1823 to 1844 the total cost of completed lines had been £70,681,000; those in progress in the latter year were estimated at £67,360,000; but in the same year, there were fourteen hundred and twenty-eight projected railways, with an estimated capital of £701,243,000, many of which were only gigantic frauds. In the amusingly satirical "History of the Glenmutchkin Railway," in *Blackwood*, the rise, progress, and end of one of these ethereal schemes is fully described.

At this period, lawyers and engineers quickly made large fortunes; the former received immense fees, not only for their professional labours, but also for doing nothing; or, at least, for withholding their services from others who wished them. The engineers had a regal time of it; but they were worked like slaves, and, in many cases, were not in bed for a week at a time, in their anxiety to finish the Parliamentary plans for a new line by a certain day, or they would not have been received.

Holding, as they did, the key of the position, they were bullied unmercifully when in the witness box by opposing counsel, under, over, and through every possible and impossible phase of the question, and required not only to be masters of their art, but masters of strategy as well, to enable them to carry their point. They had to know how to advance their crushing statements under fire from the enemy's batteries, and when to retire behind their defences. If the scientific witness were too closely pressed, he had one safe retreat at all times, into which none could follow him; he would retire into a thicket of algebra, from which he could shoot forth a furious volley of arguments relating to sines and co-sines, tangents and co-tangents, optical squares and chord angles, zenith distances, equatorial axes, the curvature of the surface of a spherical triangle in relation to the ellipticity of the earth, and so on, until his persecutors were glad enough to let him alone.

What magnificent opportunities, too, the Q. C. of the period had for the display of forensic genius! Under his eloquence one would have imagined that raising embankments, crossing rivers, and penetrating mountains, was quite an elegant recreation. "The talent of the engineer would easily overcome every obstacle; in short," he continued, "there never was a line so advantageous in every respect, nor one which would prove so remunerative to the shareholders." The opposing counsel, however, did not quite entertain the same views. He, too, could give a brilliant oration, but concluded *his* remarks by observing that "he had the greatest confidence in the ability of his learned friend, who had spoken so truly on many points, but opinions differ, and he had every reason to believe, from what their engineer had informed them, that although the tunnels, bridges, and embankments, could, no doubt, be successfully executed, it would be at such an enormous cost, as to entail a heavy loss, if not ruin, on all concerned in the undertaking; therefore he, for one, would not sanction the scheme." In this manner, railways, in early days, were lost or won.

They are now spread nearly all over the world, and have, at last, made a good beginning in China, where there is unlimited scope for extension.

In 1875, Messrs. Jardine, Matheson & Co. conceived the idea of constructing a small railway from Shanghai to Woosung, 9 miles. It was only a tentative scheme,—just to see, in fact, how the Celestials would take to it. The "Woosung Road Company" was therefore formed, and the line commenced, Ransomes and Rapier, of Ipswich, supplying the locomotives and other requisite machinery. When the line was opened in 1876, the people were enthusiastic—many thousands of visitors per day coming to see it work. There were, moreover, none of the dreaded "disturbances of the spirits of the air and earth,"—everything went well,—the adjoining land went up in value, and a magnificent future seemed to be in store for all. Unfortunately, however, the dispute, which at this period arose between the British and the Chinese Governments, in reference to the murder of Mr. Margary, gave the authorities an opportunity of alleging a grievance in the matter of the railway; and, although everything was done that could be done by the more enlightened officials to retain the line, the whole of the obnoxious plant and machinery were dismantled and shipped to Formosa, where they lay for years rotting and rusting in the mud.

Thus ended a professionally successful, but diplomatically unfortunate scheme, which was expected to have been the beginning of the Railway System in a vast empire possessing only the most primitive means of transport.

They manage these things better in Japan, where engineering has not only been warmly received, but is making astonishing progress in all branches. They have an Engineering College at Tokio, under English professors, and, in railway matters, are making rapid advancement. Those who come here to learn are most industrious, and, as a people, they are very intelligent, as the following example out of many will show. It is said that on one occasion a new steamer had gone out for a trial, but, on her return, the Japanese engineer, somehow or other, forgot, at a critical moment, his "formula for stopping the engines." No time was to be lost, so he at once drew his fires, put the helm hard over, and gave the ship a little practice in circle sailing, until the steam was used up; he then anchored. Very many students have come to this country, and in numerous instances competed most successfully with their British associates, and, only recently, two of them carried off first prizes in Sir William Thompson's class at the Glasgow University.

There are many amusing as well as ghastly stories told in connection with our own railways—the following may lie between the two extremes. There used to be on the North British line, a driver who was profanely called "Hell-fire Tom." The name originated in this manner. Coming along the main line one day on his unattached locomotive, he discovered, when too late, that a bridge had fallen in. There was not a moment to lose, and he couldn't stop, so putting on full steam, he came down at a fearful speed, and with one supreme effort made in the engine leap the chasm in safety!

On another occasion—which I well remember—a cow strayed into forbidden territory, and would not move off in time to clear the express which was approaching. Down came the engine—bang went the "coo," as Stephenson himself had predicted—and in a twinkling the whole of the machinery was interlaced with the flesh and bones of the annihilated animal. In America, buffaloes often get on the road in the same manner, but the "cow-catcher" pushes them off and thus prevents the possibility of accident.

The ghastly stories are very numerous, but refer chiefly to early days. In this respect, however, England and America are far ahead of any other nation. The most appalling disasters that have happened in this country, were the fall of the Tay Bridge, and consequent destruction of a passenger train which was running over it at the time, and the burning of the Irish Mail at Abergele, in Wales.

Many similar calamities of a modified description have occurred in the United States, but were it not for the "spark arrester," which adorns the chimneys of American locomotives, cities and towns, villages and hamlets, forests and prairies, would all be exposed — as they formerly were—to wide spread destruction through the sparks thrown out by the wood fires of Transatlantic engines. Now, however, such evils are almost unknown.

CHAPTER II.

GENERAL ENGINEERING.

Fairbairn and Hodgkinson's experiments—Britannia Bridge—Fairbairn's Canal Street Works—Begins Shipbuilding at Millwall—Heavy Losses—Character of Sir William Fairbairn—Whitworth's Machinery—Different kinds of Marine Engines—P.S.N. Company and the Compound Engine—History of a "New and Improved" Design—Lucrative Inventions—Value of Good Machinery—What it did at the North London Railway Works—Richard Roberts.

DURING the time that railways and steam vessels were being established, engineering in other branches was springing into vigorous life. Penn, Maudslay, Napier, and others, were rapidly simplifying, skilfully proportioning and generally improving the construction and arrangement of engines and boilers. Mill-gearing, another most important branch, received all attention from Fairbairn, who greatly benefited the mill proprietors by introducing his improved shafting, engines, water-wheels, &c., to their works. He also developed the best proportions and designs for iron bridges of every description. In conjunction, too, with Professor Hodgkinson, of Manchester, he entered upon a most elaborate and careful series of experiments and calculations relating to the strength of columns, girders, trussed beams, &c., which were of the highest value to the profession.

On such points little was known at this time, theoretically or practically, it was all guesswork, which resulted, naturally enough, in very serious disasters. Another subject of very careful investigation was the art of "Construction," which every engineer knows is all-important, neutralising as it does, when defective, the most accurate calculations and plans.

The wonder of that day was the Britannia Bridge over the Menai Straits, but neither Fairbairn nor Robert Stephenson would venture to construct it until a complete series of experiments on a grand and costly scale had been made, to verify their calculations and confirm the accuracy of their designs. In this branch of Engineering, variations in size range from the colossal "Forth" down to the smallest foot-bridge. In style also, there is extreme diversity, and, in most cases, separate computations and sets of drawings have to be made, to suit the ever-changing conditions of general practice.

The late Sir William Fairbairn carried on for fifty years an increasing and most lucrative business, and his Canal Street Works, in Manchester, were considered one of the finest establishments in this country for general engineering. He also started, in 1835, a large shipbuilding and marine establishment at Millwall, where he built upwards of one hundred vessels during the thirteen years the works were in operation, the largest orders for which came from the Admiralty and East India Company. Partly owing to the distance, however, between the two places, his frequent and prolonged visits to the Continent, and other causes combined, Millwall caused him a loss of £100,000 in twelve years, which he fortunately covered by his profits in Manchester.

This was a time of great anxiety, and notwithstanding his immense energy, perseverance, and buoyancy of spirit, he had fits of melancholy, during which he fancied he saw every possible aud unhappy contingency. When the railway system began to spread, the canal people thought they could, to some extent at least, compete with it by the use of high-speed steamboats. A series of experiments were therefore made by Fairbairn on a little iron vessel named the "Lord Dundas," but so conclusively did those efforts demonstrate the impossibility of high speed ever being attained, on account of the shallow and narrow channel, that the project was abandoned.

This great engineer was one of those intellectual people who are never happy unless they are fully occupied. He had extreme earnestness of purpose—work was a necessity of life, and business a pleasure. He was also unceasingly occupied with his pen, his pencil, and his draughtsmen, in planning, scheming, and improving. Besides all this, he was a most able and prolific writer of books and papers for learned societies on practical science, and his treatises are among the best ever written.

He received many marks of distinction from foreign governments, and in England his principal titles, besides knighthood, were D.C.L., and LL.D. Simple-minded and amiable, good, kind, and courteous to all, he became a universal favourite both at home and abroad.

Born in 1789, and sustaining throughout a long and arduous career a highly honourable character, which may be taken as a model by all aspiring workers, Sir William Fairbairn passed away in 1874, but his name will long live in what he has done.

Another "eminent," who flourished contemporaneously, was Sir Joseph Whitworth, but his "line" differed from Fairbairn's, inasmuch as he devoted himself almost entirely to constructive machinery, or machines for making engines and other work, such as those for turning, planing, slotting, boring, &c., which every engineering establishment possesses to a greater or lesser extent.

When I thought about commencing business, it was intended that I should enter an Edinburgh bank, and application was accordingly made in furtherance of this object; but as it proved there would not be a vacancy for two years, I had to look out for something else. Strangely enough, I had a great love of engineering and architectural drawing, in which I made rapid progress.

This induced one or two of my friends to propose that I should learn practical engineering, and efforts were made in that direction to accomplish their wishes on my behalf. There was one serious drawback, however, and that was that I did not like the idea.

Jim Macfarlane, a young friend of mine, was at that time a pupil in Hawthorn's locomotive establishment, in Leith, and had to get up at five in the morning, to enable him to be at the works by six. He was also obliged to go in "dirty clothes"—which an old and excellent uncle of mine rather objected to—and when he hadn't time to trim himself up, occasionally came among us in his war paint.

He used to speak about the strictness in the works, what they did if he came late, and what they didn't do if he did something else, and how they were fined for "jobbing," or making tools of any description for themselves. All this set me more against it, but it was of no avail, as I had lost my father in a far-off clime when very young, had only my own efforts to trust to, and had to take what I could get, and that was a start in practical engineering, which a kind friend was fortunate enough to obtain for me.

No sooner, however, did I see Whitworth's machinery, with which the works abounded, than all my objections vanished, and I became almost fascinated with it, and from that day to this have never ceased to take a deep interest in every thing relating to the profession. On this point, however, I shall have more to say further on.

In the first place, Whitworth's machines were remarkable for extreme elegance and simplicity of design; in the next place, their fitting together was absolutely faultless; and lastly, their finish could not be surpassed. I saw other people's productions as well, but they were commonplace in comparison, although they did good work. There was one lathe in particular, which was made by a firm in Leeds, who subsequently acquired celebrity; but for badly constructed wheels, complicated arrangement of parts, and ugly outline, I have seldom seen anything to equal it. The foreman said it was "only fit for the melting pot."

There is nothing of such vital importance in all manufacturing processes, from that of making a match box or pin to the colossal engines of the "City of Paris" or "Umbria," or, indeed, large or small work of any kind, as good machinery. By this term I do not mean machinery which merely looks well, or works well, but that which turns out the best work with the greatest rapidity. In our time of extreme competition and very low profits, nothing else will do, and hence it is not uncommon to find the most admirable machines and engines set aside as useless, on account of some small improvement which effects a great saving, and soon repays the money expended in obtaining it. Nowhere, perhaps, has this been more remarkable during late years than in the iron and steel manufacture, and in steam navigation.

I remember the time when almost every engineering firm had its own pet type of engine. John Penn had his "oscillators" and "double-trunk," the latter of which he made in large quantities for war vessels. Napier had the "side-lever," which he put into all the Cunard steamers of that period. Tod & McGregor highly valued their "steeple" engines, which they supplied to the Inman and Peninsular and Oriental Companies, as well as others; and Caird, Denny, and a few more, made an immense quantity of the "inverted direct action" species, which were of the same family as those now so generally used in ships, but of a different construction.

The other kinds referred to have become obsolete, as the two cylinder compound, and, eventually, the triple and quadruple expansion engines proved to be more economical.

In all these engines there was a vast amount of excellent work done by hand, which is now executed by machinery, and the engineers of that time had splendid opportunities of learning practically what those of the present day will never have in their power. As may be supposed, however, labour of this description was slow and expensive; the increased use of machinery has, therefore, greatly lessened the cost of production, and wonderfully expanded manufactures of every conceivable kind, which has been most beneficial to the world at large; but, in this respect, a very great amount of prejudice has been shown, in connection with the introduction of engines as well as machines.

About the year 1852, John Elder,—who had been educated in Napier's, but was now the head in the marine department of his very eminent firm,—introduced, in a greatly improved form, what had been known as the "compound engine," invented in 1781, and first used in the steamers "Union" in 1829, and "Le Corsair Noir" in 1842. Many of Napier's splendid "side levers" were taken out of steamers to be re-engined with those of the new type. The Pacific Steam Navigation Company, who owned them, quickly saw the great advantage they would derive by adopting it in their numerous ships, thus reducing considerably the consumption of coal, which was rapidly swallowing up their profits, and from that time until the year 1887 they used no other description.

Here, then, was a splendid and economical engine thrown into the market, which had been most successfully tested on long voyages, and possessing virtues hardly anyone could see but the great Company just named. The Cunard people clung pertinaciously to the old "side levers" which had helped them to fame and fortune; the Inman Company were quite as faithful to the "steeple" and "horizontal" engines they had learned to esteem; and all the other people had their own favourite types which they would not relinquish, even for the new one.

In the year 1868, I happened to be in the employ of Messrs. Laird Brothers, whose Birkenhead Iron Works did an immense quantity of work of every description and of all sizes for home and foreign governments, and for the merchant service, jogging comfortably along with the old and universally recognised systems of marine machinery. Unconsciously, however, a change was at hand of which we little dreamt. Some one outside of the Pacific Company discovered that the "Compound" was, after all, a first class and very desirable engine, and we got our first order to "convert" a large steamer—the "Belgian." Like an epidemic the idea spread amazingly, it came upon the world like a flash, and plenty of similar orders came pouring in; at one time for a new ship and engines, at another for the alteration of one or two more, and we were all kept extremely busy for several years.

Now why was this "good thing" not discovered by the general public long before? The Liverpool and other shipowners had it working in their midst for many years, and yet could not appreciate its value. I suppose the answer is "prejudice." The writer and others associated with him have also, in a small way, been the victims of this unhappy failing, as the following narrative will show.

Some time after I began private practice, two seagoing engineers came to me in the hope that I could help them with a not by any means matured idea of theirs, and put it into practical form. This idea took the shape of an extremely rude sketch of a "New and Improved type of Compound engine" with Corliss valve gear. I told them I had about as high an opinion of this gear as they possessed, on account of the ease with which it is worked when exposed to high steam pressures, and also from the fact that in America it had for a long time been most successfully used on land and sea, and also in this country on mill engines, "but," I said, "you will find the British public won't adopt it on the water, particularly when it was tried in one Liverpool steamer and taken out again." Well, they would persist in having their own way, so after stretching a large sheet on a drawing board, and making a preliminary sketch, I began the design with diameters and stroke of pistons, and steam pressure of 100 pounds per square inch as a basis.

I had frequent visits from these worthies to see how I was progressing, or "getting on," and to hold conferences on important points. Alterations were suggested, lines taken out and put in again, shafts were removed, levers shifted, and the position of every detail rectified so as to approach perfection as nearly as we could.

What earnest discussions we had over those engines!—sparing neither time nor trouble in our anxiety to obtain the very best results, which we aimed at quite as much in this speculative design as if it had been for a mail steamer. Our individual proposals were sometimes unitedly condemned, or in other words, what was statically right, proved to be dynamically wrong. They were plain men with small means, and I saw clearly that I would get very little for my trouble, but did my best for them nevertheless. They were also good, experienced, sea going hands, who knew well what they were talking about, and we accordingly got along most pleasantly.

At last the design was finished, complete in its details—two elevations and two plans—but our ideas having developed faster than we imagined, we unitedly condemned the whole thing. The engines looked "too sprawly,"—not compact enough,—but that was my clients' fault, so we at once began No. 2 design.

This time we shortened the stroke six inches, and made a sweeping alteration in the position of the low pressure cylinders, still adhering, however, to the Corliss valve arrangement, and the result was a plan which pleased us all. We now had a quantity of lithographs taken of them, with printed descriptions, which were sent to shipowners and engineers throughout the country. The general opinion was that the design was excellent, almost everyone liked it, but the Corliss valves were condemned on all sides.

We were not going to be sat upon in this way, so we made a third attempt. "Now," I said to my clients, "we'll cut out the obnoxious Corliss gear for the high pressure cylinder, and treat them to the piston valve, equilibrium type, easy to work, you know. Keep the common slide valves for the low pressure cylinders as before, and let all the pumps and other gear remain exactly where they are." We also designed an "Improved marine boiler."

At last success smiled on our continued efforts, for the general opinions now were—"a very nice arrangement, indeed;"—"fine long connecting rod;"—"very compact and symmetrical;"—"very get-at-able;"—and so on. The valve gear was also approved of, and the boiler received great praise, indeed, an eminent authority in Liverpool, himself an engineer as well as shipowner, spoke most highly of both; but when I asked him if he wouldn't introduce them into his own fleet, he said, "they had never been tried; his own special engines gave him every satisfaction, and he did not wish to make alterations; besides," as he wisely added, "if anything should go wrong at sea, it is not the cost of repairs that I dread, but loss of time on the voyage."

Everyone seemed to have similar opinions, too, and asked if they had "been tried?" We said "no," and that was enough, they all waited till "someone else" made the experiment before they would have anything to do in the matter, and thus our work in the end went for nothing. I like to point a moral, as well as adorn a tale, if I can, and I think the moral is this: avoid, as much as possible, dabbling in *big and expensive things*. Our engines would have cost thousands of pounds to make, and therefore people were afraid of them. Had we, however, designed an improved pencil-holder, or something similarly useful, to sell by the million, the plans for which could have been sketched in a few hours, my clients might have made a fortune, as some people have done through the most trivial, but nevertheless popular, inventions.

A few individuals have made immense incomes out of simple devices they have patented, but certainly did not originate. In this respect, schoolboys have unconsciously disclosed a perfect mine of wealth by means of their ingenious discoveries. If, for instance, anyone had—about thirty years ago—turned inside out the pockets of some of those youths, there would have been found amongst other treasures, a small piece of lead pencil stuck into the nib end of a steel barrel pen, the other end of which contained a plug of india rubber. Sometimes slate pencil and a piece of rag were used instead, but, at any rate, this was the germ of the now well known india rubber tip pencil, which has yielded a profit of £20,000 to the patentee, merely from royalties paid by its manufacturers.

The "return ball," with elastic cord attached to it, is another schoolboy invention which brought in a revenue of about £10,000 a year to the person who appropriated it in legal form. Long ago, those youths sometimes fastened to their feet two little flat boards on wheels, and then got some one to haul them along. This was the beginning—the crude idea—of the roller-skate, the patentee of which made nearly a quarter of a million sterling through the working of his "invention." Truly the boys deserve looking after in more ways than one.

Mr. Fox realised £170,000 out of his "paragon frame" for umbrellas, and the owner of the "stylographic pen" made £40,000 a year by his discovery. A few patent toys have also produced magnificent results, but one of the most profitable novelties of the present day has been the sewing machine, which was invented by Elias Howe in 1844. After the idea had flashed upon him, he worked upon it earnestly for years, struggling with poverty, until his beautiful mechanism was perfected, and eventually his income rose to £100,000 a year. Wheeler and Wilson were each equally prosperous, and Mr. Singer left behind him as clear profit from the same source, three millions of pounds.

Fortunes may still be made in a similar manner, if people can invent something really useful,—like the perforating machine for stamps, etc.—something that will save time and labour, or catch, in some way or other, the popular taste. It may appear strange, but it is nevertheless true, that the shareholders' available profits, derived from some of our most stupendous railway undertakings, fade completely away when compared with the magnificent results of the humble and inexpensive Switchback lines, whose lives are short and merry, and wonderfully beneficial to all concerned.

In the history of this branch of engineering, there are indeed many dark shades. Fortunes have been lost, health has been ruined, hopes have been blighted, even by the most deserving people, while trying to win the success which, after all, was achieved by others who profited by their labours. Fortunes have also been lost by those who thought they had discovered something of real value, but had not done so. The aim of designers is to make their schemes remunerative, but between a professional triumph on the one hand, and commercial prosperity on the other, there is sometimes a very wide chasm. Probably there may not be a demand for the article even when perfected, or perhaps the cost of manufacture is too great to enable it to compete successfully with what is already in existence. Occasionally, however, the so-called "improvement" is only the dream of an unpractical enthusiast, whose aim may be to produce perpetual motion, or something approaching it, if possible. The history of inventors abounds with cases similar to those referred to, but perhaps enough has been said to shew the difference between two distinct and well known classes of ingenious experimentalists.

The field of invention is vast and varied, and open to everyone, regardless of age, sex, station, or means, but it is often very disappointing, and those who enter it have frequently to exercise sound judgment combined with unlimited patience and perseverance under difficulties, to enable them to attain their desired end.

Good machinery is absolutely necessary in conducting every kind of manufacture rapidly, successfully, and profitably, and perhaps one of the best illustrations I can give, relative to the "constructive" species, is to be found in the history of the North London Railway.

This line was opened in 1850, but its locomotive works were not built until five years afterwards. In the meantime, a gigantic traffic had sprung up, and when the making of their own engines was added to that of repairing, they were nearly overwhelmed with work which the superintendent was obliged to execute at all hazards. So great was the strain thrown upon the establishment at one time, that the Directors hardly knew how to deal with it. The men were working on night and day shifts doing repairs, but in spite of this, no engine could be spared long enough to enable its defects to be properly rectified at one lying up. It is said that goods trains were worked in the dead of the night, with the engine leading tyres so loose that they had to be run only at such speed as would enable men to follow them with lanterns and hammers to see that they did not come off. I fancy, however, that this is a mythical story, but it nevertheless had a foundation of truth.

The fact was the line and workshops were taxed far beyond their capacities, and, to tide them over the difficulty, special, and in some cases very simple machinery had to be devised. Besides this, there were little things known as "appliances," which helped very materially in rendering assistance, and to crown all, a most admirable system of management was planned and carefully worked out in every little detail. These united and well directed efforts eventually produced the happiest results.

Constructive machinery has now attained great perfection, and nowhere is this more observable than in vast establishments, such as the London and North Western Railway Works at Crewe. All the fixed and movable plant, including bridges, canal boats, locomotives, steel rails for the lines, steel plates, &c., for the steamers at Holyhead, and everything else, great and small, is made on the premises by means of special machines and engines, which execute everything to perfection and with great rapidity. The same remarks may also apply to similarly colossal and unique establishments of another description, such as the Elswick Works of Lord Armstrong & Co. at Newcastle, and those of Sir Joseph Whitworth & Co. in Manchester, where some of the most costly and gigantic machinery in the world is to be found. The former, however, is now closed against non-official visitors. In Messrs. Platt Brothers' Works, at Oldham, and also those of the Singer Sewing Machine Co., on the Clyde, constructive machinery of a more or less delicate kind is employed in the manufacture of textile mechanism and appliances in the one case, and of the American invention, combined with steam-boilers of a special description, in the other.

All these works are interestingly instructive, both to professionals and non-professionals, as they are among the best and largest of their class in this or any other country. The Elswick establishment alone employing fully 13,000 hands, Platt Brothers at least 5,000, and Crewe about 16,000 in all departments.

The term "special" is applied to everything which is used for one particular purpose, and, in locomotive and some other establishments, there is such a large quantity of details of a similar kind and size constantly in hand, that the adoption of the generally useful machines of a "marine" work would neither be desirable nor economical. Having had a turn among locomotives myself, I cannot admire those branches of engineering which change men and boys almost into automata, as they are kept such a long time doing the same thing, and, in too many cases, of such a simple character, that it might easily be learnt in a month. So far, however, as the apprentices are concerned, a good premium protects them from this evil; and in the manufacture of engines for ships, and also a great variety of heavy "general" work for pumping, winding, mill-driving, and other purposes, it cannot well exist.

To carry on the indescribably miscellaneous assortment of everyday manufactures, such as wood-work, and metal work of every conceivable description, there is an immense quantity of machinery employed, which would astonish an outsider. For example: a "splint" machine, in the hands of a boy, will cut splints for at least 10,000 matches in one minute, and even this can be greatly exceeded. There is, however, no establishment in Great

Britain so instructive in this respect as Woolwich Arsenal, on account of the extreme variety of the machinery employed in the production of everything, large and small, connected with warlike stores and appliances on a gigantic scale. This vast institution covered in 1866 three hundred acres, and during the Crimean War employed 15,000 men and boys night and day.

The last class to which we shall refer is that most important one used so extensively for all textile fabrics in silk, wool, cotton, alpaca, &c., which the united efforts of many able engineers have done so much to improve. To them alone the ladies owe a debt of gratitude, for enabling them to obtain every article of dress they wear at such extremely low prices, and to no one ought they to be more thankful than the late Richard Roberts, of Manchester.

He was a man of great ability, and one of the most prolific and useful inventors of his time. To the highest practical and scientific knowledge, he added the qualities of great perseverance, and studious research. Ultimately he became a partner in the firm of Sharp & Roberts—now Sharp, Stewart & Co.—but, after coining wealth for the cotton spinners, and benefiting the world at large, he unhappily died in poverty, and left his family to be provided for by others.

CHAPTER III.

DUMBARTON AND THE CLYDE.

My apprenticeship in Denny's 1852—Great prosperity in the various Works—Engineer Workmen—Strikes in the Shipyards—William Denny hands over a large contract to Caird & Co.—Later Strikes among Coal and Iron people—Belgian Iron Trade—How Strikes begin—Generalship of the Masters—The "Delegate"—Unhappy Workmen—Dumbarton at this period—Disastrous Storm—Death of William Denny—Engineer Foremen—S.S. "Yorkshireman"—The Penalty—The Wreck—A good Speculation.

In the end of 1852, I entered the works of Messrs. Tulloch & Denny, now Denny & Co., for the purpose of learning marine engineering.

Dumbarton at this time was a very quiet place, provided you kept out of hearing the clattering of hammers in the ship yards with which it abounded. If you walked down the main or "High" Street during the day, you were forcibly tempted to ask "Where are all the people?" as the only individuals visible were a few stragglers, or one or two shopkeepers standing at their doors looking for customers who were at that time elsewhere. At one end of this street stood the Parish Church, and a little distance down, the "Elephant and Castle" and "King's Arms" hotels rose to view, then came a bridge across the Leven, and proceeding onwards to the other extreme end, you arrived at the beautifully situated place where all the engines and boilers were made for ships built in three of the yards. The engine works were washed on two sides by the Leven,—a broad outlet of Loch Lomond,—and were also fully open to the Vale of Leven, and the charming mountain scenery of Dumbartonshire.

In short, there never was a work of this kind so pleasantly located,—to my knowledge at least.

In fine evenings everyone was out promenading, the magnates of the town and others marching up and down the centre of the High Street, while the workmen, in a similar manner, occupied their leisure time in crowding the street generally. An air of peace and serenity prevailed everywhere, except in some late working establishment, and on Sundays this was of a very marked character, as all traffic by land and water had ceased.

Such, then, was the place where I had to reside for the next few years, the monotony of which was only broken twice a year by a fortnight's holiday in July and December, and by occasional brief visits to Glasgow. In former times, Caird of Greenock had made all the engines that were required for the ships built by the Dennys, but in 1850, the establishment I had just entered was opened to meet a want which had been increasingly felt, and the result was, that for a long time afterwards, they had as many orders in hand as they could possibly execute, indeed, for about two years, eight and ten o'clock work was the order of the day—or night,—for most of the hands.

The men and boys were remarkably steady, respectable, and well conducted, and during the whole period I was among them, often worked a great deal more than six days a week on account of "overtime," which many got tired of however, although "time and a quarter" from six to eight, and "time and a half" from eight to ten, were considerable advantages in a pecuniary way, Such was my opinion then, of those employed in the engineering department, and such it has ever been, but no similar commendation can I give the shipbuilders, who were, without exception, the most cantankerously unmanageable crew I have ever seen. They were very fond of drinking, and much liked striking. At one time the rivetters would strike, and the "holder up" boys go off for a holiday. Then the youths would have a turn at the same employment, and their masters—the rivetters—"go on the spree," compulsorily or otherwise, *generally* otherwise.

Next in order came the platers, who thought they might try their fortune, and the carpenters and joiners followed in the rear. Thus they went on by stages until some one found out that "union was strength," then they all struck. I remember on one occasion Mr. William Denny had received an order for four steamers of 1,000 tons each, which were to be built with all despatch. No sooner did this become known, than the men thought it would be a fine chance for obtaining more pay, and accordingly struck at once. This was a very imprudent movement on their part, as the work was not quite begun. Mr. Denny therefore rounded on them cleverly, by immediately handing over the whole contract to Caird, and left them to come to at leisure. We, in consequence, lost the engines.

Another striking era, with which, however, I was not associated, occurred about the year 1876. This time it was among the coal and iron people of Wales. Iron ran up by degrees until it reached the highest price ever known, which was very embarrassing to engineers and shipbuilders. Coal was also advanced to fabulous rates, thereby causing the British householder much annoyance and loss. It was curious to note how these two classes of workmen, while studying their own individual interests, played into each other's hands, until they were, we might say, masters of the situation, and enriched by conquest. Such, at least, was my own opinion, when I heard of them wearing sealskin jackets and caps, and also gold watches. Luxurious living, too, was highly prized, and first-class travelling on railways, &c., was frequently adopted, all of which became, for a time at least, somewhat unfashionable.

There is an old saying that "every canine animal has his day," and I think the aphorism quite applicable in this case. The colliers and ironworkers had now reached the summit of their ambition, but, like old Rome and ancient Greece, their glory trembled in the balance and then departed. Things righted, as many, though not all, do in time, and the two products of the earth gradually came down in price until they were lower than they had ever been; but this was only part of the play. A great deal of mischief had been done by the iron people, from which they have never recovered.

The Belgian manufacturers, seeing the state of affairs here, at once began to open a connection with this country, which, in course of time, became most powerful and damaging. They commenced supplying us with all sorts of iron beams, girders, and bridge or roof-work generally, and at such low prices, that English iron for such purposes was almost driven out of the market, and even now, with our own materials so extremely cheap, their importations are extensively used in all kinds of building constructions.

At one time those continentals bought our iron ore, worked and manufactured it for themselves, and delivered it in England for much less money than we could do on our own territory; and the reason was this. The Belgian workmen were very steady and reliable, they had longer hours and less pay than the British, and were content to live in a style corresponding to their position, and, above all, to keep sober. Those who know this subject intimately have also their tales of disaster to relate on a gigantic scale, of men and women impoverished and trade ruined; such, I believe, was the case with the once prosperous business of iron ship-building on the Thames.

The annoyance such men as I have mentioned cause their employers is sometimes very great. Say, for example, a large firm gets an extensive order to execute with all possible speed, under, it may be, heavy penalties for delay beyond the time specified. In the first place, their estimate, which must be adhered to, has been based not only upon the current prices of material, but upon current wages as well. Whenever the contract is signed, the work commences, and the greatest activity reigns in all departments.

The men knowing this, or their "delegates" for them, at once organise a strike, and try to compel the masters to give them an increase of pay. Well, now, what is to be done, with the whole establishment in full swing? If the employers agree to give what is asked, they may be put to serious loss; if they do not, the hands may leave off work, and perhaps a greater disaster arise on account of the penalty, unless protected by the "conditions of contract." The best course to pursue, in similar cases, is for the men to stay where they are and be content, but they will not always do this. A medium course is to settle the matter by arbitration, as the lesser of two evils, and a third is to treat them as Mr. Denny did, provided the work has not gone too far, and will not involve the firm in another harassing difficulty—"breach of contract." You will, therefore, clearly see the unhappy complications which may arise, almost at once, through the conspiracy of a set of discontented, and, it may be, drunken and dissolute workpeople.

It is deeply to be regretted that such a state of things should exist, but I am afraid it will continue, so long as men and women are what they are. I do not, however, blame the "hands" so much as I do the "delegates," who are only men advanced from the ranks, and dressed in a little brief authority. Their pay is, I think, about £2 a week with all expenses; besides this, they go about "like gentlemen," which is a coveted honour. For these valued benefits, they of course feel that something must be done in return, just as you or I would, under similar circumstances, and thus an honourable feeling is degraded into acts which cause heavy loss, if not ruin, to the employers, and incalculable misery to those who have been led into them. If you wish to study the subject in all its bearings, and if you should desire to fathom the inner workings, and even terrible crimes, such a system educates people to, the newspapers for the last twenty years will give the necessary information.

When I speak of crimes, no matter of what kind, as well as minor evils, I think most people will allow that they are all mainly due to one blasting, blighting, desolating curse, which pervades the British Isles,—the love of drink. When I take a retrospective glance at the people I have known in the various classes of society, the amiable and kind, the good and true, those whose prospects were bright, as well as those from whom the sunshine of life had departed, men and women, gentlemen and—*ladies!* it seems to me as if the English language did not contain words strong enough wherewith to crush the grim fiend, and yet I believe there is a quotation from Lalla Rookh which will be sufficiently powerful.

It refers to the veiled Prophet of Khorassan who, when disclosing his horrible features to Zelica, exclaimed :—

> "Here,—judge if hell with all its powers to damn,
> Can add one curse to the foul thing I am."
>
> . . . .

So awful was the sight, when he raised the veil—that—

> . . . .
>
> "The Maid turned slowly round,
> Looked at him,—shrieked,—and fell upon the ground."

The poor "heathen Chinee" destroys himself just about as surely by opium smoking, but when in the seventh heaven of delight, through the use of the fatal drug, he is an inert, insensate, harmless mortal, whereas when *our* people use their beverage too freely, they become raging demons, and this makes all the difference.

When I went to Dumbarton, I was young, very prejudiced and conceited, and a great deal more ignorant of the world than I hope I am now. At this period, there were no reading rooms, no lectures, and no entertainments of any kind, beyond an occasional "Grand Concert" in the Odd-Fellows' Hall, by Glasgow stars, among whom Stembridge Ray, Gus. Lloyd, Sam. Cowell, and others used to shine. Miss Emily Ray, too, at that time very young, assisted in a small way. When not enlivened by these festivals of song, the town was extremely dull in the evening. Fortunately for me, however, Sheriff Steele,—an intimate friend of ours from his boyhood,—and his good lady, who resided there, helped in no small degree, by their kindness and attention, to make my few years residence among them more agreeable.

I had not been long in the works before I discovered that it would be a source of great pleasure and advantage if I could get permission to sketch and take dimensions of the engines in progress during leisure hours, and draw them out fully at home. This privilege I succeeded in obtaining, and during the whole of my apprenticeship esteemed it all the more highly because engineers at that time were very jealous of anyone in their employment taking notes, and as "leisure time" proved to be part of the dinner hour, as well as Saturday afternoons and summer evenings when necessary, I had always plenty to do. The system I adopted was this:—every detail, big and little, about the engines, was overhauled and carefully sketched and dimensioned, so that I could from the rough particulars make complete general drawings at home—plans, elevations, and sections, to scale.

It was splendid and fascinating practice, but it often gave me more work than I cared for, and very frequently allowed me only four-and-a-half hours' sleep, when the drawings had to be sufficiently far advanced before the engines were taken to pieces in the erecting shop. No one, perhaps, could have made a greater hobby of any employment than I did of mine, and I rather fancy that if the Firm had had any idea that the plans of every kind of engine they made were to have found a place in my portfolio, the favour would not have been granted.

One of the memorable events that happened in my time was the storm of February 6th, 1856. We were on that occasion working till midnight, erecting the engines of the "Min," a China steamer, and, as one of those so employed, I went home for tea at six. A calm prevailed, but soon afterwards the wind began to rise in gusts, until about eleven o'clock, when we were in the middle of a perfect West Indian Tornado, and as the works were fully exposed, we felt the tempest in all its fury. Call it a cyclone, hurricane, or anything else you please, there was one thing very certain, and that was, that things seemed as if they were going to pieces, and had the great doors of the building not been securely stayed inside with timber props, they would have been blown in, and great damage might have resulted.

Since that eventful night, I have witnessed many a terrible storm, but never one so destructive to property, or one which left its marks behind it for such a length of time. Helensburgh stone pier was destroyed, and many house windows blown in, tall chimneys, etc., thown down, and amongst a variety of other disasters, was the wreck of Tod & McGregor's building shed, which had recently been erected in Crystal Palace style, at a cost of £15,000.

A correct knowledge of the force of wind is most essential to an engineer, but strange to say, until after the Tay Bridge came down, the greatest authorities on the subject differed very widely. Some said one thing, and some another, but no one seemed to know what the greatest wind stresses really were. If this disaster had not occurred, we might still have been in the dark, but that terrible calamity caused a searching enquiry to be made with the view of elucidating facts which were certainly mysterious. In this respect, however, the engineers of the Forth Bridge have done good service to the profession, by making a series of experiments on a very large scale, which enabled them to ascertain, not only the ordinary storm pressures per square foot, but also what those extraordinary and unaccountable blasts of intense severity over a small area sometimes amount to. In this, they have been to some extent successful, as it has at last been officially decided that the greatest wind pressure to be safely allowed for on all flat and fully exposed *vertical* surfaces, need not exceed fifty-six pounds per foot.

During a recent excursion to the country, I came to know something about atmospheric disturbances which might be useful to scientists in general.

While our party were visiting the residence of Mr. Worsley, near Winwick, Lancashire, he showed us a part of his grounds which had been injured by a storm some years before. Upon questioning him closely about it, he told me that, when at its height, a blast of most intense and concentrated energy had swept over his garden, cutting like a knife through some rhododendron bushes, and snapping off two large trees near the root, besides doing other damage. The strange part of it was, that outside of what we might call the line of fire no mischief was done. In the tropics, however, such experiences are by no means uncommon.

Another event that happened at Dumbarton in those days, was the death of Mr. William Denny—*The* Denny. He was of short stature, and had a very mild, gentle, unassuming manner. He also was the genius of the family, and had conducted most successfully the very celebrated establishment over which his father had reigned before him. The day of the funeral was a day of silence, as the various works were closed, and we all escorted his remains to their resting place. Thus passed away from among us, at an early age, one to whom Dumbarton owed much of her prosperity.

The judicious employment of various metals has thus been the means of greatly reducing the weight of machinery, and this in itself is an important advantage for shipowners and others. We may only add, that the training apprentices received in Denny's, in everything that required skilful hand labour, was of such a nature as to prove valuable to those who afterwards went to foreign lands, and were thus cut off to a great extent from good workmen, and from high-class appliances of every description, which is a great deal more than can be said of workshop practice at the present time.

CHAPTER IV.

GLASGOW AND OCEAN STEAM SHIPS.

Dumbarton as it is now—Neilson & Co., Glasgow—Tod & McGregor—S.S. "Bengal" for P. and O. Company—First Sunday Steamer on the Clyde—River Steamers "Columba" and "Lord of the Isles"—Great Works on the Clyde—Cunard Atlantic Ships in 1850—Mediterranean Liners, 1852—P.S. "Persia"—Robert Napier & Sons—Compact between Cunard, Burns and MacIver.

I LEFT Dumbarton in 1857 to enter, as a draughtsman, the celebrated establishment of Messrs. Neilson & Co., Hyde Park Foundry, Glasgow, but only recently had a prolonged opportunity of revisiting the old and well-remembered scenes of early days on the banks of the Clyde. One day I paid a visit to the little town I knew so well, but it was as changed to me as Rip van Winkle's village was to him after his twenty years' sleep. I looked for relics of bygone days, and saw only a few. I went to my old works, and did not see one I could recognise, but was most courteously received by Mr. Denny, and shewn through the present splendid establishment. I walked over the remains of the past, which had not yet been obliterated by modern improvements, and thought I could see again the well-remembered faces of my contemporaries. But it was only fancy, and had it not been for those around me I should

Have felt like one
Who treads alone
Some banquet-hall deserted,
Whose lights are fled,
Whose garlands dead,
And all but he departed.

Having carefully surveyed everything I saw in the shops and drawing office, I must give Messrs. Denny & Co., great credit for their elegance in design, and also for the elaboration and carefulness with which their drawings are executed; nor must I omit to mention the four young ladies, whose work I had much pleasure in examining, and who trace those drawings so admirably in every respect.

Messrs. Neilson & Co. were, in my time, considered the best "general" engineering people in Glasgow, and made marine, locomotive, pumping, blowing, &c., engines, and a variety of other work. They had such a large business that the firm eventually removed to the suburbs, where they built a very extensive and carefully arranged establishment, and devoted their whole energies to railway engines, large numbers of which were sent to India and other foreign parts.

Tod & McGregor, of Clyde Foundry, Glasgow, was another celebrated firm I had the honour of being associated with. After a very long and successful career, however, they closed their premises a few years ago—the Inman S.S. "City of Richmond" being their last ship. At one time they were constantly building vessels for the Peninsular and Oriental Company, whose last paddle steamers, the "Ganges" and "Singapore," were built, I think, in 1852. At that time the screw-propeller was becoming better known, the above Company, therefore, gave it a trial by requesting Mr. Tod to build the S.S. "Bengal" for them, and so highly pleased were they with the performance of this ship, that paddles were discarded ever after.

Amongst the numerous ships which followed for the same Company, was the "Delhi," which had vertical trunk engines, but owing to the Indian Mutiny atrocities at this period, they changed her name to "Nemesis"—or the "Avenger." The Inman Company also gave them many vessels to build, having in nearly every case Mr. Tod's steeple engines. Their machinery was elegantly designed: light, strong, and highly-finished in all the parts above the cylinders,—which lay at the bottom of the ship. The engine-room had also abundance of natural light, and every detail was easily accessible and easily seen; whilst those on the starting platform, or on the upper deck, could take in at a glance everything around them. With many other firms too, these engines were very popular, for paddle as well as for screw steamers of all sizes.

Tod & McGregor were also greatly in favour with the Egyptians, and especially with the Pasha, for whom they built several beautiful steamers having oscillating engines, one of which—the "Faid Rabani," or "Light of Heaven,"—was fitted up as a steam yacht in magnificent style, and at a cost of £70,000. It was reported that on one occasion she ran upon a bank in the Nile, and as they could not well get her off, His Imperial Highness became so enraged that he went about the ship destroying the costly ornamental work with his own hand.

Mr. Tod died in 1859, and Mr. McGregor, of the shipyard at Partick, six weeks afterwards. Mr. William Tod, the eldest son, now assumed the management of the engineering department, and I entered his drawing-office in 1860. This gentleman was without exception the most genial and kind-hearted engineer I ever knew in Scotland. He was highly esteemed by all, was rich, and had a good business, but "died young," and this, unhappily, may be said of too many of the choicest and most promising people we have known in life.

Another Clyde Foundry worthy was Mr. R. F. Pearce, the business-manager, and formerly of Chester. There are people we sometimes meet who have an unhappy talent for looking on the dismal side of everything, either in expectation or in possession, and for colouring their surroundings with Payne's grey or neutral tint, not to mention Indian ink or lamp black. If the sun shines, or the flowers bloom, or the health-giving breezes blow, they think they are for others, but not for them, and all because these unfortunates are unable to extract the sting from the nettle,—the bitter from the sweet in life,—and either do not know, or seem to forget, that the world in general is pretty much what we make it for ourselves.

There are others, however, who, in the midst of anxiety, and perhaps trouble, are bright and happy, though often cast down, and still more happy when the end draws near, because they are masters of the art of painting their thoughts and actions with liquid sunshine, and helping to tint those around them in a similar manner. To a large extent Mr. Pearce was one of the latter. He was essentially a "happy man"—one who never seemed to feel he was getting older, or that there was any care and anxiety in *his* part of the world at least. He enjoyed his own jokes immensely, and much liked sometimes to come into our office to tell some funny story, and ask kindly for all of us. He too, I regret to say, has recently departed, but with me the memory of those two good, kind friends, will be ever green.

One of the ancient remains of the Clyde Foundry is still to be seen on that river in the shape of the old paddle steamer "Inverary Castle." She was built in

1839, but, during the interval, has had at one time a new bow, at another a new stern, and, after that, she was lengthened. When I had the pleasure of seeing her come into Rothesay some years ago, with her saloon filled with flour and meal bags to feed the Highlanders, she looked as smart and youthful as if only a few years of age. One of her crew told me about the alterations in her hull, and emphatically added, " Her plates were very tough, sir."

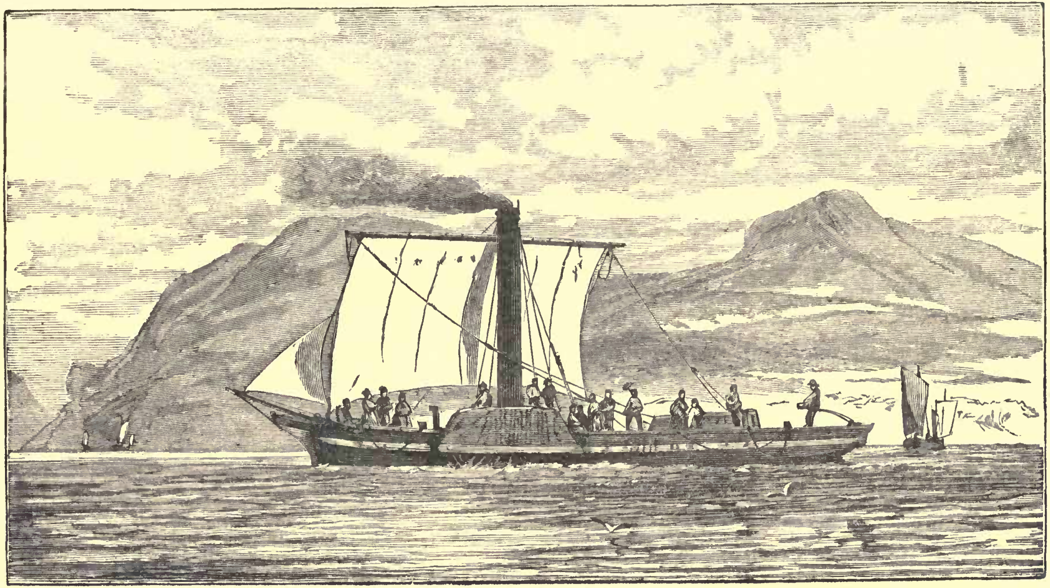
I well remember the advent of the first Sunday steamer, " Emperor," on the Clyde, in 1855, and also the howl that ran through Glasgow and down both banks of the river when the " Sawbath breaker " made her appearance. The "Nelson" followed. Her owner, however, was excommunicated, along with his family, from their church; but those who helped to do this did not think it any sin to put their own vessels on the slips, to clean, paint, and otherwise titivate on the Day of Rest.

For twelve miles below Glasgow the Clyde is almost as artificial as the Suez Canal, and during the early part of the present century was only navigable to the Broomielaw during spring tides, by vessels drawing about eight feet of water. The only communication between the city and places down the river in those days was by boats, and a story of the period is, that one dark or foggy night a party went on board one of them for a row to Greenock. They started, and in the early morning one of the oarsmen cried out, "Hey, Jock, here's Dumbarton Castle!" "Where?" said his friend at the other oar. "There," said he, pointing to what on closer inspection proved to be the Broomielaw after all. They had toiled all night, quite forgetting that the boat was moored by the stern!

The river steamers have always been celebrated for their speed and beauty, and have caused as much rivalry among their builders and engineers as if they had been ocean liners. At the present time some of them are truly magnificent, and may be said to have no equals in Europe. Especially is this the case with the "Columba" and "Lord of the Isles." The former goes to Ardishaig and back the same day, or a distance of 180 miles in about eleven hours, including numerous stoppages, and the latter to Inverary and back, or 218 miles in thirteen hours. It is interesting to contrast these vessels with the earliest steamboat "Comet," an engraving of which is annexed.

The "Columba" carries the mails, and is 316 feet long, by 50 feet broad over the paddle boxes, her draft being nearly 6 feet. The deck saloon, which runs about three-fourths of her length, and full breadth of ship, is elegantly fitted up in the Pullman car style, and below this is the dining saloon, where 140 can sit at table with as much comfort and style as in a first-class hotel. At the post office, letters and telegrams are received, and money orders paid. There is also a hair dressing establishment, a bathroom, a bookstall and fruit stall, a cloakroom, and two circular tables for writing letters, at which ladies and gentlemen are so constantly engaged during the season, that I am afraid the description I have given has now been read by the public in many thousands of their epistles. Besides a handsome piano at the end of the saloon, they are otherwise well off for music, as there is generally a good instrumental band on deck, which greaty adds to the enjoyment of a trip which only costs six shillings for the whole day.

The vessel, externally and internally, has the finish and appearance of a modern Cunarder, and is propelled by a pair of splendid engines at a speed of 22 miles an



P.S. "COMET" ON THE CLYDE, 1812.

hour. The "Lord of the Isles," on her run to Inverary, although not quite so large, can do 23 miles in the same time. The following well-known story is told about the Kyles of Bute, through which these steamers pass every day:—

When the late Mr. Charles MacIver went to live at Rothesay, he engaged John Taylor, an old man-o'-war's man, as pilot for his steam yacht. The first time Mr. MacIver sailed through the dangerous "narrows," he said to his Ancient Mariner:

"Now, are you sure you know this place well?"

"Know it?" said John, "I ken every rock on this coast, from Cape Wrath to the Mull o' Galloway—there's one o' them," he coolly added, as the ship bumped against a sunken reef, apparently in proof of his assertion.

It is on the banks of the river where the great extensions are to be seen that have taken place during the last twenty years, in connection with the engineering and shipbuilding establishments for which the Clyde is so famous. The largest of these are the works of the Fairfield Shipbuilding and Engineering Company, and the Singer Sewing Machine Co., which have been already referred to. The enclosed ground space of the latter amounts to 46 acres, and the land now covered by handsome buildings is 22 acres in extent. Their foundry alone is 448 feet long, by 352 feet wide, while the other parts of the works correspond to this, and are from one to four stories high, giving, on the whole, a handsome appearance from the river. To drive the machinery, engines of 1,600 and boilers of 2,000 horse power are required, while the extent of railways throughout the factory amounts to 2½ miles.

Amongst the numerous steamships built on the Clyde in early years were the Cunard Atlantic liners, which in 1850 were as follows:—

Caledonia..	1250 tons	500 h-p.	Niagara ..	1800 tons	700 h-p.
Hibernia...	1400 „	550 „	Europa...	1800 „	700 „
Cambria...	1400 „	550 „	Asia	2250 „	800 „
America ...	1800 „	700 „	Africa ...	2250 „	800 „
Canada ...	1800 „	700 „			

All the above were paddle-wheel vessels, the general length of the six largest being from 275 to 300 feet, and beam from 40 to 42 feet. Their steam cylinders were 90 inches in diameter, with an 8 feet stroke of piston for the 700, and 9 feet for those of 800 horse-power, while the diameter of the wheels was from 32 to 36 feet.

In 1852, the Cunard Company established steam communication between Liverpool and the Mediterranean ports, and in that year made a new departure of great importance. Previous to this, their fleet consisted entirely of timber built ships as above; they now, however, gave an order for the iron screw steamers "Alps" and "Andes," to Messrs. Denny, of Dumbarton. Their engines, of the "beam" description, had powerful spur gearing, to increase the velocity of the propeller, and were of a type frequently employed in those days, but which, for practical reasons, has long since been abandoned. Other similar vessels followed, and on March 3rd, 1855, the iron paddle steamer "Persia" was launched from Napier's.

What a sensation this ship caused on the Clyde while building! The largest vessel hitherto launched on that river was Tod & McGregor's P. and O. steamer "Simla," of 2,600 tons, and 600 horse power; but here was a paddle ship of the unheard of size of 3,500 tons, and 900 horse power. The descriptions given in the newspapers, must, I think, have caused every young engineer to wish he was in the Lancefield Foundry, helping to make her truly splendid machinery. Many a discussion we had about her in Denny's—indeed, before the order was settled, the general hope was that our firm might have the building of the vessel, since we had a reputation good enough for anything. As our erecting shop, however, was not quite high enough in the roof, and the cranes hardly strong enough for such colossal engines, we were content to let Napier get the contract.

The "Persia's" length over all, was 390 feet, breadth over paddle boxes, 71 feet, and depth 32 feet. Her hull was immensely strong, and every care was taken to make her the best, safest, and quickest ship at that time afloat. Mr. David Kirkaldy, of London, who was then in the Lancefield Works, made the most exquisitely finished drawing, in many views, of the ship and engines, that had ever been seen, and was the first of its kind admitted to the Royal Academy.

When Commodore Judkins was in command of this vessel, a passenger one day found fault with the wine, and added—

"Can't you give us something better?"

"No, sir," said the Captain, "it is the best I have in the ship, but when we arrive in Liverpool you shall come and dine with me, and I'll give you some that you will like."

The "Persia" arrived in due time, so also did the banquet.

"What do you think of that wine?" asked the host.

"Splendid! some of the best I ever tasted."

"I am glad you like it, for it is a bottle of the same quality you had on the voyage!"

In 1862, the iron paddle steamer "Scotia" was built by the same firm for the Cunard Company, She was of still larger dimensions than the "Persia," but as it soon became fully apparent that the screw was the best means of propulsion for ocean navigation, paddles were henceforth abolished. In 1879 this once famous ship was sold to the British Telegraph Construction Company, who substituted compound twin-screw engines for the old side levers, and otherwise altered her to suit their own requirements.

At this period none of the great Engineering people in the Clyde district attained such high celebrity as Robert Napier. This was attributable to two main causes, — one being the antiquity of his establishment, and the other the excellence of the work he turned out, in design, material, and also workmanship, which could not be surpassed. From the time that Mr. Napier obtained the engines of Junius Smith's steamer, "British Queen," to complete, owing to the failure of Claude Girdwood & Co., her first contractors, his business increased greatly, and a most important event in his career was a visit he received from Mr. Cunard, in 1839, relative to the formation of the British and North American Steamship Company, which they unitedly had the honour of originating.

In consultation with Mr. Cunard, who had purposely come over from America to carry out a scheme, the great results of which he clearly foresaw, Robert Napier developed what proved to be the best arrangement in connection with the first four ships of the newly created line, and at once obtained the contract for their engines, while the vessels themselves were given to Mr. Wood, of Port Glasgow, to build. Long previous to this, however, Messrs. Burns, of Glasgow, and MacIver, of Liverpool, who had been running coasting steamers for several years, amalgamated their undertakings in 1830, and this firm of Burns & MacIver was, at the time Mr. Cunard came to England, one of the most prosperous shipping Companies in Great Britain. When, therefore, the proposal to form a great Atlantic steamship organisation was made to those gentlemen by Mr. Napier, they at once agreed to it, and the result was the foundation of what ultimately became the well-known "Cunard Line."

Sir Samuel Cunard may therefore be regarded as its originator, and now that so many years have rolled away, it may only be added that his enterprising partners, the MacIvers and the Burnses, have proved themselves to be amply capable of sustaining the grave responsibility they then assumed.

Tod & McGregor, who in later years were considered the wealthiest engineers in Glasgow, also turned out large quantities of splendid work, but amongst their workmen they had not a good reputation, as so much importance was attached to the speedy execution of a contract. Mr. William Tod, however, rectified this in his usual happy way. On the other hand, Napier's was not only a very steady, but a very comfortable place to be in, and, so far as I could learn, men were never found fault with for taking what some might think a long time to what they did, provided it was of the very highest character.

This system, however, occasionally involved Mr. Napier in heavy loss. For instance, the first of the ironclads, or "batteries," as they were then called, proved a financially disappointing business for him as the builder, but so pleased were the Government with the way in which the contract had been carried out, that they liberally made good the loss which had been sustained. At other times, however, he was not so fortunate.

It was by no means easy for visitors to get inside either the Lancefield or the Vulcan Works if they were known to be engineers; anyone else, however, the proprietors did not greatly object to. Twice did I try, though unsuccessfully, to obtain admission, but when in later years I could send in my card as a "Consulting engineer," I was courteously received, and allowed to inspect everything. For their kindness I now thank them. By this time, however, the charm was broken, as I had become intimate with marine engines of all descriptions in other places.

On this point, Messrs. Laird Brothers were most generous, and, during the time H.M.S. "Agincourt" was building, from twenty to thirty visitors a day were frequently allowed to go through the establishment, after signing their names in a book, and giving a trifle to the Birkenhead Infirmary. One can hardly think, however, that this liberality to outsiders was purely disinterested, because, not long before, the "Alabama" had left their yard on a secret mission organised by her owners. As all the world knows, her career called forth very strong expressions of opinion in America towards the British Government, and I therefore fancy that the public were freely admitted, so that all might see for themselves that there were no more lurking pirates on the premises to give cause for international quarrels.

CHAPTER V.

THE BIRKENHEAD IRONWORKS.

Difference between Marine and Locomotive establishments—Description of the Birkenhead Iron Works—The Firm—The Staff—Pupils in Drawing Office—Billy Taylor's "Unlucky" Dinner—Fatal Tea Party in Chester—Troublesome French Pupil—Chief Engineer of H.M.S. "Captain"—Foremen and Workmen in the Birkenhead Iron Works—Value of "old hands"—Foremen in Small Works—The "General Utility" Engineer—H.M.S. "Euphrates."

THE only establishment on the banks of the Mersey to which I shall refer will be the Birkenhead Iron Works, because I had the honour of being on the staff for many years, and therefore can speak confidently of much that I was intimately acquainted with. The number of men employed amounted to about 4,000, but, a few years ago, upwards of 6,000 were on the books, and considerable occupation was given to others in the foundries which supplied the firm with brass and iron castings, and copper work, and also in the great forges where the heavy wrought iron parts were made.

In this respect there is considerable difference between marine and locomotive works, the former giving out all their heavy forgings, and in many cases all their castings, to other people, as it is more economical to do so owing to the extreme variations in size that exist in steamship engines. The railway engineers, on the other hand, have no such variations, as locomotives do not alter much either in dimensions or in description; hence they make all their own castings, brass, copper, and all other work, and are thus completely self-contained in their operations. Everything, however, in the way of plating, as in boilers, tender water tanks, side frames, etc., are given to the rolling mills.

Besides the 4,000 men just mentioned, the Birkenhead Ironworks had a large staff of able foremen and experienced draughtsmen, both in the engineering and shipbuilding departments, and also a full complement of clerks in the general office. I cannot say how long some of the foremen have been in the works, but I know that the late Tom Williams, of the ship yard, was about forty-five years on the premises, and some of the others also for very extensive periods. The establishment comprised a pattern shop; one light, and two heavy turning shops; two erecting shops, in the last of which the most powerful engines in existence could have been fitted up; a boiler shed—which has recently been superseded by a very spacious and admirably arranged new building outside the works; an extensive smithy, containing several steam hammers, and all other appliances for executing ship and engine work generally. At this end of the premises were placed a large joinery and cabinet-making shop; also a saw mill, with complete assortment of machines for sawing, planing, mortising, etc.

Over the smithy was a spacious mould loft, where the sections and plans of the vessels were drawn full-size on a black floor, so that the greatest accuracy might be ensured in their construction; and, adjoining this, was a drawing office, for preparing a few of the necessary plans on paper. In the same locality were to be found the rigging loft, storerooms, and buildings containing the ship constructing plant, including plate bending, punching and shearing, planing, drilling, and other machinery.

At the other end of the works stood an extensive building containing all the principal offices, keeper's rooms, and a model room, which contained a large collection of very handsome models and oil paintings of ships built by the firm. Next to this, were the paddle-wheel and also the armour-plate shops; the latter of which was part of the second of the heavy turneries referred to, and contained shafting lathes, planing, drilling, screwing, and other machines; also a most powerful hydraulic press, for bending the heavy armour-plates cold.

Lastly, we may add a large shed full of shipbuilding appliances, where all the frames or ribs of the vessels were bent to shape on a large iron face-plate. The erecting shops were swept longitudinally and transversely by very powerful overhead travelling cranes, and, the larger of the two had, on one side, a few valuable machines, including one of gigantic size for planing and slotting work of the heaviest character, also a lathe, whose face-plate was 15 feet in diameter, and bed of great length. As the foundations of these buildings had been excavated out of the solid rock, the floors were beautifully clean compared with others. The practice, however, adopted at Woolwich Arsenal and elsewhere, is a good one, as the floors are composed of hexagonal pieces of wood bedded in the ground with the end fibres uppermost—as in wood pavements—which makes them easy to keep clean, and in other respects is very suitable.

The amount of medium and small sized gear in all engines is very considerable. This is sent to the light turnery, where it is operated upon by machines and appliances of every description for rapidly executing first-class work. Nowhere is this more observable than in locomotive and machine making establishments; in such places the visitor will see quite a forest of belts, shafts, pulleys, etc., and everything arranged in the most systematic order to suit their own class of work, and facilitate every operation to the utmost.

There were five graving docks, two of which were covered, and under their roofs H. M. Ships "Agincourt," "Euphrates," "Captain," "Vanguard," and other vessels were built, while another was used as a fitting-up basin for ships getting in their machinery and masts, previous to being taken to the Birkenhead docks to finish. There were also six building slips, which, in conjunction with the graving docks, had, during my time, sufficient employment to keep them in full operation for many years.

The heads of the firm were very good in giving us most spacious and handsome offices, and, indeed, everything that tended to make us comfortable. In this respect, however, many first-class works of the old style are very deficient. Sometimes we all received invitations to a grand dinner, which latterly was given in the large general office. The first banquet I had the honour of attending was on the occasion of the launch of H.M.S. "Agincourt," and the last immediately before the marriage of the senior partner. At this entertainment there were about 150 clerks, draughtsmen, foremen, and visitors. A most excellent dinner was provided, and afterwards there were a great many speeches, one of which the author was kindly asked to contribute. Somehow or other his humble effort gave great pleasure to the whole company, but inasmuch as he had to return thanks for "the ladies," it is most likely the *subject* of his remarks was the cause of their enthusiasm, and, in that case, it shewed their good taste.

The manager at this period, contrasted materially in disposition and appearance with Mr. R. F. Pearce, of Tod & McGregor's, as the former was sombre, and did not say much; while the latter was bright, lively, happy. Had they both been on the stage, one would have made a splendid heavy tragedian, and the other an equally admirable light comedian of the Charles Mathews type. The gentleman I am referring to, however, was one of the best managers I have ever known.

He was kind and good to all, and had a quiet, pleasant way of speaking to people,—even when things went wrong,—that did him great credit. He never hurried us with our work, unless pushed for time; but under all circumstances would have nothing that was not done in the very best style. And if anything were wrongly made—which rarely happened—through an error in the drawings, he would point it out to the draughtsman, and mildly say: "I am surprised that one of *your* experience could have done such a thing, don't let it occur again." The amount of time spent on plans he supervised was considered of little value compared with excellence in design, proportion, and arrangement. This was specially the case when the drawings for a new type of engines had to be worked out, involving every kind of alteration as one's ideas became developed and matured, until at last perfection was arrived at as nearly as possible under the circumstances.

In the engineer's office, to which I was attached, there were at least twenty draughtsmen and apprentices—English, Irish, Scotch, American and Brazilian, and, as the last named were foreigners, I must say a few words about them.

Eugenio Lopez de Gomensauro—whom we may call the head of the tribe—was a perfect Adonis, elegant and refined in taste, and a remarkably pleasant little fellow besides. He was very steady and attentive, had apparently no faults, and, so far as we knew, no vices. He returned to his country, and, although possessed of influence, as his father was an admiral, I believe his expectations were not *quite* realised.

Next in order came Antonio De Silva, a mild dispositioned, amiable youth. He was a hard student, and took care to read the best and newest scientific books. If he got too much tracing to do, he would go off for a day or two to study his literature, and leave his work to be finished by others. A painstaking gentleman he was in what he liked, and what he did not care for he tried to avoid. Just before he left the works, he gave a party, to which we were all invited, but as two of us, including myself, were absent, we were asked to dine with him at his lodgings. When we arrived at the house, he received us in his shirt sleeves, made us heartily welcome, and then left us to take care of ourselves for a time.

It turned out that he was cooking the dinner downstairs! but came up now and then to see how we were progressing. At last the feast was spread, all in good order, and to his own entire satisfaction. I really forget now what the banquet was composed of, but we did ample justice to the good things, which were so admirably cooked and so liberally provided, and altogether we spent a most pleasant evening. What has become of De Silva I do not know, but I have no doubt he has found his culinary attainments very useful in a far-off clime, and I also hope that his studies have been remunerative and pleasantly profitable.

José Ferreira, another of the tribe, was as dark complexioned as if he had lived for many years under an African sun. He was a merry youth, took things very easily, and seemed to make the study of engineering a sort of elegant recreation. He used to place his drawing board on trestles, and, leaning back on his stool against a chest of drawers, looked the very picture of indolence and good humour when, with tongue lolling out of his mouth, he idly played with his instruments, and made personal remarks upon those around him, with whom he was much amused. Ferreira also went home to Brazil, but not long afterwards revisited his old establishment, and, from what he said, it appeared as if the world had not treated him as kindly as he wished.

A sad event happened at this period to an English pupil named Billy Taylor, who was then amongst us. He was a fine, amiable, good looking, studious boy, one who promised well, and was quite a general favourite. On one occasion, however, *thirteen* of us, including Billy and myself, sat down to dinner in a Birkenhead hotel, quite well and hearty. When our number was mentioned to him, he made some slighting remark, such as, "What did he care? He could eat his dinner just as well." Poor fellow! By a curious coincidence, within a fortnight we had the melancholy duty of laying him in his grave.

On another occasion I went with a large party of ladies and gentlemen to Chester. Under Dean Howson's able guidance we spent fully an hour in rambling over the beautiful cathedral, then had a walk around the ramparts, and, after that, tea. Our party was now divided, and it was again discovered that the table I was at contained thirteen. Well, I didn't care a single pin, but said little. One of the gentlemen, however, following on Billy Taylor's lines, made a frivolous remark about it, and lo! he caught cold that very evening when we were rowing on the river, and in three weeks was dead. Still more remarkable is the fact that the night before the Liverpool and London S.S. "Cheerful" was run down by H.M.S. "Hecla," in the Bristol Channel, *thirteen* people left the former at Plymouth; the *same number* sat down to tea, and *thirteen* were drowned.

There are a few superstitions that ignorant people still cling to, but it seems astonishing, in our time of enlightenment that they are not all consigned to oblivion. I cannot, for example, bring to mind a single instance of a ship's keel having been laid, or the vessel herself being launched, on a Friday; and, so far as the shipping advertisements are concerned, one would suppose upon reading them, that it was not considered proper to start an ocean liner on that day. In some cases, however, private commercial reasons may be the cause of this. There is a well known story told of a shipowner who said, "He didn't believe in any such rubbish, and would expose the fallacy to the world." In proof of his statements, he laid the keel of one of his ships on a Friday, launched her on a Friday, and named her the "Friday." She began her first voyage on a Friday, but from that time to the present has never been heard of!

Some of our drawing-office pupils were studious and persevering, others not so. A few seemed to consider engineering as a kind of doubtful amusement, and two or three of these gentlemen retired from the profession when their apprenticeship was out, and tried something else. They had a magnificent school of practice before them, and, if they had only availed themselves of it as they should have done, might have become, with fair opportunities, successful engineers.

In this respect, foreigners set us a very good example. They come here, pay all attention, and try to pick up as much as they can to take away with them. From this cause alone, a Frenchman in Napier's gave a great deal of trouble to the firm. He had been in some Continental technical school, and went to the Lancefield Works to study practice, which he did in the most persistent and audaciously appropriating style I ever heard of.

This youth took notes of everything he could lay his hands on, and although reprimanded by my old and esteemed friend, the manager, for doing so, continued to trace and copy drawings in the office for his own use—and with the help of others too. He was sent into the works, but, when there, got some of the apprentices to assist him in making figured sketches, and also in taking down the names of the makers of every machine in the place, despite the foreman's remonstrances. The firm at last became tired of him, so he politely departed in accordance with their wishes, saying at the same time, "He had all he wanted." It may be mentioned, however, that his people in France had given Mr. Napier large orders for ships and engines, which, of course, covered much that was disagreeable.

One of our frequent visitors during the time H.M.S. "Captain" was building was Mr. George Rock, her appointed chief engineer. He was "a fellow of infinite jest," or, as Mark Twain would have said, "full of laugh," and, as he was far on in years, put me much in mind of King Cole, for he was just as merry. His relations had advised him to retire from the Navy, as he had been long enough in it, but he preferred staying a year or so longer in the service so that his pension might be increased.

Not long afterwards, the ship sailed on her last cruise, taking with her Captain Cole, R.N., the inventor of the turret system, and poor George Rock also, and, during the squall on that eventful night in the Bay of Biscay, the vessel went down suddenly and drowned nearly all on board, including the two gentlemen I have named.

The foremen and workmen in Messrs. Laird Brothers' establishment were, so far as I could judge, similar in character to those I knew so well at Denny's, but, having had little to do with either, I cannot say much about their peculiarities. Mr. Young, of the pattern shop, and Mr. Barton, of the erectors, were the two I saw most of, however. The former had been a long time in Maudslay's, and was a very fine specimen of his class, but, being somewhat aged, was generally called, in our office, "*Old* Young." In Smiles' "Life of James Nasmyth," the latter, while describing those associated with him in the Bridgewater Foundry, at Patricroft, refers most kindly and interestingly to his various foremen, who were such valuable assistants.

For my own part, I look upon the heads of departments in the workshops, much in the same light as the non-commissioned officers in the army. They have considerable responsibility, as they stand between the masters and the men, and their object is to please the former by getting as much good work from the latter as possible, and, at the same time, to be kind, just, and not overbearing to them. Some foremen are very disagreeable and exacting, and cannot keep their "hands" if they can get employment elsewhere, as they dislike such overseers far more than bad masters, because they are always among them. When both, however, are good, the men take much greater interest in their work, and the result is a happy state of things all round. In the establishments of some large employers of skilled labour, this has been pre-eminently the case.

In my early years, foremen had more to do in one sense than they have now, because first-class engineering firms get up their drawings so completely in every respect that the men work to them implicitly, whereas, long ago, a great many little details were left out of the plans to save trouble and expense in the office, and thus the foremen had often to use their own discretion in giving the necessary instructions to turners, fitters, etc., which caused considerable loss of time. There are other ways in which careless or imperfect working drawings are pernicious, but this will be referred to under another head.

The chiefs of the executive are simply good, steady, reliable workmen, advanced to a higher position. They have little or nothing to do with science, but are eminently practical in their respective branches, and are able sometimes to give valuable advice to those above them, and, however accomplished an engineer may be, he can always learn something to his advantage in conference with these workshop lieutenants.

A thoroughly organised staff of foremen and workmen is of the utmost importance, as their complete knowledge of the system adopted in the establishment they belong to greatly facilitates the execution of a contract. This is fully recognised by the managers and partners of great firms, who often take orders at prices which will yield no profit, simply to keep the men together and the works going during dull times. When an old and experienced proprietor dies, and his sons succeed to the business, this state of things is still more keenly felt, because the young men are thrown upon their own resources, and, unless they have used their time well in getting as much information as possible, will find themselves entirely in the hands of their assistants, so far as practical and scientific work is concerned.

Many of the great engineers of the past superintended everything personally so long as an increasing business would allow them. Fairbairn, for example, controlled all his own departments from the drawing office downwards; and led such an active life, scheming this, and planning that, improving his details, and altering his arrangements of machinery to suit the end in view, that his great success was, we might say, the result of untiring efforts, sound and extensive knowledge, and great administrative ability.

When young engineers, therefore, take up the reins of government, relinquished by their fathers who have won fame for themselves, they cannot but feel that they are resting upon a reputation acquired by others before them, and hence will be seen the great necessity for keeping the "old hands" together, who know so well the late commander's ideas upon all those points which unitedly and individually insured success. We are quite aware, however, that with but little practical knowledge on the part of the new government, the works may nevertheless be admirably conducted; but, in that case, they must have an accomplished manager to look after things, as well as the regular staff already mentioned, who will run as much as possible upon the old lines.

The same reasoning may apply more or less to all complicated employments; but, with that of the engineer, it is often necessary to use the highest skill, in order to avoid great errors of judgment which, if acted upon, may produce terrible results. In proof of this, we have only to refer to some of the great disasters of the last twenty years, and, in some instances, to the very simple causes which created them.

In large works, the foremen occupy a very comfortable position, are well paid, and have permanent employment, notwithstanding the changes induced by dull times. They do nothing but superintend operations, and "go about," as the saying is, "like gentlemen." Mr. Barton and Mr. Young always wore dress hats, and were, therefore, the swell lieutenants of the Birkenhead Iron-works. The former supervised the erecting shops, and the colossal machinery in his department, but had able leading hands under him to take charge of each pair of engines, and see that everything was properly done.

Mr. Jones, of the light turners and fitters, had a forest of belts, drums, and pullies, to clear with his head. Mr. Ashton, of the boilermakers, had many curiously curvilinear corners to calculate, consider, contemplate, and contend against in *his* part of the premises; and Mr. Williams, of the ship yard, had a great variety of cantankerously crooked crannies and crevices to crawl and creep into. These gentlemen were, therefore, obliged to be content with ordinary felt hats, which, in their respective cases, suited admirably. They all had their own peculiarities of mind and manner. Any information, however, you wished from them at anytime, was kindly and pleasantly given, and everyone I have named, as well as the others, knew exactly what had to be done, and how to do it to perfection.

In small factories the foremen are required to assist in many ways, and are for this reason called "working foremen." In a Glasgow establishment, about forty years ago, one of these overseers had taken on a "new hand," who soon afterwards asked for a file.

"What d'ye want a file for?" asked the chief.

"To file they j'ints."

"Weel," said the gaffer, "If ye canna mak' a j'int wi'oot filin'"—that is to say, by chipping—"ye're no worth a big big D!" This, at least, is the euphemistic translation of the speech, in conformity with the requirements of modern language.

In very small places, a foreman may be anything and everything in all departments, and get little for it too. He may also have to do the work with or without what we call "drawings"—a chalk sketch on a board or bench, or the point of an umbrella trailed over the dusty floor by the master, being often considered sufficient for the purpose. I once heard of an establishment of this description at Galashiels. An order had come in for a small engine, and the proprietor and foreman were holding a consultation about it.

"What size am I tae mak' the seelinder?" asked the gaffer.

"Oh," said the person addressed, "mak' it *that* size," scribing a circle round him on the floor with the point of his boot.

"And maister, what stroke wull I gie her?"

One stride over the "stour"—dust—and, "Gie her that," settled the preliminaries.

This engine was probably of the horizontal kind, with a steam cylinder eighteen inches diameter, and three feet length of stroke; all the details, such as piston and connecting rods, valve gear, etc., having been made no doubt in a rough-and-ready style from sketches such as we have mentioned.

An old and versatile friend of mine ultimately possessed a small establishment of his own in Leith. He was highly accomplished in every sense, and combined in person all the appointments belonging to such establishments, as he occupied the posts of proprietor, manager, draughtsman, foreman, cashier, clerk, and bookkeeper. He took in his own orders and saw them duly executed, but, in spite of every effort, could not succeed financially.

The engineers in the Birkenhead Ironworks were steady and well-behaved, and, in this respect, much the same as those in similar places. The shipbuilders also conducted themselves satisfactorily; at least, during my stay of nearly nine years in their midst, I never heard of them acting indiscreetly at any time, which was certainly very creditable to all concerned, and especially so when the same class of workmen have, within a recent period, given much trouble elsewhere by their conduct.

There were many accidents, fatal and otherwise, in the shipyard during my time. This I attribute to the dangers incidental to shipbuilding, such as falling into dry docks, stepping on to planks not properly fixed, and sinking through holes in the decks which should have been well covered over, and so on; as a class, however, they are, from some cause or other, too often very careless. To give an example. One evening when H.M.S. "Euphrates" was lying in the fitting-up basin, having her engines put in, I went along one side of the main deck to the engine room, but returned by the opposite side. In doing this, however, in semi-darkness I fell through a small open hatchway, which had been left uncovered, and came down so heavily upon the wooden coaming, that I thought some of my ribs were broken.

Fortunately, however, they were not, but had it not been for a ladder which providentially caught my feet, and prevented me from falling into the hold, the consequences might have been as serious as they had been for others. In about three days I was quite well again, but have good reason ever to remember that ship, which it may only be added, is considered by some people the finest of the five similar transports built at that time by different firms for the Indian transport service. This, however, was only a natural result of the carefulness in design, selection of material, and of every little detail in ship and engines, from first to last, which characterised all the productions of Messrs. Laird.

The general arrangement of engineering and shipbuilding works depends greatly upon the extent and configuration of the land they occupy, but, in any case, the fixed and movable plant and other details do not vary much. From the brief description already given of the constructive machinery in the famous Birkenhead establishment, a very fair idea may be formed of the interiors of all other places of similar magnitude. The character of the men of all ranks who conduct operations only seems to follow the natural law of improvement by kind treatment from their superiors. Those, however—mentioned in this chapter—with whom I was so long and so pleasantly associated, may be considered excellent specimens of the people who successfully conduct some of the most important undertakings of modern times.

CHAPTER VI.

APPRENTICES.

Different kinds of Apprentices—How they get into Works—Premiumed Pupils in England—The Clyde System—Origin of Premium System—Maudslay's objections to Pupils—James Nasmyth in early days—His troublesome Youths at Patricroft—The use of Idle Apprentices—"Marine Works"—"General Works"—"Special Works"—Cause of false steps in entering the profession—Lives of the great Engineers—History of Harland and Wolff—Workshop Practice, past and present—Prospects of Engineers at home and abroad—"Repairing Works"—Tools and Instruments for Pattern-Shop and Drawing Office—Working Dress.

I HAVE known very many apprentices, good, bad, and indifferent, premiumed and free, in works and offices, some of whom no doubt hoped to occupy important positions in after life, although they had a strange way of qualifying themselves for such appointments. A few of those who paid entrance fees seemed to have a high opinion of the efficacy of their father's gold, and also a strong belief that the prestige of the great firm they were with would make their path to distinction smooth and easy. This was very complimentary, no doubt, both to the parents and to the eminent firm, but any earnest efforts on their own part to benefit by surrounding advantages seemed to be quite a secondary affair. The following sketch may help to illustrate the characteristics of one of these pupils.

Charles Hardinge is a youth of sixteen, just leaving school,—he has one brother in the army and another in the navy; his father is a barrister; and he has also an uncle in London, who is a rich merchant. This gentleman considers the advancement and pay of the officers in both services very unsatisfactory, but hearing from others that engineering is a "good profession," he fancies it would do for his nephew, and accordingly tells his brother so, adding, at the same time, "that it is often very difficult to know what to do with a youth, and Charley doesn't seem to have made up his mind on any subject."

Application is now made to several well known firms for his admission as a pupil. They all say "they have not a single vacancy at present, and may not have one for some time to come." A firm is at last discovered, however, who promise to do what they can; and, in about six months afterwards, Mr. Hardinge, upon payment of a handsome premium, has his son fairly installed in a celebrated locomotive establishment. His mother, who comes to see him settled, boards him with a suitable family in a good locality, and leaves the youth to take care of himself. As he lives so far away from the works, he soon finds out that the half-hour allowed for breakfast is too little to enable him to return in time. The firm is, therefore, appealed to; they are asked to let him come at nine instead of six in the morning, as "he is not strong." They say "it is against their rules to do so,"—"sets a bad example,"—and so on, but eventually the point is conceded.

This shortening of the ordinary hours interferes seriously in course of time with steady work; but the kind foreman treats him as a "young gentleman," and gives him plenty of simple employment which there is no hurry for, such as cutting quantities of stud bolts to a certain length, or polishing hand rails and other things. If he is occasionally "ill," as he says, and off duty, the foreman makes few remarks, but takes care that all the really good practice he might have had is given to others with more robust constitutions, and of more regular attendance.

When he gets into the drawing office, he comes in for a vast amount of tracing, because he cannot do anything else; and has even to learn the simplest rudiments of drawing and the use of his instruments, which he ought to have known well long before. Every one likes him, as he is a fine, gentlemanly youth—amiable and humorous also. He writes very many letters in office hours, and larks about in great style, to the annoyance of the draughtsmen who have serious work in hand, but to his own amusement. Becoming in time a goodish tracer, he is promoted; that is to say, he now copies drawings and makes details, with the help of those around him, from other similar details, refreshing himself at frequent intervals with a few holidays; but, the manager is considerate, or, perhaps, has long since discovered that it is "no use saying anything to that fellow."

At last his apprenticeship expires, but, as he has not taken any real, practical, foresighted interest in his work, and has looked upon home study as a myth, he finds in a short time that his services are no longer required, and leaves with a certificate which states, that "he has served a five years' apprenticeship with us, and has been in our employ as a draughtsman for six months."

If they can manage to squeeze in something about being "steady and attentive, and conducted himself to our entire satisfaction," they may do so on his father's account; but, most likely they will not, as first-class firms are very particular on this point, and sometimes say too little. The name of the great people he has left gives young Hardinge a good standing, but such appointments as he wishes cannot be obtained; so after waiting a considerable time in the hope of "something suitable turning up," he enters the drawing office of a locomotive and machine making establishment as junior draughtsman, at, say, thirty shillings a week, and here we shall leave him for the present.

Apprentices in the works are of a very miscellaneous description, and comprise the sons of noblemen, professional men of all ranks, commercial, and manufacturing people, tradesmen and workmen; and the varieties of character are perhaps as comprehensive. Some are industrious, and some are not; some are well bred, and others are the reverse; some are enterprising and persevering in lines of thought and action too numerous to mention; some are witty, and others dull. In short, every class of society, and every shade of morals and disposition — the good and the worthless — are to be found among the youths of a great engineering establishment.

They obtain admission in three ways: firstly, by influence; secondly, by money; and, lastly, by both. The first system is, I believe, exclusively adopted now in Scotland, and the two latter seem to be largely used in England, thus forming what we may call two distinct systems,—the premiumed and the free,—whose operations I shall endeavour to describe. In works on the Clyde, even of the highest celebrity, no premium is taken, and a boy gets into them because his father, or uncle, or some other relative or friend has given the firm orders for ships, engines, or machinery of any kind. Perhaps they have been otherwise useful, or may indeed from pure friendship, have a sort of claim upon the kind assistance of Messrs. So-and-So, who in cases of this kind will gladly do all they can.

Some engineers have so many friends of this description, that it is extremely difficult to find an opening in their works or offices; and, as frequently happens in other pursuits, a long period may elapse between the application and admission. On the other hand,—and as I found it,—the latter may quickly and unexpectedly follow the former; at any rate, you must take your chance, and this applies even to places where premiums are accepted. Both systems, however, are defective.

In the first instance, a premium is paid as an entrance fee, and also to enable the pupil to obtain certain advantages which those who do not pay are not expected to possess. This, everyone must allow, is very fair; but, unfortunately, it opens out a serious evil that I have seen and known, which is injurious to the boy, and bad for every one concerned. When the young gentleman thus begins his career, he is frequently treated too indulgently, or at least not kept sufficiently in check. He may work, or be idle; he may be steady, or the reverse; and may, indeed, be a source of great annoyance to foremen and leading hands, if they are occupied with important work upon which no time must be lost. And all this arises because a handsome premium has been paid, which imposes too many restrictions on one side, and gives too much liberty on the other.

I fancy, however, that engineering firms may sometimes consider it the best policy to say as little as possible about the vagaries of their apprentices, lest they may offend good clients, who might perhaps transfer their favours to other quarters, and thus it may often be safer to bear the ills they know, than fly to those they know not of.

Well do I remember a pupil who came to the ship drawing office of the Birkenhead Iron Works in my time. His father was a very celebrated marine engineer in London, who had won his way to fame and fortune by his own merits, and wished his son to have a good opportunity of learning shipbuilding amongst people with whom he was intimately acquainted. This youth evinced from the first a sort of aristocratic dislike to labour, and his amusements were of a diversified character, one of which was, I believe, to sit at times upon the entrance rails of the general office and admire the clerks, or note those who came in or went out. On one occasion, a partner of the firm came upon him suddenly in this attitude, and was at once saluted in a sprightly, off-hand, friendly style, with—

"Well, Henry, are you coming out to hunt to-day?"

They did not send the youth off quite, but we heard that a polite letter had been written, asking his father to take him away. What happened behind the scenes I am unable to say, but soon afterwards the young gentleman departed. In another sphere of usefulness, however, he developed latent talent, and eventually became a partner in his father's firm.

Having briefly described what may be termed the English side of the apprentice question, I shall now endeavour to treat that of the Scotch in a similar manner. In doing this, however, I think I am correct in stating that, at the present time, none of the engineers in the Clyde district take premiums, although in earlier days some of them did so; but there is reason to believe that this habit entailed upon them so much unpleasantness and loss, that it was ultimately abolished. They now virtually say to intending pupils, "We'll take you if we can, and not charge anything for doing so, but you will have to work steadily and attentively, keep good hours, and behave yourselves, as you should do, or we shall have to part with you."

So fully was this principle recognised and acted upon, that its results were highly beneficial, at least to those apprentices I was associated with in Denny's, Neilson's, and Tod & McGregor's. In Denny's, for example, where I knew them best, they had an excellent character for steadiness and good conduct generally. They rarely lost even a quarter of an hour at 6 a.m.; they attended to their duties, and were hardly ever away except on special occasions, for which they obtained leave. We were a very healthy race, too, and seldom lost time from indisposition of any kind. We were a merry lot also, and got along pleasantly and happily, and some of us have done well in various parts of the world.

Looking, then, through the vista of many years which lies between the time I am now writing about and the present, I have every reason to speak favourably of those who were my contemporaries when an apprentice. This, however, I attribute in a great degree to the excellent system adopted in the establishment, which, however, has recently been much improved in various ways. As an example of wonderful steadiness in a young engineer, it may be added that a well known, highly esteemed, and most prosperous shipowner in Liverpool was never once late during the whole of a five years' apprenticeship.

Napier's was a favourite place in those days, and very comfortable for good men in all departments, but they had the character of being very strict with their pupils, some of whom were dismissed because they did not attend properly, or were otherwise careless. The foreman's authority in this, as in all other similar establishments, was supreme, as it is not considered etiquette for masters or managers to interfere with, or give directions to, men or boys. Turners, fitters, etc., were discharged at a week's notice, or received instant dismissal on the foreman's own responsibility, for misconduct, and although in some places an apprentice could have been easily enough sent away for a time, they were not dismissed before a statement of the grievance had been made to the manager or principal, and a conference held as to what should be done. In practice this system worked admirably, and caused remarkable steadiness among those who, in after years, no doubt realised its advantages.

From what has been said, therefore, on this subject, the whole question may appear simple enough. In other words, you may pay for your son's admission to a Work, and, if an idler, he may do what he pleases, and at the end of five years have only a general sort of smattering—a very superficial knowledge indeed—of that valuable practical branch of the profession he will never again have such an opportunity of acquiring. On the other hand, get him in without a premium if you can, and he will either have to do what he is told or go elsewhere. In many cases this is certainly the best plan, but there is another aspect of the question which is complicating, and which will be referred to further on.

The premium system, in its application to good marine establishments, is, to some extent, unnecessary, unless it provides for ample practice in the drawing office. Its legitimate objects are, however, too often neutralised by the conduct of those upon whom it is intended to confer benefits, and to confirm my own ideas on the subject, I may add those of others well qualified to judge.

The system originated, no doubt, in the persistent efforts of those who had means, to get their sons into engineers' offices and works in earlier days at any cost. They offered handsome fees, and were in some instances additionally supported in their applications for admission by powerful private influence. On the other hand, engineers themselves were so overwhelmed by the number of these applications, that they were compelled to ask high premiums, and thus probably Brunel's, and others' since his time, ran as high as £1,000. At present, however, the sum generally required by great firms in England is £100 a year, when sufficient influence is not forthcoming to enable them to take the youth without payment.

In 1829, a Mr. Nasymth of Edinburgh, started from Leith in a sailing smack, and after a four days' voyage arrived in London. He took his son with him in the hope that after an interview with Mr. Maudslay, whom he had previously known, he might succeed in getting the youth installed in his celebrated establishment. Mr. Nasmyth could not pay for his son's admission, and although he knew that Maudslay and Field had ceased to take pupils, he nevertheless made the attempt.

They were both received most kindly, and upon the elder Nasmyth explaining the object of their visit, Mr. Maudslay replied, " I must frankly confess to you, that my experience of pupil apprentices has been so unsatisfactory that my partner and myself have resolved not to take any more of them, no matter at what premium," and the reason was, as he said, " because they gave the firm so much annoyance by irregular attendance, — setting a bad example to others,—and, on the whole, being such disturbing elements in the work of the establishment."

A ramble through the works was now proposed, to enable the visitors to see the fine machinery they contained, and upon observing the beautiful engines which drove it, young Nasmyth was so delighted that he begged for employment in any capacity, which rather surprised Mr. Maudslay, who said to him, "So you are one of *that* sort, are you? Bring your drawings and models to-morrow at noon, and let me see them." This was accordingly done, and so astonished was the great engineer with the ingenuity and skill displayed in these productions, that he at once decided that the boy should have a week to himself, to enable him to see as much as he could of London, and then be employed as an assistant in his private and admirably arranged workshop and office, in which he remained for several years.

This youth became in time the celebrated James Nasmyth of Patricroft Foundry, whose reputation was little, if at all, inferior to Fairbairn's, and his own experience of pupils may be thus given. "We had a few apprentices who paid premiums,—in some cases we could not well refuse to take them,—and yet they caused a great deal of annoyance and disturbance. They were unsteady in their attendance, and consequently could not be depended upon for the ordinary operations of the foundry. They were also careless in their work, and set a bad example to the unbound. We endeavoured to check this by agreeing that the premium should be payable in six months' portions, and that each party should be free to terminate the connection at the end of each succeeding six months, or at a month's notice from any time. By this means we secured better conduct on the part of the apprentices."

Slavish, or even constant labour of any kind is not desirable. We are all the better for a little amusement, and a hearty laugh does us quite as much good now as it did to those who attended banquets in the time of the jesters, or even as it sometimes does among the barristers in our law courts, but there is a very great difference indeed between this legitimate relaxation and the continuous hilarity of those who ought to know better.

I must not, however, be too severe upon these festive young gentlemen, as they are very useful to us. The profession is terribly over-stocked, and if every youth who entered it persistently aimed at getting by his own merits to the top of the tree, some of us could never expect to be promoted. Things are bad enough as they are, but they would be overwhelmingly so if the young idlers in our works and offices did not keep a good many ambitious ones out, and cause them to try something else. What we have said, therefore, on this subject, has been only through a desire to explain the true state of the case for the guidance of others; and if the hints thrown out in this chapter are the means of preventing people from sending their sons to engineering when they have no capacity for it, and also from spending money and time uselessly when they might be better employed, it is probable that what has been written will not be in vain.

I have mentioned in the previous pages the disadvantages of the premium system, and now propose to shew the benefits it confers.

In marine establishments the work is always changing. In the olden times this was especially the case, when no two orders were alike, and when every possible variety of paddle and screw engines were frequently being made. Even at the present day, when one type,—the direct action triple expansion engine,—is almost universal, there are great variations constantly arising.

For instance, in places like Elder's or Maudslay's, an order may come in at one time for a tiny pair of launch engines you might almost carry in your arms, and at another, for those of 10,000 or even 15,000 horse power in one set alone. This extreme diversity of size necessitates great alterations in design and construction, to suit the ever changing circumstances of each particular case. Hence it will be seen that a good marine work is the best school of engineering in existence, and often a source of fascinating study to those who practise in it.

To general engineering establishments a similar line of argument may be applied, but in places where a large quantity of special machinery is made, say for flax and cotton spinning and other textile manufactures, also steam winches, and a variety of work which is got out rapidly and extensively, the men and boys are, by the division of labour system, turned more or less into automatons. They are kept, for a very indefinite period, turning this, planing that, and boring something else, also fitting up details, say connecting rods, valve gear, shaft and wheel work, etc., until those who wish for a change of employment are completely wearied on account of the extreme monotony of their occupation.

No doubt the extra pay for work of this kind is an encouragement to those who will never be anything more than workmen of a special description, but for apprentices whose aim is to rise to the higher branches, such a system is disadvantageous in every respect. Looked at from a commercial point of view, it is, no doubt, good for the masters, and perhaps also for the men, on account of greater remuneration thus obtained, but nothing could be worse for gentlemen apprentices, who are not protected from it, and this is what the payment of a premium does, or ought to do. Under these circumstances it therefore becomes a source of great advantage, so long as, for the reasons already given, it is not abused.

In locomotive work, even at the best, there is too much sameness in description, and very little variety in size. For example, passenger and goods engines on our main lines have their cylinders generally from 16 to 18 inches diameter, and a large establishment may perhaps get an order for 50 of the latter from India ; not long afterwards 40 more might come in for Australian or other lines, to the former size, and at another time a lot more of 17-in. cylinder engines for English railways. Thus involving an immense quantity of details, similar in kind and size, which have to be executed by the division of labour system.

That so many false steps are made in the choice of engineering as a profession, is attributable, on the one hand, to a want of proper knowledge of what is required of them by those who wish to enter it, and on the other hand, to unsuitability, or want of application, on the part of those who feel somewhat inclined to study it. The former is not to be wondered at, when we consider the private nature, generally speaking, of a vast amount of engineering employment. Of course there are great schemes, which everyone knows about, such as the Forth Bridge, etc., but there is also an immense variety of excellent practice constantly carried on, of which few, indeed, outside of the interested people, have any idea.

The error of judgment so many make in such matters, seems to be an idea that the practical and scientific branches are easily learnt: that drawing-office work is simple; and that, as a whole, neither energy nor patience are necessary. Never was there a greater mistake, as those who have been successful know well. Locomotive engineering may be comparatively easily learnt. Marine needs a much longer time to acquire; but those who aim at private practice, or foreign appointments, which throw men entirely on their own resources, and necessitate a thorough knowledge of many branches, will find that close and prolonged observation and study confer advantages of inestimable value.

If we study the lives of some of the great engineers, such as Watt, Fairbairn, Penn, Maudslay, Nasmyth and others, we shall find that they owed their prosperity to innate energy, industry, skill, and opportunity from first to last, and we might also add, the possession of that useful quality which enables people to make whatever they undertake a pleasure instead of a labour.

The history of Sir E. J. Harland, the celebrated shipbuilder of Belfast, is briefly given in Smiles's admirable book, *Men of Invention and Industry.* In a chapter written by himself, Mr. Harland interestingly describes his apprenticeship in Stephenson's, at Newcastle, and his employment in the marine works of J. & G. Thomson on the Clyde, as a draughtsman. After this we find him occupying the post of manager at Mr. Toward's on the Tyne, and soon afterwards at Belfast in a similar capacity until 1852, when he became sole proprietor, ultimately taking in Mr. Wolff—of Whitworth training—as partner.

The rise and progress of their immense establishment is given in detail, and throughout the narrative one cannot but see that industry, intelligence, and perseverance, during a long career, have in this case been fully rewarded.

Looked at broadly, engineering is so complicated in its higher ranges, and composed of such an infinite variety of details, the arrangement and proportions of which have to be carefully worked out, that we can only excuse indifferent students upon the supposition that they are financially independent, or that they really have no conception of what lies before them.

Some people are born engineers; these need no comment, as they are quite able to look after themselves. Others are engineers by education, having, like myself, been obliged to take to it almost against their will. Whilst a few are totally unsuited for it, and ought to have been, we might say—*anything* else. In my own case, however, a love of drawing proved invaluable, and enabled me at starting, and ever afterwards, to take a deep interest in all I saw relating to machinery, and it is this same taste for mechanical drawing which so often indicates who should be engineers, and makes all the difference between those who will never be anything else but "hands," and others who show that they have heads.

A youth's surroundings may have occasionally originated the idea that engineering was an easy-going profession. His father, for instance, may be a barrister who apparently does nothing but watch law cases in a Court of Justice, and one or two of his uncles may get a very fair income as clergymen by preaching two short written sermons, without a spark of vitality in them, on Sundays, and taking recreation for the rest of the week; and, therefore, for want of information on the subject, engineering may sometimes be looked upon in a similar light. Another very strong reason why so few people have even the most superficial knowledge of its requirements, is that the mechanical branches are only of recent date, whereas civil engineering and the other professions I have mentioned are of great antiquity.

Thirty years ago, workshop practice was very different indeed from what it is now, as a great amount of time was spent in acquiring sufficient manual dexterity for the proper execution of difficult and important parts. Now-a-days machinery does almost everything, and thus practical instruction has been robbed of its charms and general usefulness. If a youth, therefore, is content to remain as a workman, and take the ten-thousand-to-one chance of being a foreman, or become a sea-going engineer, the training he now receives will be sufficient for the purpose; but for those who aim at higher positions, their whole future hangs upon a thorough knowledge of the scientific branches practised in the drawing-office, which, as already stated, are only open to the privileged few.

In view of all this, the best plan appears to be to send the ambitious ones for about three years to the office of some good mechanical engineer, where they will be carefully educated in drawing office routine, including the construction, application, and arrangement of machinery details. A large amount of valuable knowledge may thus be acquired, which will greatly assist them to understand what is done in the Works, and extensively enlarge their future prospects.

Those prospects are not quite so encouraging as they were in earlier days, because there are now so many engineers in the field. But although England may be overdone in this respect, engineering enterprise is extending so rapidly abroad that many good appointments are to be had in other lands for those who are capable of holding them. This, however, depends largely upon the manner in which the apprentice employs his time when surrounded with advantages. An excellent thing to observe in life is—Do not wait until your rich relations—if you have any—or your poor, but kind, relatives and friends help you out of a difficulty. Act for yourself with all the power and ability you possess, and they will think all the more of you for doing so, and be more inclined to give their aid.

If you cannot command the winds, you can spread the sails, and well-directed and sustained efforts are generally rewarded in some form or other, and frequently in the most unexpected manner. The art, therefore, of doing as much as possible for one's self is highly to be commended, and especially so because some of the most eminent men in the various walks of life have, in this respect at least, been most diligent.

During the early American war, a gentleman in plain clothes occupied himself on one occasion by having a quiet walk among the soldiers, just to see how they were getting along. He came at last upon a man in a very unhappy state of mind, whom he tried to comfort.

"What is the matter with you, my good friend?" said the visitor.

"Boo-oo-oo," replied the soldier, "here's a job I want done, and can't get anyone to do it for me."

"Can't you do it yourself?"

"No, sir; I am the sergeant-major of the regiment!"

"Indeed! Can I be of any assistance to you?"

"Thank you, sir, I wish you would."

The visitor set to work. Bang went one thing, splash went another, and in a short time the "job" was finished.

"The next time you want anything done," observed the departing stranger, "send for General Washington!"

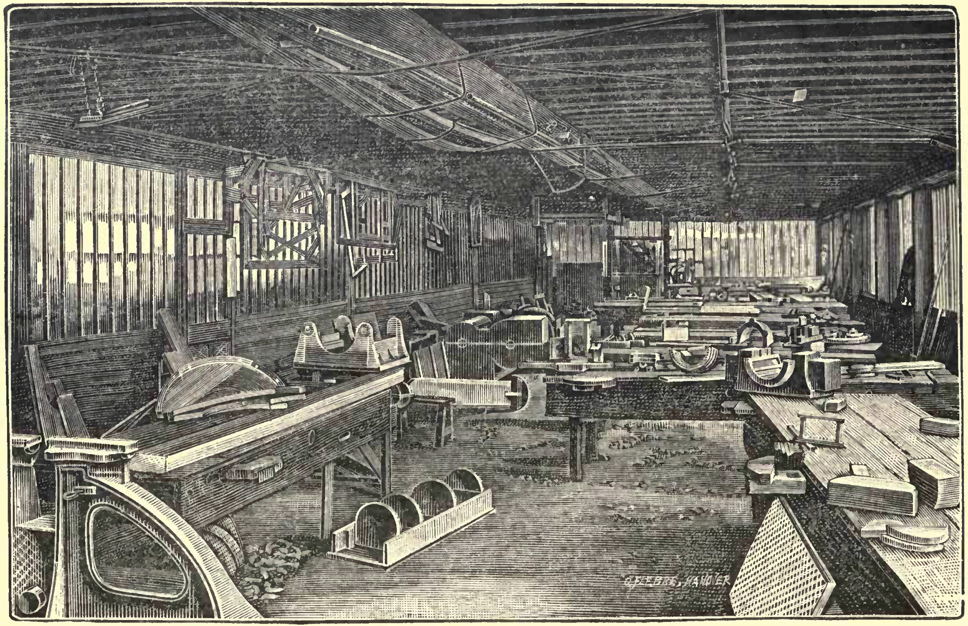
Said a lady to me one day—

"The So-and-So's have got their son into the engineering establishment at Blanquetown, without paying any premium, and they are giving him six shillings a week to begin with!"

"Quite right, ma'am," I replied, "he may well have such liberal treatment, because he is only in *repairing* works, where he will not learn much, and where they will make a machine of him."

So it was, and is, and ever will be in such places, so long as they are what they are. With the exception of the Crewe Works, and others of similar nature, where, in addition to continuous repairs, they make their own locomotives, there is really nothing that an ambitious apprentice need trouble himself with, even, if possible, for double the above pay. The reason is this:—In those establishments—marine included—the work is connected with damaged, worn, or broken details, which may have been long in use, and require renewal in some form or other. Pins of various sizes have to be turned, new brasses fitted, valves of different kinds need rectification, the working gear needs touching up in various places, broken framings want patching, and so on to the end, amidst greasy dirt of the most atrocious nature. The patterns are very limited in number, as well as in size, and the drawings are just what might be expected in places where no new machinery is designed or made.

Hence, for all these reasons, a repairing shop is in every respect the worst possible school of thought and



INTERIOR OF A MODERN PATTERN SHOP.

practice a youth can enter. People generally do not know this, and the poorer members of the aristocracy are quite ignorant of it, fancying all the time that their sons are highly favoured by being admitted for nothing to what they consider a great "engineering establishment," and getting, besides, the sum of six shillings or more per week for their valued services.

The annexed plate shews the interior of the pattern-shop at the Neptune Marine Engineering Works, Newcastle-upon-Tyne. Those who enter this department in any locality must provide themselves with a chest of tools for working in wood, which may be had for about £6, but in the iron departments, files, chisels, hammers, and all other appliances, are supplied by the firm. In the drawing office, however, every draughtsman and apprentice needs to have his own instruments, that is, a 36-inch ebony-edged tee square; one ditto 45° set square, 8 inches long, and another of 60°, 10 inches in length; two oval section 18-inch boxwood scales, one of which will be divided to ⅛″, ¼″, ½″ and 1″ to the foot, and the other similarly to ⅜″, ¾″, 1½″ and 3 inches. One of Faber's H.H.H. pencils, a good piece of vulcanised indiarubber, and, say, three good colour brushes will complete this part of the outfit. The most important thing, however, is a box of instruments of first-class quality, and of book form for conveniently carrying in the pocket, the cost of which need not exceed £3, even for those who love luxury.

The best place for obtaining the squares and scales above mentioned, is Mr. W. F. Stanley's, Great Turnstile, Holborn, London, which I can confidently recommend to architects, as well as engineers, having used his productions for the last twenty-five years, and supplied them in every case to my own numerous pupils. Such instruments last a lifetime, and, therefore, well repay the care bestowed upon their selection.

The dress of the engineer should be of the simplest character, and perhaps no materials can be better suited for the purpose than good Navy blue serge and white duck. For dirty work, the latter is very useful in the form of "overalls," as it can be so easily washed. Especial care, must, however, be taken when ordering a suit, as the tailor, having in view the fashionable style of trousers, breeks, or galligaskins, will probably make them much too tight to allow for future shrinkage, and thus cause considerable discomfort afterwards, not to mention the attenuated appearance they will certainly give to the legs of their unhappy wearers.

CHAPTER VII.

CIVIL ENGINEERING.

Meaning of the term "Civil Engineer"—The Great Pyramid—Ancient Suez Canal—Hero of Alexandria—Archimedes—Their Mechanical genius—Euclid—A Dream of Antiquity—Great Tunnels—Railway Ferry Boats—Bridge Engineering at home and abroad—Drainage and Reclamation of Land—Gigantic Pumping Operations—Origin of the Goodwin Sands—Freaks of Rivers in India and China—Gradual Elevation by Silting process—Vast Inundations and change of Bed—The Hoang Ho, etc.—Scouring and Deepening process in Rivers, etc.—Ordnance Survey of United Kingdom.

As the exact meaning of the words "Civil Engineer" is very important, and has given rise to much discussion, the Council of the Institution of Civil Engineers considered it desirable to state the sense attached to them by the Institution.

The charter defines "the profession of a civil engineer" as "the art of directing the great sources of power in nature for the use and convenience of man," and some examples of this definition are given. But it was pointed out by Thomas Tredgold, who drew up the "Description of a Civil Engineer,"—partly embodied in the charter—that "the scope and utility of civil engineering will be increased with every discovery in philosophy, and its resources with every invention in mechanical or chemical science." Consequently, since the charter was drawn, the range of practice of the profession has become much enlarged.

Thus the practitioners in this art may now have to do with many classes of work; for example:—

1. Works for facilitating and improving internal communications—as roads, railways, tramways, navigation by canals and rivers, bridges, and telegraphs of various kinds.

2. Works connected with the sea-coast, and for facilitating communication between the sea and the land, such as harbours, docks, piers, breakwaters, sea-walls, lighthouses, etc.

3. Works for facilitating communication across the seas, including naval architecture, iron shipbuilding, and the construction and laying of submarine telegraph cables.

4. Works for the reclamation, irrigation, or drainage of land; and for the prevention or the regulation of floods, including the improvement of rivers, as arterial drains.

5. Works for cities and towns, such as sewerage, water supply, lighting, and street improvement.

6. Large and massive buildings generally, in their scientific and mechanical arrangements.

7. The operations of mining and of metallurgy, so far as they involve the application of mechanical science.

8. The design and construction of the mechanical prime movers, such as steam engines, water-wheels, and other hydraulic motors, windmills, electric and other engines.

9. The design, construction, and adaptation to practical use of machinery and mechanical appliances of all kinds.

10. The design and manufacture generally of all large and important metallic structures, including artillery, and other munitions of war.

This is a comprehensive but by no means complete catalogue, and if an estimate is attempted to be formed of the work done under it during the last century, and of the effect this work has had on the development of trade and commerce, on finance, on government, on every branch of industry, and indeed on every possible aspect of human interest, it must be admitted that the profession of civil engineering has become truly a great power.

It is important to define accurately what is meant by the prefix "civil."

There has sometimes been a disposition to confine this word to those who practice in works of building and earthwork construction, such as railways, roads, harbours, docks, river improvements, and so on, to the exclusion of engineers who are engaged in some of the other branches of engineering enumerated.

There is no authority for such a limitation. The meaning of the word "civil" is quite clear when the history of the profession is borne in mind.

The earliest application of the term "engineer" was to persons in military service, and down to a comparatively recent period it was only known in this application. But when the construction of public works in England for civil purposes began to take a large development, their designers, finding their work analogous to that of military engineers, adopted the same term, using the prefix "civil" to distinguish them. There is reason to believe that Smeaton was the first civil constructor of large public undertakings who called himself an engineer, and who used accordingly the distinguishing compound title.

The term "civil engineer" implies, therefore, an engineer who is a *civilian*, and it is intended to include all classes of engineers who do not belong to the military service. This, it may be added, is the meaning now attached to the words by the "Institution."

When we think of the stupendous edifices, and other great works of ancient days, it is astonishing that the people of past ages were so ignorant of the prodigious power we now use so effectually, and which, strange to say, is in its successful application only about a hundred years old. Had they only possessed a *little* of our knowledge on such points, what an immensity of labour and time it would have saved them!

The ancient Suez Canal, during its excavation, is said to have cost the lives of 120,000 people, and the Wall of China occupied for a long period the efforts of every third man in the empire. We have also reason to believe that no mechanical appliances of any kind were employed upon either of them during their construction.

Briefly told, the Canal was a scheme originated by Darius the First for connecting the Red Sea with the Mediterranean; but so gigantic did it appear to the people—who were afraid it might be the means of inundating the country—that they caused the priests to stop all the works.

We are also informed that the causeway, leading from the quarries to the great Pyramid, required the labour of 100,000 men for ten years, and 360,000 additional men were required for twenty years in building the Monument itself. As the Canal was excavated by the labourers or slaves paddling out the sand and mud with their unaided hands; and the colossal stones of the pyramid were pushed along and lifted, partly by the use of rollers underneath, and the sheer force of the multitude, it will at once be seen that the methods adopted were of the most primitive description, and entailed an enormous amount of severe and unnecessary exertion, which a few of our modern machines would have abolished.

Amongst those who flourished in ancient Greece were three very remarkable men. One was Hero of Alexandria, another was Archimedes, and a third was Euclid. The the two former touched the very borders of our system of mechanical engineering, but were unable to develop their ideas sufficiently on this subject.

Hero flourished about 130 B.C., and his extremely primitive steam engine, named the Æolipile or "Ball of Æolus," was almost identical in principle with the "Barker's Mill" of our own time. He also employed steam as an agent in giving life-like actions to the gods of the period, and thus deluded their worshippers, who attributed those movements to Divine interposition.

A writer in the *Quarterly Review* observes that: "Archimedes was a profound genius; he drew from his intellectual treasury a rich store of the most curious theoretical discoveries, and of the most useful practical inventions. He maintained a rank among ancient philosophers, similar to that of Newton among the moderns. He may also be considered the father of the science of statics and hydrostatics, for to him we owe the true theory of the equilibrium of forces in machines, and also in the pressure of fluids. He understood the theory of optics, as is evident from his invention of the burning mirrors, by means of which he set fire to the Roman fleet at a furlong's distance. He was a man of taste and activity, and combined in an extraordinary degree theoretical knowledge and practical skill. His discoveries in pure geometry alone would secure for him the admiration of all ages, as he travelled in so many unbeaten paths, and adopted methods to aid him in his investigations which were so admirable, that antiquity has assigned him the first place among geometricians.

"When we contemplate the extraordinary effects produced by the machines of Archimedes, we cannot but lament that so great a man should have been infected with the ridiculous notions of the Platonists, which would not allow them to leave anything in writing, relative to the details of mechanical contrivances. In consequence of this, posterity has unfortunately lost not only the benefit of those particular inventions, but also the high proficiency in mechanical arts to which an acquaintance with them would naturally have led."

Plutarch tells us — in his *Life of Marcellus* — that Endoxus and Archytas were the first to give attention to the science of mechanical engineering, which was so highly developed by Archimedes not long afterwards. Plato was greatly annoyed at this, and inveighed against them for "destroying the real excellence of geometry, by making it leave the region of pure intellect, and thus become sensuously associated with bodies which required so much servile labour in order to perfect them." In this manner practical engineering was separated at the outset from mathematics, and although regarded with contempt by philosophers, it was nevertheless reckoned amongst the military arts.

Archimedes had a mind so exalted that, in accordance with the ideas of the Platonists, he would not condescend to leave behind him any writings upon what he himself considered the vulgar business of mechanics and the useful arts, preferring rather to immortalise in his various treatises the sublimely intellectual science of pure mathematics, in which he was so profound.

Thus we have a distinct reason given for the application of steam to the various systems of modern engineering remaining a dead science throughout all those centuries, until James Watt arose, and, with a few master strokes of genius, laid the foundation of its present world-wide extension in ten thousand and one different forms.

We cannot now learn much more of the history of Euclid than is generally known, nor is it indeed necessary to do so. Those, however, who have studied his analytical science must be fully aware that it is the only pure and exact science we possess, and one that is entirely free of all terms such as "very near," "just about," "something like it," and so on. It is not surprising, therefore, that some people are fascinated by it, as the logic of mathematics is crushing,—the reasoning beautifully clear and simple, though at times requiring profound consideration,—and its statements incontrovertible. Besides this, there is such variety in Euclid's problems and theorems, and so much practical benefit to be derived from them, that they become invaluable to those who need their aid in many ways.

If it were possible for those three worthies to revisit the earth, and witness the changes that have taken place since they left it, how they would stare and rub their eyes in blank amazement, wonder and surprise! How they would solemnly gaze all around in mute astonishment, and, after recovering themselves a little, begin to chatter away in choice Greek about what they saw and what they thought of things in general! I can imagine the scene.

There stands the trio of grave, thoughtful, antiquated gentlemen, with the stamp of intellect on their handsome features. Archimedes breaks the silence with—

"Well done the Moderns!"

"Very well done!" says Hero.

"Remarkably well executed!" adds Euclid.

'Ah!" says the Alexandrian, "didn't I just give them the start with my steam engines? Didn't I shew them how the thing could be done? If I had only lived a little longer, wouldn't I have James Watted them—quite? But, dear me! have they taken all this time?—*all* these centuries—to find out for themselves a practical solution of the grand ideas I had on my mind when Death snatched me away? It is indeed astonishing!"

"I quite agree with you, sir," observes the mechanician. "Their engines and machines, and wheels and shafts, are admirable, but I am surprised to hear they are not even one hundred years old. What in the name of all the gods and goddesses, have they been doing or thinking about for ages past? Is it possible that much of what they pride themselves on was known to myself? My mind was so filled with magnificently useful schemes I hoped to accomplish that it is hard to say what I would have done if the Destroying Angel had not paid me a visit and put a stop to them; and to crown all, those old fools the Platonists would not let me write out my valuable experience for the benefit of future ages."

"Very sad indeed to see such folly," the mathematician musingly observes. "What a benighted race these Moderns must have been to take so long to find out for themselves the grand improvements you made in engineering. I am glad to see, however, that they appreciate my science, which is reflected in many of their works. They have simplified the solution of many of the problems and theorems which fascinated me in ancient Greece, but the truths contained in them remain unaltered. I left twelve volumes behind me, and, if Marcellus had only left me alone, it is difficult to say how many more I might have given them. That wretch, the Caliph Omar, had an idea that if the books in the Alexandrian Library agreed with the Koran they were of no use, and if they didn't agree they should be destroyed, so he fired the building, and deprived the world of four of my best treatises. Too late *now* to restore them."

The ancient sages again smile and laugh at the "stupidity of the Moderns." But why this sudden lull in the merriment? Wherefore that thoughtful expression which clouds their noble faces? Ah! their time is up, their frolic is ended, and they know it. . . . We try to scan a great but distant railway bridge which has been pointed out to us by Archimedes, and as we turn round to speak to him about it, find to our astonishment that all of them—have vanished!

It was only a dream—a dream of antiquity; but fanciful as the idea of their visit has been, the fact remains that two of them at least have left a fame and a name that will endure to the end of time, and serve as noble examples of what the higher ranges of the intellect could accomplish under great disadvantages in days of yore.

Civil engineering as it was, and as it is, are two very different things indeed. When railways in large numbers had to be constructed; when canals were greatly in demand; when the road system throughout the country was being developed; and when, in these three cases, an immense amount of highly skilled labour was required, and few in the land possessed the requisite experience, engineers prospered greatly, large fortunes were frequently made, and good incomes easily obtained. Now, however, Great Britain has become so overrun with railways, roads, and canals, that there is not much left to be done at home in this direction. On the other hand, so enormous is the demand for similar undertakings in foreign countries, and so extensive are the resources of modern civilisation, that a bright future appears to be still in store for the engineering profession in all its branches.

Since the present Suez canal was completed, other gigantic projects of a similar nature have been brought forward from time to time, and are now in progress. The most prominent of them, however, are now so well known that further comment is needless.

Another branch of civil engineering that has been wonderfully developed in later years is the science of tunnelling, which even yet appears capable of great extension. The Mont Cenis and St. Gothard tunnels were great undertakings, but they sink into insignificance when compared with what has been proposed, or what may yet be thought of in the near future, by enterprising speculators. From an engineering point of view, there is apparently no serious obstacle in the Channel Tunnel scheme, beyond its prodigious cost of from fifty to eighty millions sterling. Three gigantic steamers, however, of great beam, and capable of carrying loaded trains at all times, would probably perform what is required in the most satisfactory and economical manner. Indeed, Sir John Fowler and Mr. B. Baker have designed an excellent Channel ferry on this principle, the total cost of which is estimated at two millions only.

At Granton, near Edinburgh, where the Forth is five miles in width, and greatly exposed to storms, this system has long been successfully adopted. And across the three mile wide Straits of Carchenas, near San Francisco, four lines of trains, amounting in all to fifty cars, are ferried across at one time in the easiest possible manner, by means of a steamer 450 feet long, and 130 feet broad.

The difficulties attending the excavation of the Mont Cenis Tunnel were very serious, owing to the extreme hardness of the rock, but they were most successfully overcome by the aid of excellent machinery, and so accurately were operations conducted from both sides of the mountain at the same time that the junction in the centre was all that could be desired. A sad story is related in connection with a similarly important undertaking.

At the Inter-Oceanic Canal congress, held some years ago in Paris, there sat among the leaders of the enterprise a grey-haired and intellectual-looking man, with a somewhat melancholy expression of countenance. The assembled visitors congratulated him upon the approaching termination of one of the grandest engineering schemes of the century. Turning to a friend who stood beside him, he said:—

"I have worked all my life for a little renown, and a little wealth, and now, in the moment of my triumph, I find that neither is worth the trouble it has cost me. Indeed, the only use of the money I have made is to help those who are less strong and less happy."

The speaker was Louis Favre of Geneva, the contractor for the famous St. Gothard Tunnel, which had just entered upon its eighth and last year of construction. He went straight from the congress to Airolo, at the mouth of the tunnel, and was shewing the levels to a French engineer, when he suddenly complained of cramp, called for a glass of water, and instantly expired.

In future years, some ambitious promoter of great schemes may endeavour to form a Company for the purpose of working what he proposes to call the "Anglo-American Submarine Railway Company Limited," the object of which is to unite the Old and New Worlds by a tunnel underneath the bed of the Atlantic. But here we must draw a line between the practicable and the impracticable, and, so far as we can see at present, apply a word which Napoleon said was not to be found in the French dictionary, and that word was—"Impossible."

Civil engineering also includes the designing and construction of bridges, in timber, iron, brick, and stone, and there is probably no kind of structure in which more ingenuity and fertility of resource have been needed than in those which cross rivers, ravines, etc., requiring in most instances to be specially adapted to the ever-varying conditions of site, locality, width of span, loads to be carried, such as those which are created by railway, road, or foot-passenger traffic, and we may also add the caprice, fancy, practical considerations, and taste of the designer or promoter.

In countries such as England, which abounds in rivers, bridges are invaluable. So long as the population was limited, intercourse between one place and another was of the most primitive nature, hence there did not exist any necessity for our modern methods of sustaining the continuity of the roads or tracks which then prevailed. The shallow parts of rivers were naturally selected as the proper places for fords, which could easily be waded by men and horses when the water was low, and even in times of flood might be crossed by swimming.

The magnificent City of Palmyra owed its origin to a little oasis in the midst of the Syrian desert, which formed the favourite camping place of roving tribes, or of caravans on their journey, and thus we have an apparent reason for the subversion of a natural law, which has caused towns and great cities to arise chiefly on the banks of navigable rivers, or on the sea coast.

Towns and villages sprung up at some of the fordable localities we have referred to, from which they derived their names, such as Dept*ford*—" deep ford" originally—Dart*ford*, Ox*ford*, and so on, and in course of time the civil engineer was called upon to design and erect the much-desired bridges, which in many instances are to this day lasting records of his skill.

Between the simplest and most primitive form of bridge, consisting of a piece of timber spanning a small stream, and the colossal structure on the Forth, there is, indeed, a very wide gulf, and between these two extremes, bridges are to be found in endless variety, and involving considerations of the most diversified character. A plank thrown across a ditch may cost a few pence, and if it should break in the middle with a passing load, the the damage will be insignificant; but if, on the other hand, a structure such as the Britannia Bridge across the Menai Straits, or that across the Niagara, were to give way while a train was passing over it, the rolling stock and all it contained would be annihilated, and one country at once become severed almost, if not entirely, from another, so far as the traffic was concerned. Thus the importance of high-class bridge engineering will at once be seen.

The Forth bridge, already mentioned, has a clear headway of 150 feet from the surface of the water. Its two central spans are each 1,700 feet in width, while the other spans—22 in number—are much narrower. The total length of the bridge, including approaches, measures upwards of a mile and a half, and the contract price of the whole was £1,600,000, or nearly £200 per lineal foot.

The East River Bridge, between New York and Brooklyn, is the largest yet constructed on the suspension principle. It is 6,000 feet in length, by 85 feet in width, and is divided into three great spans, while its cost has been about £2,800,000, or £467 per lineal foot.

In India, where skilled labour is not easily obtained, a special type of bridge is required which involves the least amount of trouble in erection; and, in places difficult of access by the ordinary means of transport, the weight of each part has to be reduced considerably for convenience in carriage. In the Colonies the rudest system of construction is sometimes quite sufficient for the purpose, as a tree thrown across a stream, or a rope-bridge of the simplest form, spanning a deep ravine, are equally advantageous to those whose heads are not easily disturbed, and whose feet are somewhat of the prehensile kind.

Amongst the most useful and least expensive bridges on the suspension principle, are those so frequently employed in mining districts, consisting of wire ropes, sometimes of great length, extending from a high level to a low level, such as from a mountain side to an adjacent river wharf, or to a seaside pier. Trucks containing minerals, etc., are suspended from these ropes, and made easily workable by means of grooved pulleys which run upon them, and thus enable the loaded wagons in their descent to haul up the empty ones. As the strain upon the ropes is equal to many times the load upon them, the greatest care should be taken to make their end fixings secure. When this is properly done, passengers as well as goods may be carried with safety across chasms 1,000 feet deep, in any part of the globe.

At Monte Penna a continuous span system is adopted over openings ranging from 85 feet to 2,230 feet, so fully recognised, however, is the value of this method of transport that it it now extensively employed both at home and abroad.

The timber trestle railway bridges of America are very suitable in some localities, but they are complicated looking structures compared with others. This is specially observable amongst those of large size, such, for instance, as one in the far West, which spans a ravine and is 164 feet high and 1,086 feet long.

These are but a few of the leading characteristics of bridges in different countries, which require to be adapted to the ever changing conditions already referred to.

Works connected with the drainage, irrigation, and reclamation of land, also fall within the province of the civil engineer, and contribute in no small degree to the welfare of nations as well as that of private companies and individuals. The reclamation of land on a great scale gives considerable employment to the mechanical engineer, upon whom so much of the success of the scheme depends when pumping operations are necessary; and one of the most notable examples is to be found at the Ferrara Marshes, in Northern Italy. To give an idea of the magnitude of the project, it may be stated that the tract reclaimed covers an area of nearly 200 square miles, and that the total quantity of water lifted to a height of 12 feet, by means of four pairs of centrifugal pumping engines, exceeded 2,000 tons per minute. This machinery was made by Messrs. John & Henry Gwynne, of London, and is said to be amongst the most powerful of its kind in the world.

The reclamation of territory in England has been of a most extensive character, as vast expanses of valuable land were two or three centuries ago completely under water. This has especially been the case on the banks of the Thames, and also in the great fen district, which was from sixty to seventy miles long, and from twenty to thirty miles broad, but now contains about 680,000 acres of rich pasture. The territory thus reclaimed by the skill and labour of successive generations of engineers is, however, only protected from injury by continuous watchfulness from day to day.

Works of this kind are among the greatest that energy and perseverance have ever achieved; indeed the kingdom of Holland may be said to owe its very existence to the great dykes that protect it from inundation by the sea. Almost from Richmond to Gravesend, the Thames is quite an artificial river, vast tracts of country along the banks having at one time been completely submerged, and these, too, owe their present fertile condition to the labour of many talented engineers, who directed their attention towards confining the river between its present boundaries by means of embankments, the failure of which has often produced great havoc in the neighbouring counties. On one occasion a large part of Kent was thus laid under water, when the gap in the river wall became so deeply scoured out by the tide, as to baffle for a long time the sustained efforts of those most experienced in this kind of practice.

What is now known as the Goodwin Sands formed at one time part of an estate belonging to the Earl

Godwin, but the cause of its destruction was unknown to many in later years. Bishop Latimer,—in a sermon preached before Edward VI, in the year 1550,—described the method adopted for clearing up the mystery. He said that a Mr.—afterwards Sir Thomas—More paid a visit to the little town of Tenterden with the object of ascertaining the cause of the disaster, which greatly excited his curiosity. Upon discovering that well-known individual, "the oldest inhabitant," he questioned him in the "be careful" style as follows:—

"Have you known this place long?"

"All my life, sir," replied the man of one hundred summers.

"Do you remember when the Goodwin Sands were dry land?"

"Oh, yes, that was before Tenterden church steeple wor built."

"Now, tell me, when did the water come in?"

"After the steeple was built."

"What then do you think was the cause of the sea covering all that land, and bringing about such a deplorable catastrophe?"

"Well, sir, you see, afore the steeple wor built the sea was far away, but after the steeple was finished it came in and flooded us—I think, sir, the steeple wor to blame."

This reasoning was illogical, but the old man told the truth—the steeple was indeed the cause of the evil!

For ages the Godwin estate had been protected from the ravages of the sea by a strong embankment, which was constantly kept in good order. Unfortunately, however, during several consecutive years, storms were almost unknown. This lulled the people into fancied security, and the money which should have gone towards keeping the sea wall in repair was applied in beautifying the village church. Immediately after the steeple was finished, a great tempest arose—the wall was destroyed—the land inundated,—and thus it has remained to the present day.

At no period since the Deluge, has the world been visited by such an appalling calamity as that which devastated the rich province of Honan in 1887, the cause of which was the bursting of the Hoang Ho embankment, and the consequent inundation of a vast territory. England is happily protected from such occurrences owing to the configuration of the country, and the nature of its rivers, but in India and China the case is completely different, as some of the great arterial streams flow for hundreds of miles through a flat and alluvial district, which creates a sluggish current, and consequent deposit of silt along their whole course. Thus, slowly but surely, laying the foundation of a serious danger, which the highest engineering skill is sometimes unable to prevent.

This method of raising a river bodily, extends more or less over various periods of time, and requires a gradual increase in the height of the embankments, until at last, the surging pressure of a mighty torrent causes them to give way at some weak point. A province is consequently wrecked, the old channel leading to the sea is forsaken, and a new one is formed which finds another outlet.

Amongst numerous practical examples of the processes referred to, the Hoang Ho stands pre-eminent. This river is larger and swifter than the Ganges, and possesses the peculiar property of enriching the land through which it flows by the silty deposit of a previous inundation, and then again destroying it by overwhelming floods. The

Po, whose bed is in some localities forty feet above the Lombard plain, acts in the same manner, and so also do other similar streams, hence the urgent necessity of guarding them at all dangerous places. Since its outburst in 1852, the bed of the Yellow River has risen so far above the plain, that enormous embankments, from 300 to 500 miles long, have been constructed for the purpose of protecting the country from floods. These require very careful supervision, as any faulty or leaky part will rapidly insure disastrous failure.

The Hoang Ho is, therefore, a source of great danger to those who live near it. Its ordinary width is about one mile,—or the same as the Mersey at Birkenhead,—and its depth about 70 feet, but when the mountain snows melt, it rises upwards of 20 feet, and in some places has a very high velocity.

The freaks of alluvial rivers are sometimes of a surprising character. The Mississippi, for instance, has obligingly shortened itself nearly 250 miles in 176 years. That is, it has, from time to time, cut through the narrow isthmus of an elongated horse-shoe bend, and made a new channel for itself, to the delight of some planters, who thus had a navigable waterway unexpectedly opened out for them, but to the dismay of others, whose estates could not now be approached for want of water. In India and China, some of the rivers travel from 2,000 to 3,000 miles before they reach the sea, and the greater part of their course lies across dead level plains, so devoid of rocky boundaries that the water may run in any direction during a flood, and of this we have many examples. Amongst them may be mentioned the Damoodah,—a tributary of the Ganges,—which has baffled the most skilful engineers; and the Brahmapootra, which, up to

1830, entered the sea 200 miles eastward of where it now joins the Ganges.

In 1852, the Hoang Ho burst its bank 250 miles inland, and cut out a new channel, which discharged its contents into the ocean 500 miles from its old mouth; but the calamity which overshadows all others was the flood of 1887, previously mentioned, which laid a tract of country much larger than Wales, or at least 10,000 square miles in extent, from ten to thirty feet under water, and destroyed the lives of, it is said, nearly seven millions of people. Although the Chinese built another embankment, at a cost of £2,000,000, it was again carried away in 1888, thus exemplifying the capricious nature of these earthwork barriers in Asiatic countries.

This branch of engineering chiefly refers to the working of rivers and tidal estuaries, and possesses two distinct features; one of which involves a correct knowledge of the silting process, just described; and the other, of the scouring powers of running water. When the currents caused by the tide are sufficiently strong at any particular place, the scouring effect thus produced will shew itself by local deepening of the channel, and this is especially observable in seaports such as Liverpool. The action of the Mersey on its channel and estuary, clearly illustrates what takes place more or less in other navigable rivers, according to the nature of their beds; and the cause of this action is the enormous volume of water which rushes through the narrow passage opposite Birkenhead, and fills the greatly expanded upper reaches of the river. A vast reservoir is thus formed, which, on discharging its contents by the ebb-tide, creates sufficient scouring power to keep the estuary channel sufficently free from silt.

The Forth provides a good example of what may be done in time by rapid currents similarly originated, and passing over alluvial beds. On both sides of Inchgarvie Island, which forms one of the pier foundations of the great bridge, the narrow passages have been scoured out to a depth of 180 to about 220 feet, but shallow rapidly, as the river widens both above and below. The most wonderful of all rivers in this respect, however, is the Saguenay, in Canada, a tributary of the St. Lawrence, whose astonishing depth of 600 to 900 feet is maintained throughout nearly the whole of its length.

One of the most curious and instructive examples of the manner in which scour may be created, is to be found at Coney Island, near New York, where, in 1888, a hotel three stories high, 465 feet long, by 150 feet broad, and weighing 5,000 tons, had to be removed bodily, on wheel work framing, a distance of 239 feet inland. The cause of this was the construction of *protecting* sea walls on the adjacent property, which had thus produced an amount of scouring power sufficient to carry away the beach in front of the hotel, and allow the sea to encroach to such a dangerous extent upon the building, as to necessitate an alteration of its position.

The greatest work of modern times is the Ordnance Survey of the United Kingdom, which was begun in 1784, and has been continued without intermission ever since. At the end of 1885 the staff of Royal Engineers and Civil Engineers thus engaged numbered 3,240, and it is now expected that the whole of the survey will soon be completed. We may here observe that a cadastral survey is carried on by means of a series of triangles proceeding from a base line—that is, a piece of level ground, usually about five miles long—which is measured by chain in the most exact manner. Upon this base line a triangle is formed, and the length of the two unknown sides computed by trigonometry, From the primary triangle other triangles are formed and similarly calculated, until the series, extending like a network all over the country, is completed. These measurements, however, have also to be verified by other base lines, termed "bases of verification."

As an illustration of the marvellous accuracy of the survey, it has been found that the length of those base lines, calculated from the original one by trigonometry through all the intervening triangles, coincides within *four inches* of the length actually measured by chain. We have thus, from one or two measured spaces, a system of triangulation worked out over the whole country, and its area and the relative geographical position of every spot on its surface fixed for all time.

Previous to 1840, a scale of 1 inch to the mile was largely adopted, after that the 6-inch scale was used; but the four northern counties of England were re-surveyed, and maps published to a scale of 25 inches to one mile. It is impossible to form an adequate idea of the inestimable benefit conferred upon the nation by this vast undertaking. It has proved of great value in matters of the highest public interest, including the drainage of land, water works, railways, and engineering projects generally. And, as a practical example of the public advantage thus obtained, as well as of the vastness of the work, it may be mentioned that, on a recent occasion, no less than 453,000 maps were required by the Boundary Commissioners to enable them to carry out their investigations.

These few remarks will perhaps serve to show the great advantages conferred upon the world by the

"Civil" branch of the profession. It must be borne in mind however, that although the ancient undertakings mentioned in this chapter might well have been carried out in the past with the aid of the pickaxe, the spade, armies of workmen, and unlimited time, the mechanical resources of modern times are now so enormous as to render Civil engineering, even on the most colossal scale, perhaps still more of an "elegant and intellectual recreation" than it was supposed to be by some of the members of the legal profession in the early days of railways.

CHAPTER VIII.

PRACTICE OF ENGINEERING.

Preliminaries of Contract for Merchant Ships—For Ships of War—Conference between Shipowner, Builder and Engineer—Description of proposed Ships and Engines—The Estimate—Contract settled—Drawing Office—How Working Plans are prepared—Good and Bad Engineering—Chief Draughtsman—Results of interference by unqualified people—Style and system in modern working drawings—Also in olden times—Swell Draughtsman from Maudslay's?—Heliographic Process—"John Russell's Sailor"—"Urgent" Plans of Machinery for Ironclads.

So FAR as we have gone, the history of engineering has been very briefly touched upon, because those who wish to study it fully may do so in many well-known books, especially those of Samuel Smiles, such as: *Life of George Stephenson; Boulton & Watt; Lives of the Engineeers; Life of Sir William Fairbairn;* and his recent production, *James Nasmyth;* all of which will be found interestingly instructive to those who like this kind of literature.

I have described works on the Clyde and Mersey, and in the latter have referred to the principals, glanced at the manager,—mentioned the peculiarities of some in the drawing office,—explained the duties of foremen and workmen, and enlarged considerably on the apprentice question. In all cases I have given my own experience of them during many years' practice in their midst, and now propose to give a rough sketch of the operations usually adopted in the construction of marine engines and ships. Whilst attempting to do this, it is not necessary to refer to any particular establishment, because first-class firms generally do not vary much in their system of management. The descriptions, will, however, be largely drawn from what I knew of the Birkenhead Iron Works, and other places I have been associated with.

Let us suppose, for example, that a shipowning firm wish a few additional vessels built for a particular service and with a certain speed, cargo and passenger capacity, draught of water, and so on. This would be right enough for the merchant service, but for home or foreign governments, the "cargo and passenger capacity" is an unknown quantity, except in troopships. In gunboats, armed cruisers, ironclads, and others, a somewhat different set of conditions is adopted.

If the Admiralty desire an ironclad of say 6,000 tons, built in a private yard, and in accordance with the latest and most improved principles, they will either submit their own plans and specifications to people they invite estimates from, or they may give only a few leading particulars of ship and engines, and leave certain favoured firms to design, in a sketchy style, what *they* consider the best arrangement, reserving to themselves, however, the right of judgment in such matters, and also the selection of the most suitable firm to whom to give the contract.

In the merchant service this last-named system is frequently employed in a greater or lesser degree; but at other times the shipowner, through his consulting engineer, somewhat sketchily designs his own ships, and then requests builders, etc., to estimate for their construction in accordance with these plans, and also a specification, which is a very carefully written document, giving in detail the leading proportions, material, workmanship, and other conditions too numerous to mention here, in reference to the required work. But even in this case, full liberty is given to engineers to adopt their own most approved methods of executing those details.

It may so happen, however, that a Company has had a number of successful vessels built and engined on suitable terms, and with the least trouble to themselves, by firms in which they have every confidence, such as for example in olden times, the Peninsular and Oriental Company and Tod & Macgregor; also the Cunard Company and Napier. Now, if a steamship owner, even at the present day, wishes to act in a similar manner, he will hold a conference with the builders, and thus arrange speedily all that may be necessary regarding the new ships, and in furtherance of his views will pay them a visit, when he will be most cordially received by the principal partner,—who is probably the director in the ship department,—and also the engineering-manager, both of whom will, very likely, conduct the interview in the following manner:—

The latter gentleman telephones to the drawing office, "Send down immediately the general plans of engines 801 and 816." The draughtsman, or apprentice who replies, now opens a large drawer, containing a great variety of similar plans, in the fire-proof room, and upon finding what he wishes, takes them downstairs.

"Now," says the manager to his client, spreading out the drawings on a large table, "here are the plans of two fine sets of triple expansion engines we made recently for the 'Hispania' and 'Corcovadore,' which gave great satisfaction; they worked remarkably well upon a very small consumption of coal, and indicated about 4,000 horse-power.

"Very admirable arrangements indeed," replies the shipowner, "and as those of the same type you have already supplied us with have been most economical, I think you could not do better than make similar machinery for our new vessels, but of much greater power. You are also quite at liberty to introduce any novelty or improvement you may consider advisable."

A lively discussion now takes place upon the relative merits of different kinds of engines and ships, in which they all join. The senior partner has a good deal to say about "style of ship," "watertight bulkheads," "economy of steel in construction, in reference to increased carrying capacity," and other matters which the visitor quite agrees with. The manager also fluently describes in detail his ideas about "long stroke," "rate of expansion," "high-pressure steam," "simple arrangements," "steel shafts," "steel boilers,"—so on and so forth—in all of which he is ably confirmed, in a general way, by the shipbuilder, until the client feels he is in the presence of people who know *everything*, and this causes him to think that his proposed vessels could not be placed in safer hands.

During this interview, three talented people have discussed in the happiest possible manner, and with the greatest intelligence and ease, a scheme which involves an outlay of several hundred thousand pounds, quite as if it were an everyday occurrence. They have all been perfectly above saying anything that was not absolutely correct, and free from that colouring which inferior persons so often adopt, but they are, nevertheless, masters of the art of "putting things," and also of clothing their ideas in expressive and elegant language. In short, this conference has enabled them to explain all that was necessary, and the only thing that now remains is to arrange about the cost of the ships. Before the ship-owner leaves the office, the following particulars are agreed upon, on which the builders are to base their estimate for the vessels, complete in every respect.

"Three steel-built steamships, length over all, 460 feet; beam, 49 feet; depth of hold, 35 feet 6 inches. Each vessel to have accommodation for 126 first class, 154 second class, and 400 steerage passengers.

"Engines to be of the triple expansion type, and 6,000 indicated horse power. The crank shaft, tunnel and screw shafts to be of Vickers' mild steel, and the propellers to be of cast steel, with movable blades.

"Boilers to be of steel of the most approved quality, with Fox's corrugated furnaces, and capable of carrying a steam pressure of 160 pounds per square inch.

"Design, material, and workmanship to be in every respect of the highest class, and speed of ships on trial trip to be 16½ knots per hour."

The above simple and expeditious method of describing a shipowner's requirements is adopted in this case because, with the exception of the modifications referred to, the builders know almost exactly, from past experience, what is desired, as they possess full specifications of similar vessels supplied to the same firm, between whom and themselves the greatest confidence exists. Were it otherwise, a carefully prepared specification would have been drawn up by the owner's consulting engineer, lithographed copies of which would have been sent to engineers and shipbuilders who were "invited" to tender for the contract.

In the course of a few days, our friend the eminent steamship owner receives a statement of cost of the proposed addition to his fleet, which is carefully examined and commented upon in his private office. "These people," he observes, "ask a high price for the three ships and I know I could get a lower estimate elsewhere, but they turn out splendid work, and we shall make up for the extra expenditure by economy in repairs and maintenance." The other partners of the firm express the same opinion, so without further delay, the contract is handed over to the builders, with strict injunctions to execute it as speedily as possible.

In bridge, roof, and other work, however, of a more regular character, "Quantities of Materials" are also added to the specification, and thus estimates can be given with greater exactness and less trouble. But however binding this arrangement may be upon both parties, there is always provision made for alterations which may suggest and develop themselves as the work proceeds, involving, it may be, an increase or perhaps a reduction in the cost, and this is clearly understood by those who give the order, as well as by the people who execute it.

THE DRAWING OFFICE.

In good establishments, the drawing office is practically the seat of government. The fact is that this department locks or unlocks the whole of the complicated and extensive machinery of the works, and a great deal that is outside of them as well. In short, all the immense capital that may be provided for carrying out some great scheme remains idle until set in profitable motion by the scientific staff, who have to provide plans and details of everything, large and small, before the workmen can do anything.

When, therefore, an order is received, such as the one we have mentioned, it is at once handed over to the drawing office authorities, who initiate the first movements. The diameters and stroke of the steam cylinders having been already fixed, a preliminary sketch design, to a small scale, consisting of front and side elevations, and also plan, is begun with the object of ascertaining the general arrangement of parts, in which numerous calculations, and large scale details of a temporary character, and roughly executed, are of great assistance.

After finding the size of crank shaft, distance apart of centre lines of engines, and also centres and diameters of air and circulating pumps, and dimensions of condenser, etc., the working design is commenced to a scale of at least one inch to one foot on a sheet of web-paper damp-stretched on a large drawing board. When this is done, the general arrangement of details, which have afterwards to be separately designed and considered, is proceeded with, while working drawings of some of the details themselves are put in hand.

These are drawn to various scales, according to circumstances, but 1½ inches and 3 inches to one foot, half size, and for small gear, full size, are very generally used. Everything has to be most carefully and patiently worked out with the greatest accuracy and elaboration, and every dimension figured so that neither scales nor foot rules need be applied in the shops, except for the purpose of checking, if required. In this last operation every line and every figure has to be critically examined, rectified, or added to, before the draughtsman will allow a tracing of the drawing to go into the works, and after all this is done, it is surprising sometimes how errors will creep in, in spite of every effort made to avoid them.

These inaccuracies, however, are very seldom worked to, perhaps they flash unbidden into the draughtsman's mind when he is going home at night, the manager may possibly detect them, but sometimes it is the foremen or workmen who make the discovery, and get them put right in the office.

It is at this point where the very highest practical and theoretical skill of the engineer is most required, and where any mistake may easily cause serious results if not detected in time. Numerous calculations have to be made, verified, and compared with past practice—the "Theory of strains" is fully worked out, so also is the "Strength of materials," and between these two valuable branches of engineering science the proper proportions of all the parts is determined, and the work proceeds.

However excellent, from a scientific point of view, these proportions may be, they are all more or less overruled by practical considerations, which generally cause greater strength to be given to the details than theory alone would indicate, and in this respect good designers generally keep well on the safe side in everything. Another most important consideration is "Construction," since upon this depends the economical, or, indeed, possible execution of all the parts, and also the accessibility of, and facility in working and repairing the engines at sea. On all these points the skilled draughtsmen, in whose hands the drawings are now placed, as well as the manager who superintends them, have many opportunities of realizing the value of their early training.

It is here, too, that the difference between good and bad engineering begins to show itself. Under the former, and with due care and constant vigilance, everything goes on well, the progress in the shops is rapid and satisfactory, patternmakers, founders, turners, fitters, erectors and others all work together, and when the engines and ship are completed and sent to sea, the result is most gratifying to all concerned.

With bad engineering the case is very different, since at the outset, grave errors may creep in which threaten the life of the machinery. Boilers may be too small, condensing surface insufficient, steam ports and valves improperly proportioned; patterns are made which cause cracked or unsound castings; forgings, and other parts are made of an unnecessarily expensive and unsuitable form; indeed, much may be done unwittingly to bring in the end heavy financial loss, decreased prestige, and loss of clients.

As an illustration of this, it may be mentioned that while visiting, some years ago, a marine establishment which had been added to a small shipbuilding yard, I observed a few wretchedly designed working drawings of machinery in the shops, and also a curious looking casting of a "bed plate" in the yard without any holding down bolt holes or flanges for fixing the engines to the keelsons. These engines proved a failure.

The same thing happened a few years ago to a large and costly pumping engine for water works in America, simply through bad design; and not long since, a large ocean steamer had new machinery which could not give out the power required; and another vessel "improved" boilers which would not work properly until important and extensive alterations had been made in them.

This, therefore, is the point where three distinct classes of engineers begin to manifest their powers. Those who adhere rigidly to old ideas because long practice has shewn their value, notwithstanding that better, though newer, systems are within easy reach.

Those who are always on the look out for novelties, or rather the numerous " improvements " which enterprising inventors are so delighted to introduce, and so ready to prove capable of doing great things. And, lastly, those who—taking a middle course—reject the old but well known systems, in favour of modern innovations which their own sound judgment indicates must be really beneficial. This, it may be added, is the true reason why marine and other machinery of the present time is so greatly superior to that of earlier years, in strength combined with lightness, and also in general suitability and economical construction. The requirements of engineering drawings, which may represent very many thousand pounds worth of good work in one order alone, will thus we hope, be clearly understood.

The presiding genius of the drawing office is the head draughtsman, whose duties are perhaps more anxious and harassing than those of any other head of department in the works. Besides possessing high scientific attainments, he must have a thorough knowledge of the possible and impossible, and also the simplest and best systems of construction. As a complete set of drawings for marine engines are elaborate, expensive, and require much time in execution, a large amount of administrative ability is necessary to keep all the others going, so as to lose as little time as possible.

When many orders are in hand, the " chief " has a very busy time, having not only his own special work to do, but also to supervise every drawing and examine every tracing made in the office before it is sent to its respective department. The regular draughtsmen have all their own responsibility to bear for any mistakes that may occur through wrong figures or lines, or misinterpretation of plans for want of clearness, or insufficiency of views; and, although the chief draughtsman cannot be expected to check everything, he nevertheless verifies, to some extent, the proportions and arrangements of machinery before they leave his hands. A certain amount of mental toughness is also required to protect him from the meddling propensities of heads of firms, and managing directors or others, whose position may entitle them to advise professionally, without being qualified to give their opinions on such points.

However clever and able these gentlemen may be in general business, they often damage their own interests as well as those of their draughtsmen by this line of action. Most of our best modern engineers are thorough masters in design as well as in practice, and, therefore, know exactly how to advise, or even to receive counsel in the drawing office. Others cannot do so; and the consequence is, that the principal in this department is sometimes worried when work is in a hurry with their proposed alterations, which are anything but "improvements."

There is a vast amount of time thus lost which cannot be clearly realised, as an alteration made in what appears to be only *one* drawing may involve erasures and additions in many more, which is bad enough if the plans are still in the office; but expensive as well as troublesome, if patterns and forgings are partly made from them. If a director, therefore, fancies that increasing the stroke of engines, say, from four feet six inches to five feet, when the details are well in hand, is a trifle, he will be much mistaken.

A good chief draughtsman in a large marine establishment is accomplished in many ways. He is generally one who has closely and persistently studied everything in his profession—has worked while others played—and, in course of time, has accumulated an immense quantity of rules, tables, memoranda, data, etc., from his own and from other people's practice. These are invaluable, as they enable him to design and proportion the most important work with facility and confidence, whether for a firm, or on his own account at a future time.

When, therefore, an inexperienced proprietor says to him, "I am afraid you have not made that strong enough, or this light enough," or comes into the office with his head full of "ideas" he wishes carried out, it will be easily seen that a principal draughtman's lot is not always a happy one, particularly when, in addition to these unnecessary changes, he has to push on the work expeditiously, see that everything is right, and, if anything breaks when the engines are at sea, probably get the blame of it.

The style in which drawings are prepared is of the highest importance. The practice pursued in some offices, of unduly hurrying them, is perhaps more pernicious than that of allowing dawdling and idleness to prevail. Before a drawing can be properly understood, the piece of machinery it represents must be clearly and fully shewn in a sufficient number of views, and if any one of these is left out through a wish to economise time, the detail is very likely to be made wrong, unless one of the foremen insists upon having the additional view put in. Every engineer, therefore, who designs or executes work, knows this well, perhaps occasionally to his sorrow. Another source of error and trouble is sending out tracings carelessly or insufficiently dimensioned, under the belief that the foremen or workmen can measure them with their foot rules. This, we need hardly say, is a vicious practice, and entails mischief and loss in various ways.

In the Birkenhead Iron Works, and other similar places, every working drawing, large and small, is so fully and carefully figured, that no one need at any time apply a rule or scale, except for the purpose of verifying some doubtful measurement. In this way the work is greatly facilitated, and the risk of error reduced to a minimum. Besides this, everyone in the office knows exactly how things have been made, when referred to in future, and should any departure from the original become necessary, the plan is altered, even to the smallest bolt holes, generally in red lines—to shew the distinction—before anything can be done with it in the shops.

In olden times they seldom troubled themselves about office alterations. If the manager saw anything outside which he could possibly improve, he simply said to the foreman, "Make that a little thicker," or "I wouldn't put quite so much metal there," and if the bolts were not quite to his mind, directions would be given to alter them from $\frac{7}{8}$ths to 1-in. diameter, or from $5\frac{1}{2}$-in. to 6-in. pitch, no notice being taken of the drawings, and thus no one exactly knew where they were unless they saw the thing when made.

The above described modern system is in every respect most admirable. With some firms, however, it has a deterrent aspect because it is costly, and requires a large staff of draughtsmen; but the saving of labour and time and loss from other causes in the works, combined with easy adaptation of the drawings to similar engines and boilers in future, is a sufficient recommendation.

The usual practice is for the regular hands to make full and correct plans of what is required, and then get the apprentices, or perhaps young ladies—as in Denny's, and elsewhere—to trace them on transparent linen,—if for the shops,—or on tracing paper if to send by post. The former is very tough and durable, and lines and figures in Indian ink or colours can easily be taken out by washing them delicately with a brush, and drying up with blotting paper. If a similar operation is required for tracing paper, wet the lines as before, drying with blotting paper, and while they are damp rub them with vulcanised indiarubber, and they will come out as cleanly as if they had never been put in.

Writing about draughtsmen and drawings puts me in mind of a gentleman who came to Laird's when I was there. He was a handsome, stylish-looking man, of about thirty-five, and was formally introduced to us all by Mr. B——, our chief. We bowed, smiled, and said pleasant things, and fancied our new comrade might have been a swell from Penn's or Maudslay's, but when he made a start he did not seem to know much. The turning gear for a pair of engines was given him to draw, but he had to ask what the "pitch line of the wheel" meant. Ultimately he struggled through somehow or other. Afterwards he had to make a small scale drawing from a tracing of the machinery end of an Egyptian frigate, but here he was out of his depth entirely, and someone else had to do the plan over again.

We saw no more of our friend after this performance, but often wondered how the talented Mr. B—— could have brought such a "duffer" to the place. My own idea is, that he must have known him long before as a gentleman apprentice with means, one of those festive youths who can spend five years in a first-class establishment without learning anything useful,—and that he may have exhausted his fortune in various ways, like the prodigal of old, and, when it was gone, had taken up engineering again to make a living. Such at least was my theory, since Mr. B—— was as reserved and reticent in character as his predecessor, Mr. T——, was frank and genial.

The plan of keeping drawings in the office, and sending tracings into the works, is reversed in some places. but I cannot see the advantage of it, as the originals get irreparable damage through rough usage. Sometimes, however, they are framed and varnished, and that also is objectionable. At other times the drawings are kept clean and nice in the office, and heliographs taken of them. This is a good and rapid method of copying plans that are thoroughly matured, and not likely to be altered in any way; but when you have the apparatus at hand, it is not difficult to take new and amended impressions if required. A full description of the heliographic process, by Mr. B. H. Thwaite, C.E., is given in *The Engineer* of December 24, 1886.

The various systems adopted in the preparation of engineering drawings above mentioned, have reference chiefly to first-class firms, but there are some, no doubt, who seem to imagine that, so long as they turn out good work, the plans may be done in any sloppy, off-hand style. There are others, however, who think differently, and we commend them for it, especially because there are so many people in the world who reason like John Russell's sailor. John was a fellow apprentice of mine at Denny's, and had been several voyages before the mast. Amongst the various stories he used to tell us was one about a coloured sailor on board his ship, who always exclaimed when he saw anyone do something difficult, "Well! well!! well!!! – de man dat could do dat ting could make a *chronometer!*"

It may be well to add that the term "picture drawing," so much used by engineers, indicates something very different indeed from what has been referred to. Plans of this description are of the *high art* species, and, while intended to give non-professionals a clear and general idea of proposed arrangements of machinery, they are, at the same time, expected to attract their admiration and attention by means of beautiful shading, colouring, and sometimes shadowing as well. Very pleasing effects, however, of a similar nature, are produced simply by the drawing pen and Indian ink, but for practical men, good, clear, steady lines, well laid on flat tints, and first-class figuring, are quite sufficient.

I have said that we were seldom pushed with our drawings in the Birkenhead Iron Works; sometimes, however, when necessity demanded it, we made a grand dash to enable us to get finished in time. When the engines of merchant steamers were in a hurry, we worked steadily and earnestly at them, and lost as little time as possible, but some of our greatest efforts were spent over Admiralty orders in prospect, or for those in possession.

On one occasion we had a tracing of a large plan of machinery to prepare for an ironclad in great haste. It was big enough to let a draughtsman into each of its four corners, and away we drove at it as merrily and heartily as we possibly could. The lines and circles grew rapidly, and when they had all been put in, we turned the tracing paper upside down, pinned it tightly round the edges, and laid on the colours in light flat tints, of prussian blue for wrought iron, neutral tint for cast iron, crimson lake for copper, yellow ochre for brass, and darkened all apertures such as the furnaces of boilers, with washes of Indian ink. After trimming the tracing all round, we turned its face uppermost again, and when the finishing touches had been put in, the plan had a handsome appearance, and no doubt created the desired impression on the minds of their Lordships when they received it.

It may be added, that all tracings should be coloured on the *back*, as it prevents the possibility of that most unsightly "running" of the lines or figures, when put in too strongly. Another reason is, because the tints, when looked at from the right side, have a subdued and very pleasing appearance, which they do not possess on the reverse side owing to the nature of the paper or cloth.

On another occasion, I had been engaged on a large "general arrangement" drawing for a twin screw ironclad. To the uninitiated, this costly and important plan could only appear as a confused, and, in some places, intensified conglomeration of lines, every one of them, however, having a distinct practical meaning which will be referred to further on. As all these lines were in pencil, and a few additions and alterations had to be made before tracing the drawing, I had to do everything myself. Firstly, because the Admiralty wished the tracing as soon as possible, and secondly, and more importantly, because I was anxious to get away for my holidays.

It was one of those cases where the engineer in charge of a plan has no time for anything else, and is so carried away by the urgency of the work, as to stand by it almost like a slave by day and by night. If this were unduly sustained, some of our constit*oo*tions would get out of order, and perhaps bring on an attack of the dismals.

To avoid such an evil, however, we have outbursts of hilarity occasionally, which do us great good. So much indeed has this been the case with myself, that I would recommend all men and women who are closely engaged in intellectual work, to relax their earnest efforts from time to time, turn their minds into a new channel by way of change, and fancy themselves boys and girls again.

Speaking from my own experience, the application of this principle has helped to keep me in continuously splendid health and elastic spirits, for which I am extremely grateful. Celsus advised those who wished to keep in good health to have a *variety* of pursuits, and think of *many* things—this, we countersign in full.

After three weeks' close application, the tracing referred to was satisfactorily completed, and it was certainly one of the handsomest and most elaborate works of art that ever left the Birkenhead establishment. I cleared out just in time to catch the boat for Liverpool, and then the train for the north, glad enough to get off for a little change and relaxation. That was many years ago, but it is nevertheless a pleasant reminiscence of bygone and very prosperous days.

These two examples just mentioned will be sufficient to indicate the manner in which, with willing hearts and active hands, we carried through our work when speed combined with excellence were particularly desired, and will no doubt represent the practice of the present day in the same place, under similar circumstances.

CHAPTER IX.

DRAWING OFFICE CALCULATIONS.

Faulty Design and Construction of early Engines—Value of Hand Sketches—Accuracy in Working Drawings—Two distinct systems of Calculation—Simple practical rules in general use—Method of recording leading dimensions of Machinery—"Allowances" made by Engineers—The graphic system of Calculation—Complicated Rules—How to construct safe Empirical Formulæ—Rational Science Considerations—Drawing Office Practice—Value of Tabulated Proportions—Economy in Design and Manufacture—Office "Tables"—Sudden changes in Engineering Practice—Costly results of Injudicious "Improvements" in Machinery.

THERE is nothing in the whole range of Engineering which is of greater importance than a correct knowledge of the science of proportion, as applied to the multitudinous details which unitedly constitute a statical or a dynamical structure, and this will be apparent to everyone who studies the subject carefully. There was a time when engineers had to feel their way by a kind of trial and error process, but their failures became the pillars of success. Not only were all the parts of machinery badly proportioned, but they were also unskilfully arranged, and this produced many evils of a serious nature.

In the framings of early side lever and other engines, the architectural orders were much used, and while massive columns and entablatures may have been considered beautiful adornments, they were, at the same time, excessively heavy, and structurally weak at vital points. The bearings of main shafts heated greatly, because the lubricants were squeezed out, on account of the rubbing surfaces being so small in area as to create excessive friction. Pins were fractured, one thing after another gave way, and one detail after another was added for the purpose of producing greater safety in working. For instance, some of the early marine engines had no escape valves on the cylinders; when water, therefore, got into them through condensation of steam, or through priming of boilers, it could not free itself, and thus the bottoms of the cylinders were knocked out, or the pistons or covers were smashed.

The early engineers had thus to gain their experience by sheer practice, and in time machinery became greatly improved, and disastrous boiler explosions much reduced in number, as their defects in design and construction were more fully realised.

There is reason to believe that what is now termed "Drawing office practice" was at this period almost unknown, and that a large amount of work was executed either from verbal orders given to the foremen, or from rough hand sketches. Those sketches have been very useful, even from the earliest times, and will always continue to be, because they are the expressed ideas of their originators, and form the bases of every engineering scheme as a whole, or as a detailed part. And it is from those rough, though carefully considered, designs—dimensioned in accordance with the required proportions—that the exact and elaborate working drawings are now prepared. A set of these plans ought to be so complete in every respect that, when the details are made from them, they should be capable of erection in position with the least amount of trouble, and thus facilitate the execution of a contract.

Even after everything has been done to perfect a new set of drawings, there is always something to amend as the work proceeds, and as one's ideas become matured, which cannot be avoided if the highest excellence is aimed at. The plans for Solomon's Temple at Jerusalem are, perhaps, the finest example of correctness on record, because all the various parts came into position without even the sound of axe or hammer being heard on the premises. It is probable, however, that faulty work was removed to a distance, and chipped or chiselled to fit.

Two distinct systems of calculation are utilised in the profession, one of which is adopted by pure scientists and philosophers—who seem to float in a sea of algebra and mathematics—and embraces everything that is learned and perplexing. The other, by practical engineers, who aim at obtaining what they require in the simplest and most direct manner. The former is exemplified in some engineering books, but frequently attains full maturity in the technical journals, whose pages are sometimes filled with algebraical and other calculations of a wonderfully intricate character. Even practical engineers of eminence have not been free from this cumbrous system; and, in some instances, have given in their books rules and formulæ very different indeed from what might reasonably have been expected from them.

In a well known thick quarto, and at one time very useful volume on Land and Marine Engines, by an "eminent," as above described, there are—in the 1862 edition—some complicated methods of proportioning various details, which is all the more surprising when many celebrated firms, long before this date, made their splendid machinery from extremely simple formulæ. Take, for instance, the piston rod of an engine. This most important detail may be treated scientifically as a solid column fixed at both ends; or empirically, in accordance with a thoroughly reliable rule based upon long established practice. The most vital part of these rods is the screw for securing them to the piston. If this is large enough all is well, but if not, a sudden and disastrous breakdown will take place, no matter how strong the rest of the rod may be.

To avoid this, care must be taken to give the screw sufficient area at the bottom of the threads to enable it to withstand the full tensile strain that will occur at any time. In other words, find the total load in tons upon the piston, either from steam alone, or from steam and vacuum combined; and, as no greater working strain should be allowed for than $2\frac{1}{4}$ tons per square inch for $22\frac{1}{2}$ ton iron, or 3 tons per square inch for 30 ton steel, the total load on piston, divided by $2\frac{1}{4}$ or 3, will give the area required at bottom of threads for each metal.

In all engines, this true science rule is employed, but in triple expansion machinery, the body of the piston rod for the low pressure cylinder is proportioned by means of the well-known formula $D \div 10$, that is:—for a cylinder, say 100 inches bore, the rod will be 10″ diameter if of iron, and $9\frac{1}{2}$″ if of steel. For the sake of uniformity and also interchangeability, the piston rods of the intermediate and high pressure cylinders — say 66″ and 40″ diameter respectively—are made exactly the same, although they would be too large for those cylinders if used as single engines. This, however, is constantly being done, and forms only one of the numerous instances where practical considerations overrule the deductions of mere science.

Many other useful rules, similar to the above, were frequently employed when the marine engine was running with 25 or 30 pounds steam, and when the stroke of piston was generally about two-thirds of the diameter of the cylinder. Tod & McGregor, for instance, reduced their calculations to such a simple form, that some of the leading proportions for any size of engines—say, 60″ cylinders and 3′ 6″ stroke—could have been given at once, and in such a way as to lead the algebraical professor to fancy there were some sleight of mind secrets in the business. Suppose, for example, that you had asked Mr. Tod to give you the dimensions of the piston-rod, crank-shaft, single acting air-pump, branch steam pipe to each cylinder, and exhaust steam pipe, for the aforesaid engines, having $D=60''$ and $S=42''$, the calculations would have been worked out in this style:—

"Piston-rod, $D \div 10 = 6'' + \frac{1}{4}''$ for turning down when worn $= 6\frac{1}{4}''$ diameter.

Crank-shaft, $D \div 5 = 12''$, but put on another inch for extra safety, $= 13''$ diameter.

Air-pump, $D \times \cdot 6 = 36''$ diameter; and stroke, $D \div 2 = 30''$.

Branch steam pipe, $D \div 5 = 12''$—better make it $13''$ diamr.

Exhaust do., $D \div 4 = 15''$ diameter—quite large enough."

What! "a regular smash-up, breakdown system, was it?"

Well, no; not exactly. These formulæ were certainly empirical, but they saved a great deal of trouble, and were all based upon practice which was known to be good and sound by engineers who quite knew what was wanted, and who modified all their calculations so as to be on the safe side with everything. Besides this, the firms who used those beautifully simple rules among the "fifties" and "sixties," became famous and acquired wealth, which were certainly strong recommendations in their favour. The engines of this period rarely broke down, and everything went well—so well, indeed, as to create confidence all round. I may add, however, that Mr. Tod's P.S. "Juno" fractured her paddle shaft and smashed the paddle centre on her first voyage, but as the forging was unsound internally, she got another shaft the same size. Then, again, the S.S. "United States" mysteriously broke her air-pump crosshead, the new one was therefore made a little stronger; thus exemplifying, in these two cases, practical rules which are constantly used by all designers of machinery.

They had in the Clyde Foundry a very good method of recording the leading sizes of engines for future inspection and comparison. Down the left-hand side of a number of foolscap sheets, a list of names of the principal parts was printed, all of which referred in systematic order to ships, engines, boilers, propellers, and paddle-wheels, the lines opposite them being left for filling in with the exact finished dimensions. The upper part of these sheets contained the name of the vessel, the number of the engines, etc., and space was also left down one side for "general remarks." These loose pages thus became very useful, and gave at a glance desired particulars of the most trustworthy nature.

The value of the system of calculation just mentioned greatly depended upon the care and judgment exercised in the collection of data from existing engines of different sizes. In addition to this, the circumstances of each case had to be studied, and when these particulars were compared with each other, the formulæ deduced from them could be relied on. Although every pair of engines was designed more or less in accordance with the rules thus found, the skilled engineer used his own experience in making "allowances" when advisable, and also in confirming the accuracy of any doubtful calculation by more scientific formulæ. The same style of doing things may even now be utilised in triple and quadruple expansion and other engines, and in a great variety of engineering work generally. Care must be taken, however, to verify the strengths of important parts when necessary, by resolving the strains upon them directly into those of tension, compression, torsion, and transverse breaking. And, secondly, to ascertain by a knowledge of the strength of materials if sufficient metal has been allowed for to meet those strains.

In this branch of science, there is no better book than Box's *Strength of Materials*, which, in common with the same author's treatises on *Heat*, *Mill-gearing*, and *Hydraulics*, combines great perspicuity with sound practical reasoning and appropriate examples. Equally valuable in their own lines of marine and general engineering, are A. E. Seaton's *Manual* of the former, and W. S. Hutton's *Practical Engineers' Handbook* for the latter.

But whilst recommending these and other volumes, it may be well to add, that no engineer should trust implicitly to any of them for the proportions of details, or of machinery for which he is responsible, unless compared with executed work, owing to the simple reason that, in text-books generally, the ever-varying surrounding circumstances of each case cannot well be given, whereas in actual practice they are clearly understood.

In roof, bridge, and other kinds of constructions, the graphic system of calculation is invaluable, as it enables one to see at a glance, by means of diagrams, not only the strains at different parts of a structure, but almost annihilates the chances of error. If, for example, the pressures upon the sides of a water tank 40 feet square, and 20 feet deep, are required at every foot in depth:— Multiply 20 by ·434 = 8·68 pounds per square inch, and this × 144 = 1250 pounds, or say $11\frac{1}{6}$ cwt. per square foot of side at the bottom.

Now draw a right-angled triangle to any scale—say half inch to a foot—whose vertical side of 20 feet = depth of water, and whose base of $11\frac{1}{6}$ feet = load in cwts. Then, if you divide the vertical line into twenty equal parts, and draw horizontal ordinates inside the triangle, each line will give at once, by scale measurement, the exact pressure upon the side of the tank, beginning with nothing at the water level, and ending with the full load at the bottom. For ready calculation, however, *half a pound* for every foot in depth will give the approximate pressure per square inch. The same system can be used in a great variety of ways. Take, for instance, a plate girder 20 feet span, 2 feet deep, and carrying an equally distributed load of 10 tons. The strain on centre of the top and also of the bottom flanges will be

$$\frac{\text{Span} \times \text{weight}}{\text{8 times depth}} = \frac{20 \times 10}{16} = 12\tfrac{1}{2} \text{ tons.}$$

Now draw a line 20 feet long to any scale you please, and also a vertical line on the middle of it measuring $12\frac{1}{2}$ inches by the same or any other scale. Then construct a parabola with these dimensions for base and height, and this will give, by means of vertical ordinates, the tensile and compressive strains in the flanges at any point. If, in addition to the E. D. load, we add a central one of 10 tons, extra strains of 25 tons will arise at the middle of the top and bottom flanges—calculated thus:—

$$\frac{S \times W}{4\,D} = \frac{20 \times 10}{8} = 25 \text{ tons.}$$

On the same 20 feet base line, erect another perpendicular 25 inches high at centre, and complete the figure as a triangle. The ordinates thus enclosed, added to the others, will shew the combined strains at any point in the flanges of girder; and further, if any irregular method of loading the beam were adopted, the same system of triangles and parabolas would give all that was required without further calculation, if specially arranged to suit each case. In beams as above, having E. D. loads, the shearing strain is gradually reduced from each end where it is greatest, to the middle where it is nothing, but with a central load it is the same throughout. Therefore, in the former instance, the diagram will be a triangle, and in the latter a parallelogram—the sum of the ordinates of both indicating at a glance the shearing strains caused by the compound loads referred to.

Lattice and other bridges, roofs, etc., can all be calculated in a similar manner, and, although the diagrams are of a more complicated nature, they nevertheless—if properly worked out—shew clearly the various strains in the whole structure. The graphic system is consequently invaluable on account of its exquisite simplicity, its clearness, and its accuracy. We have only incidentally given an outline sketch of its application; those, however, who wish to study it fully, may find what they desire in special books on the subject, one of the best of which is Humber's *Handy Book for Strains in Structures.*

This, then, is one side—the sunny side—of the picture. Lights and shades produce beautiful effects in art, in nature, in literature. The shades are coming.

Upon turning to one page of the thick quarto volume previously mentioned, we find, amongst a variety of calculations, a wonderfully empirical method of finding the exterior diameter of the large eye of a crank, which requires for its description fully ten lines of about thirteen words each. In a simplified form, this rule is as follows:

Exterior diameter of eye of crank equals

$$\text{Dia. of Shaft} + \left\{\frac{D\sqrt{(1{\cdot}561 \times R^2 + {\cdot}1235 \times D^2)}}{15{\cdot}12 \times \sqrt{R}}\right\}\frac{2}{3}.$$

The formula for ascertaining the thickness of the web of crank is of a still more advanced kind, and need not here be given. A very simple and good rule adopted by engineers generally, while calculating the former, is $D \div 3$, that is, we make the length of the large crank eye, for marine or other engines, equal to $\frac{3}{4}$ or $\frac{7}{8}$ diameter of shaft, and the thickness of metal round the eye one-third of the diameter. Therefore, the length of eye or "boss" for a 12″ shaft would be 9″ if cramped for room, and about $10\frac{1}{2}''$ otherwise, while the metal round the aperture would be 4″ in thickness when finished, thus giving 20″ as the diameter of eye externally.

The thickness of the web $= D \times {\cdot}55$, which, in the present instance, would be $6\frac{5}{8}''$.

In small sized shafts, which are not used as prime movers of machinery, the cranks, or "levers," as they are termed, have their bosses equal in length to D—the metal round the eye $D \div 3$—the thickness of web $D \div 3$—the breadth being found geometrically by drawing two lines in the well known manner, and, after putting in the beauty curves, the thing is completed. If treated, however, in the rational science style, the web may be considered as a solid rectangular beam fixed at one end and loaded at the other. The sizes of the end pins are found directly by ascertaining the load which is to come upon them, and allowing, say, two tons per square inch for single shear, and three tons for double shear, with as much extra as you think proper for wear, or any other consideration.

The thickness of steam and other cylinders in iron and steel—of valve boxes for steam pressure, and water pressure, etc.—and of large and small pipes for all purposes, when made of cast and wrought iron, brass, steel, copper, and lead, should be proportioned directly in reference to the tensile strain per square inch on their sides due to the internal pressure. But ample allowance must be made in every case for extra thickness of metal, with a view to sound and true casting, re-boring when worn, if required, also for strength to resist shocks caused by the sudden closing of valves, and for corrosion.

It is most important to have trustworthy methods of finding the transverse strength of timber, and this is ascertained by taking as a basis the breaking weight of full sized beams loaded on the centre. In some text books the formulæ give too high results, as the original experiments were made upon small sample pieces of wood instead of large balks of timber, where imperfections which considerably diminished their strength were sure to exist. In this respect, the Mersey Docks and Harbour Board have performed valuable service by means of costly experiments on a large scale, the records of which are extremely useful to engineers.

Molesworth and Hurst, in their well-known *Pocket Books*, and D. K. Clark, in his 1,000-page tome—*Rules and Tables*—as well as other authors, have given an infinite variety of excellent formulæ in the various branches of the profession. These treatises are most useful in many ways; but practical considerations, such as those already mentioned, compel the designer of statical or dynamical structures to study all the circumstances of each case, and make allowances accordingly. Tabulated records of detailed proportions from complete and varied sets of working drawings are invaluable, as they are not only useful for future reference, but form in themselves a substantial basis for the construction of simple rules, much more serviceable to those who make them than any treatise can supply. Here again, however, the printed books come in handy for guidance and for comparison. And here also, it may be added, that we stand upon the brink of a course of study some people enter upon enthusiastically, and which in at least a thousand-and-one different forms may occupy their attention for the best years of their lives.

Bridge engineers sometimes delight in abstruse and extensive algebraical calculations, their object no doubt being mathematical exactness; but it is an exactness that is liable to be vitiated by a misplaced bolt or rivet, or by some other unforeseen cause, all of which are covered by the simpler methods of computation previously mentioned, combined with sound judgment.

The technical journals previously mentioned occasionally treat us to page after page of profound calculations of this class, which may be charmingly attractive to some of their readers, but perplexing and tedious in the extreme to those who prefer simpler methods.

In the drawing offices of good engineering establishments there are very many simple and valuable formulæ of a far-reaching nature which extensively permeate their every day practice. These refer to the proportions of bolts and nuts, and everything connected with them: to pipes of every description for high pressure and low pressure steam, and for water pressure: to valves of all kinds for the same purposes, and a variety of other details too numerous to mention.

For solitary cases such rules may not appear of much consequence, but their great importance will be seen when it becomes known that the good design and economical construction of machinery so much depends upon them, and also that the parts referred to are made in large quantities for all kinds and sizes of engines. A well-known axiom among engineers is this:—"Economise material when you can possibly do so in general work; but when things are made by the hundred, or by the thousand, and especially in the costly metals, their proportions cannot be too carefully considered with a view to reduction of weight and also of labour. Hence the numerous office tables of dimensions which exist in some places—tables that shew at a glance what is required, and, when well constructed, save a great deal of time, a large amount of material and workmanship, and thus prevent in every way the useless expenditure of capital.

For example—the thickness of a bolt head is usually $\frac{5}{8}$ of its diameter, a nut from $\frac{7}{8}$ D. to D.; both of them are $1\frac{1}{2}$ D. across the sides, but in a good "Bolt and Nut Table" for marine work no calculations are required, as the sizes run from $\frac{1}{4}''$ to $6''$ diameter, advancing by $\frac{1}{8}''$ at a time, and on to $8''$ or $10''$ diameter by quarter inches. In such a table—divided into the required number of vertical and horizontal lines—the diameter at top and bottom of the screws, and also the number of threads per inch for each size of screw, are given. Then follow the "width across the sides,"—"width across the angles,"—"thickness of head,"—"thickness of nut," and various other particulars, including the safe tensile strengths in pounds for each bolt. All our tables of proportions are valuable, this one, however, is simply *invaluable;* and connected with it are a few short rules which closely affect the strength, simplicity, and economy of almost every detail in land and marine engines, and machinery of all kinds. Take, for example, the following:—

Centres of bolts from $\frac{3}{8}''$ to 1″ diameter to be D + $\frac{1}{16}''$ from outside of pipe or other flanges when truly faced, and D + $\frac{3}{16}''$ from body of pipe. Thickness of cast iron flanges = D + $\frac{1}{8}''$ about, and, when of brass, = D minus $\frac{1}{8}''$ to about D for high pressures.

All faced joints to be $1\frac{1}{2}''$ wide for $\frac{1}{2}''$ bolts; $1\frac{7}{8}''$ for $\frac{5}{8}''$; $2\frac{1}{8}''$ for $\frac{3}{4}''$; and so on; but if the flanges are to be fixed in a rough state to boilers, or ship's sides, and liable to corrosion, bolts $\frac{1}{8}''$ larger, and joints a little wider than the regulation sizes mentioned above are necessary.

Then, again, all copper pipes connected with the boilers and cylinders of triple and quadruple expansion engines, as well as those for steam or water purposes in general, have the diameters and numbers of their bolts,—the diameters and thicknesses of their flanges,—the weight in pounds per square foot of copper,—and other particulars, fully given in carefully arranged tables.

Different standards of taper for rods, etc., are in constant use, such as 1 in 7 to 1 in 8 for piston and pump rods inside of their respective pistons or buckets. This is an excellent and well-known method of fixing them, both in the Navy and in the Merchant Service; indeed, nothing better can be desired. Rods having such a taper require no "shoulder" upon them, and, besides being incapable of "draw," possess the useful quality of being easily disconnected.

A very general taper for the plugs of all kinds of brass cocks is 1 in 5. For the cottars of some kinds of connecting rods, and for every description of pin, etc., which requires to be driven tight against a shoulder, a taper of 1 in 16, or $\frac{3}{4}''$ to 1 foot, is usually employed. The same taper has been very much used for the ends of shafts which fit into screw propellers. Owing, however, to the difficulty of disconnecting the screw after long submergence in the water, a taper of about 1 in 12 is considered more suitable.

The strengths of a great variety of steam, water, and other circular box valves, for pressures under 30 pounds per square inch, are determined chiefly by practice. But for all pressures, the safest plan is to have good reference tables of the bursting strains of cast iron and brass pipes of different thicknesses and diameters, and of a certain quality of metal, and make ample allowances according to circumstances.

Note books filled with particulars similar to those we have given, are the result of many years' close observation, but they handsomely repay the time and trouble spent upon them as the days go by.

The simple and efficient, though empirical, methods of calculation adopted by practical engineers whilst designing machinery, etc., and preparing working drawings, have only been briefly referred to in this chapter for want of space. The true science system of computation has also been similarly touched upon, with, it is hoped, sufficient clearness to indicate in a general way how the thing is done. It may be well to add, however, that the former is liable to vitiation at any time by means of sudden changes in practice, and hence will be seen the importance of having a clear view of the first principles upon which these simple rules are based. When the compound engine came into general use, and steam pressures went up with a bound from 30 to 60 and 70 lbs. per square inch, many serious breakdowns occurred, because engineers had not sufficiently modified their old and trusty formulæ to suit the new order of things.

The experience thus gained has proved of great value, and especially since the introduction of triple and quadruple expansion machinery, which caused boiler pressures to rise to more than double what they had hitherto been.

As already stated, however, when the tensile, compressive, shearing, transverse breaking, and other strains due to those increased pressures, are once met by the skilful distribution of material, and the altered circumstances are thoroughly understood, a new set of empirical rules may be constructed, and, as formerly, safely trusted within reasonable limits.

From what has been said about the drawing office, it will be seen that it is a ruling power for good or evil, and that, while laying the foundation of successful engineering, it has also originated some of the most costly mistakes. For these reasons it holds the key of the position, and as the great engineers of the past owed much of their prosperity to a clear knowledge of everything that constituted good practice in this department, so those of the present would do well to cultivate, as far as possible, the sciences of design, of proportion, and of practical construction. They may further record in their morocco-bound note books, that the whole of the colossal system of civil and mechanical engineering in its multitudinous branches, may be reduced to two separate heads as follows :—

(1.) Find out exactly what has to be done.

(2.) Use your skill to the utmost in discovering the best and simplest methods of executing it.

When these have been satisfactorily accomplished, put your machinery in motion and go ahead full speed as happily as possible.

As an appropriate ending to this chapter, we may add that a very eminent and still prosperous marine engineering firm had for many years an almost total exemption from failures of any kind. This created a somewhat rash confidence, and they began to make novel "improvements." Things were done that should not have been done with the working drawings of large steam cylinders, which resulted in some of the castings cracking at the foundry. Then again, the screw propellers of a few of their ships were trimmed until they looked a little more genteel, but this unfortunately created a sort of epidemic amongst them when at sea, as one blade after another gave way, to the astonishment of every one.

The causes of both evils were discovered—the necessary alterations were made in the plans—and the successes of the past were renewed in the future.

CHAPTER X.

ENGINES IN PROGRESS—THE SCREW PROPELLER.

Triple Expansion and other Engines in the Works—Ship Drawings—Steel Boilers—History of Steel and Iron Crank Shafts—Detection of Errors in Drawings—Arrangement of Machinery in Ship Plans—First Appearance of Mr. Macdonald, the Superintending Engineer—Peculiarities of the Screw Propeller—"Positive" and "Negative" Slip—Influence of a Ship's Lines upon the action of a Screw—Modern Propellers—Cause of Destruction by Irregular Corrosion—The Remedy—Screw of Cunard S.S. "Etruria"—Mr. Macdonald's ideas of Screw Propulsion—Condemns the Manager's Calculations—Fortunate Discovery—Unnecessary alteration of Plans.

OUR triple expansion engines are now "progressing favourably," as a physician would say, and tracings of some of the principal parts have been sent to the works, and also to outside people; but there are very many detail and other plans to follow in course of time. It must be borne in mind, however, that the firm has several other orders in hand more or less advanced. There are, for instance, an ironclad of 6,000 tons for our own Government; another of 3,000 tons for the Brazilians; two turret ships for the Dutch; one magnificent paddle steamer for a great railway company, whose guaranteed speed is to be nineteen knots an hour; and two mail screw steamships of 4,000 tons each, one of which, recently launched, is in dock having her machinery fixed on board.

No sooner was this vessel in the water than preparations were made for laying the keel for the first of the three ships we have been specially observing. Since the time the order was received there has been great activity in the ship drawing office and mould loft. The immense black painted floor has been partially covered with the "lines" and various sections of the ship, all of which are drawn full size to ensure the greatest accuracy, and facility of transfer to the frame bending department.

A working model to a scale of half an inch to a foot has also been prepared, shewing the position of frames or ribs and the whole of the outside plating, the length, breadth, and thickness of every plate being marked on for reference. These, as well as the stem, keel, stern and rudder posts, also deck beams, angle iron for frames, and other parts are ordered from the rolling mills and forge people, and upon arrival are operated upon in various ways, such as drilling, punching and shearing, planing, bending, etc., to enable them to come together properly in place, and to provide for all necessary rivetting.

The boiler plans, too, are so far advanced as to enable orders for the different kinds of plates used in their construction to be given out to the manufacturers. For such a high pressure as we are going to use steel is preferable to iron for the outside shell, because the latter would require to be too thick for convenient rivetting; but in the production of the former at the rolling mills, and also in its subsequent manipulation in the boiler works, the greatest possible care is taken in every part of the process.

In the engineering department the work is getting on by degrees, the forge and pattern shop being the first to receive orders; the former of which has been supplied with tracings of the connecting rods, piston rods, and other gear, to be put in hand at once. The latter, however, is doing its best to get the castings of pistons, cylinder covers, etc., into the hands of the turners, and thus considerably facilitate matters at the outset.

The crank shafts have a little history of their own which may here be referred to. In former times they were all of iron, even for large ships, and complete in one length, which made them most unwieldy to manage in the lathe, and, if fractured at sea, too often entirely disabled the vessel. This caused them to be constructed in two pieces exactly alike, which were firmly bolted together, thus rendering them much easier to manufacture, and if the forward or after part were broken, the "spare" half which the ship carried could be used at either end.

This was a very good plan, but the increased speed and consequent vibration of the engines, combined with other influences, caused such disintegrating action to take place in the fibres of the metal, that frequent disasters occurred, involving serious inconvenience and loss. Hence, forged steel was used instead of iron, but this was not satisfactory, as the failures continued, sometimes in the most unexpected manner. Whitworth's improved steel was therefore resorted to, with the best results. The method adopted in manufacturing shafts of this material is as follows:—

The metal is first cast in hollow ingots, and while in the melted state is subjected, by means of an 8,000 ton press, to a load of at least six tons per square inch, thus insuring the exclusion of all gases, and the thorough consolidation of the entire mass. It is then reheated, and squeezed by hydraulic pressure into the required shape, that is to say, a straight shaft with coupling flanges at the ends for bolting together. It is now cut in two, the cranks and crank-pins, which have been made separately, built up and securely fastened in position; and each half, or, in triple engines, each third, is firmly bolted together with the utmost nicety, until the whole becomes almost as rigid as if it had been solid. In important details such as those we have mentioned, the slightest deviation from absolute "truth" in construction will entail much trouble afterwards, hence the adoption of every precaution which can possibly secure accuracy.

The crank shaft of the "City of Rome" was made as described above. It is 26 inches diameter, and has a central hole 14-in. diameter throughout its entire length, and when completed weighed 64 tons; but had it been of solid iron would have weighed 73 tons, and cost at least £7,300. This massive detail is frequently supplied by Messrs. Vickers, of Sheffield, to steam ship companies by whom their own special steel is highly esteemed. In the plate of Wigham Richardson's erecting shop, two very fine built up crank shafts for engines in progress are to be seen. These views explain themselves.

The pattern-makers, who have now made a fair start, are very busy indeed, as few of the old patterns will "come in" for the new type of engines. The condenser is being pushed forward, but here an incident occurs which will illustrate the effect of a wrong dimension on the tracings. In the sectional elevation there is a row of figures which reads thus: 3′ 9″—2′ 8″—1′ 10″—2′ 8″—3′ 9″, and below them is a dimension line giving "length over all" 14 ft. 8 in. In the plan, the same *detailed* figures are given, but the "over all" measurement is 14 ft. 3 in., thus indicating an error somewhere; and so thinks the workman, who looks at the tracing enquiringly.

Running his hand through his hair to enable him to collect his ideas, he "tots up" all the dimensions in each view two or three times, and finds the sum of them, 14 ft. 8 in., quite right, as stated in one case, therefore the other must be quite wrong, although the measurement by foot rule gives the correction at a glance. Euclid says: "If equals be added to equals, the sums are equal," but the worker in wood, while unconsciously trying to confirm the truth of this axiom, finds them to be *unequal*, "which is impossible, Q. E. D."

As his instructions, however, are to take only figured dimensions, he will not do anything until he sees the foreman. This gentleman, on being appealed to, does not say anything, but, taking the tracing in his hand, goes straight to the draughtsman who originated it and observes, "I think there is something wrong here, Mr. Dalrymple," pointing to the condenser plan.

"Oh," replies Mr. Dalrymple, after gazing intently at the figures, "it is most astonishing, I checked that drawing twice, and, after all, I have made a mistake; those 'threes' and 'eights' are so like each other sometimes you can hardly tell the difference."

The alteration is made while the visitor waits, and, in a minute or so, he goes away happy and contented.

This error, which the head draughtsman failed to discover, is of a very harmless kind, because the discrepancy in the dimensions created suspicion and prevented danger. It might easily have been otherwise, however, as *all* the figures might have appeared correct, and yet some inaccuracy might have crept into both views, which neither foreman nor workman could have detected, and the condenser would consequently have been spoilt. Happily, unpleasant discoveries of this kind are of rare occurrence. In course of time, intelligent engineers become wonderfully sharp in finding out faults in drawings. They will, for example, look at a complicated mass of all kinds of arrangements in a plan, and pick out a flaw no one else can see, just as if it were the only thing they did see.

They also appear to have a latent distrust of other people's figures in work they are responsible for until they have mentally run over them, and yet these clever and experienced people will sometimes make the most absurdly stupid mistakes themselves—not through ignorance, but owing to a temporary mental blindness, we may call it, which for the time clouds their faculties. This I have frequently seen in others, and have sometimes experienced myself. Strangely enough, however, the mind often recalls in the most unexpected and gratuitous manner something which has been done wrong, and which is in consequence rectified at once.

Oliver Wendell Holmes tries to describe the "mechanism of the mind" in one of his books, but neither logicians nor metaphysicians, nor any other "icians," have ever been, or ever will be able to solve satisfactorily such a mysterious science, or explain how it is that fancy's flash and reason's ray have so often done infinitely more than the most studiously calculated plans could possibly accomplish.

Under the guidance of the office staff, the drawings for our engines are making progress, and ideas on the subject generally are becoming more matured. The "shafting plan" is given to one draughtsman, and the "general arrangement plan" to another. The former involves all the working drawings of shafts in the tunnel, thrust blocks, plummer blocks, stern tube, propeller, and all their attachments. The latter is a most complicated affair, as the main engines and boilers, and all the pumping engines, valves, cocks, pipes, ladders, gratings, ventilators, and other gear belonging to the machinery itself, or connecting it in any way with the sides or bottom of the vessel, have to be shewn on it, and afterwards in full detail on very many sheets. This plan requires a board about five feet by four feet, and usually from four to five views drawn to a scale of half an inch to a foot for large engines, and to a larger scale for small engines. Should, however, the whole of the machinery be too large for one board, the engines and all attachments are drawn on one sheet, and the boilers similarly on another.

One view consists of a longitudinal section of the machinery part of the ship, and underneath it is a full plan; there are also transverse sections through engine and boiler rooms, so that everything may be fully shewn and clearly understood individually and collectively. All these sections of the vessel are accurately drawn from full-size measurements from the mould-loft floor, and include the frames, plating, decks and deck beams, bulkheads, coal-bunkers, hatchways, funnels, etc., so that the connection between every part of the ship and all the machinery may be easily seen.

Let us suppose that one of these general arrangement plans has been commenced. After drawing in the sections of the hull, the first thing to be done is to fix the positions of engines and boilers in the vessel in the most suitable manner possible, bearing in mind the proper distribution of weights of machinery, including water in boilers and coal in bunkers, so that the ship, when light, will be in proper trim, and neither too much down by the stern, nor too deep in the water at the bow. The height of the centre of shaft is dependent upon the diameter of the propeller, but in fine-lined gunboats, etc., with horizontal engines, it requires sometimes to be a little higher at the engine-room end, to allow the widest part of the machinery to clear the bottom of the vessel.

The manager, chief draughtsman, and draughtsman who has charge of this plan, have a consultation regarding the best position of the engines and boilers fore and aft, and also vertically, and at the same time the most suitable arrangement of bulkheads. The exact positions of the latter are determined by the spacing of the frames of the ship, which, from amidships to the stern, are figured 1, 2, 3, etc., whilst those going forward are lettered A, B, C, and so on, until the alphabet is ended, when they begin again with AA, BB, etc.

The conference is ended, and the manager—Mr. Bouverie—has just given instructions to "place the centre of shaft eleven feet above the top of keel, and the bulkheads as we have decided," when a very important personage enters the office to see "how things are getting on." This gentleman—whose will is to some extent law — is Mr. Macdonald, the superintending engineer for the owners, and his duty is to visit the works from time to time, see that the specification is adhered to in every respect, and also to suggest any improvement, or reasonable alteration which can be effected before the work has gone too far. If he knows his own mind, the builders and engineers will have little trouble with him, because they quite understand each other, but if he is uncertain and vacillating, his intentions, however good, will involve them in unnecessary trouble and loss, and also considerable delay in the execution of the contract.

This visitor, who now makes his first appearance, possesses the entire confidence of his employers, having been with them for very many years. He served his apprenticeship most creditably in Napier's, but did not enter the drawing office, as this department is reserved only for the privileged few. Not long after his time expired, he went to sea as fourth engineer in one of his present Company's ships, and by steady and good conduct, ultimately became chief engineer of the S.S. "Miranda," and latterly the S.S. "Cymbeline," in both of which he commanded the steam department so successfully as to be rewarded with promotion to the sphere he now occupies—that is to say, the general superintendence of machinery of the ships of the fleet, in which he takes a fatherly interest.

Although somewhat blunt in manner, he is a very pleasant man when you come to know him. He does not "bother his head with science," but knows exactly how to drive a vessel at the highest speed upon the least consumption of coal, and also the best methods of rectifying every defect caused by wear and tear, and by the great variety of accidents engines are liable to at sea; and, what is of still more importance, to prevent them from happening at all, if possible. In addition to this, he possesses a great amount of humour; and has the power of illustrating his remarks by many amusing anecdotes, some of which, however, are rather wire drawn. His sole aim in life is to do the best he can for his Company; his intentions are good and highly honourable in every respect, but he has a curious—some people would call it an aggravating—way of sanctioning things one week, condemning them the next, and, perhaps, reverting to his original ideas at a future time, in such an easy, happy style, however, that none is really the sufferer, but the firm who makes his engines.

This, then, is a rough sketch of the visitor who is now inspecting our "general arrangement" drawing, and, who much resembles a superintending engineer I well remember—professionally, with sorrow—socially, with much pleasure.

The manager explains in detail all that had been previously gone over, and adds—"You see, Mr. Macdonald, we have given you a fairly proportioned propeller, and I think, on the whole, that this arrangement will work out very nicely."

"Oh yes, very good indeed; but, don't you think we might advantageously make the screw two feet larger in diameter—get a better hold of the water, and drive the ship faster, you know?"

Now it so happens that Mr. Macdonald could hardly have selected a more "kittle" subject for his opening remarks; that is to say, one more difficult to elucidate or explain with clearness. If, however, he had said anything else about the engines, he would have been more successful, and created a good impression of his talents at the outset.

The Screw Propeller.

The action of a propeller in the water, and its influence upon the speed of a ship, have puzzled all the shining lights in scientific and practical engineering, and perhaps none more so than the late Mr. Griffiths, whose patent screws are to be found in very many of the naval and mercantile ships of the world. After thirty years' study of his pet subject, however, he is reported to have said that he had been unable to master it, or give clear and satisfactory reasons for certain results.

The diameter and pitch of a propeller depend upon so many things affecting both ship and engines, that it is very difficult to give any definite or trustworthy rule for the guidance of others, and much must always be left to the experience of the designer, so that all the circumstances of each particular case may be fully allowed for, and the proper dimensions of the screw reasonably determined. Even with experienced people great mistakes have sometimes been committed, as the investigations carried out in reference to the failure of H.M.S. "Iris" to attain the required speed until important alterations were made in her twin propellers will clearly show.

To the professional engineer, as well as to people in general, the means employed to produce high, or even moderate speed in screw steamers, appear insignificant when compared with the results obtained. This is particularly the case when a great ocean racer in a graving dock is the subject of study. On the one hand, there is the gigantic hull of the ship, and on the other, a small propeller, which those unacquainted with its mysteries would consider quite unsuitable for the purpose.

In side wheel steamers, the huge paddle-boxes look as if they contained the means of producing great power, whilst the splash of the floats in the water confirm this idea by shewing at a glance an amount of energy amply sufficient for the purpose. In screw vessels, however, when on load draft, and steaming full speed at sea, this fluid disturbance differs but slightly from what is usually to be seen in the wake of a sailing ship, and, therefore, the irresistible logic of facts compels us to believe much that seems paradoxical until we know the true cause.

The water in which a ship lives and moves is composed of oxygen and hydrogen, whose chemical combination has been extremely beneficial to the inhabitants of the earth in a great variety of ways, and especially to those who are engaged in commerce, or in the navigation of ships and steamers. This fluid has a few striking peculiarities. Exposed to a gradually reduced temperature, it becomes denser and heavier until it reaches 39° Fahr., when a change takes place which causes the expansion and consequent decrease in the weight of the water, until at 32° it becomes floatable ice. At 212° water is changed into a highly elastic vapour, which forms the motive power, not only of marine and other steam engines, but is the occult cause of those disastrous and wide-spread convulsions which originate in the earth's interior and create such havoc on its surface.

Another property of this fluid is its wonderful power of resistance to compression, and the latest experiments have proved that the compressibility of salt water under a load of 1,500 pounds per square inch is only $\frac{1}{316}$ of its original bulk. This peculiarity fully explains the reason why the hydraulic press is so enormously powerful, and—most importantly in the present case—why the screw propeller is so efficient in its action. The apparent inability, therefore, of this instrument to drive a great and heavily laden ship at high speed, is immediately dispelled when we clearly understand the nature of the element in which it works, and which provides the necessary reactionary resistance. All that is therefore required is, to give a propeller dimensions suited to the ship it is intended for, and to make the blades amply capable of sustaining the greatest transverse strains that may possibly come upon them.

Notwithstanding the incompressibility of water, it is so flexible that a vessel's bows can easily wedge its particles asunder, but, at the same time, the resistance offered increases proportionately as the squares of the velocities; that is, if a steamer required 100 horse-power engines to propel her two knots an hour, this would have to be increased to 400 at four knots, or as 2^2 to 4^2. By doubling the speed, however, we have, in addition to the aforesaid fluid resistance, the whole weight of the ship passing over twice the distance in the same time; the power already found must therefore be increased to 800, or, in other words, as the well-known "cubes of the velocities," which in this case are 2^3 and 4^3.

Hence, doubling the speed of a ship requires eight times the original engine power, or the power required to accelerate her velocity, say from 12 to 15, or any other number of knots, will be proportional to the cubes of these numbers, and thus the great cost of working fast steamers will be at once apparent.

Cargo vessels are usually run at 8 to 12 knots an hour by means of low speed machinery, and mail steamers from 16 to 18 knots, on account of the attendant commercial advantages. For the same reason, it is now considered advisable to drive the engines of ocean racers at 75 to 85 revolutions per minute, instead of 55 to 65, as formerly. But inasmuch as the resistance of the water to a propeller increases as the squares of the number of revolutions, it naturally follows that a high speed screw may be made less in diameter than one intended for low velocities, and this can judiciously be done on account of the fine after-lines or "run" of the ship.

The importance and intricacy of the subject of screw propulsion may be gathered from the fact that several books have been written—two of them thick quartos—with the object of elucidating all that could be learnt concerning it, and also that a great variety of valuable contributions on the same subject, by the members of learned societies, are to be found in their own publications, as well as in the technical journals.

Briefly described, the screw propeller may be termed an instrument for driving ships at high or low speeds, as may be desired, and that it derives its efficiency from the resistance of the water in which it works. If, for example, a screw having a pitch of 20 feet revolved in a solid iron nut, every revolution it made would propel the ship to which it was attached exactly the same distance. Inasmuch, however, as it works in a fluid whose solidity is more or less impaired by currents created by the motion of the ship, and additionally, perhaps, by imperfect formation of the screw itself, this forward movement is generally reduced in well proportioned and fast steamers from 8 to 12 per cent., and in cargo ships from 5 to 8 per cent. That is, a 20-knot speed in one screw produces about 18 knots in the ship, and in the other, a 10-knot velocity of propeller gives, say, $9\frac{1}{4}$ to the vessel.

This is termed "positive slip," which may naturally and reasonably be expected. Here, however, we stand on the verge of what was at one time considered as great a marvel as the best Hindoo juggling performances—something that appeared to subvert a law of nature and accomplish an utter impossibility. It was proved that in some instances a ship overran her screw, or, in other words, the propeller actually drove a vessel from one to one-and-a-half knots an hour faster than if it had worked in the hardest steel instead of water. The facts were incontrovertible, but no satisfactory reason could be given for them. Engineers pondered and wondered over this weird-like and unnatural discovery, which was called "negative slip." They wondered, and pondered, and meditated. Some said one thing, and some another, but for a long time nothing could be made of it.

If the ships had only run as fast as their screws, or without *any* slip, their builders and engineers would have been considered perfect masters of the art of design, and the water of the ocean would have been thought absolutely incompressible—in some places, at least.

All the mysterious events of the world have been created by some natural cause, as in one instance an Egyptian monarch had the pleasure of discovering for himself. This gentleman had built a treasure house of much more solid construction, and even perhaps greater safety, than the future Bank of England, but his riches disappeared, nevertheless, as if by magic.

"Whisked away by the deities!" you suppose?

Oh, dear, no! they were not quite ethereal enough for that. The Emperor's faithful and trusted architect put in the very best workmanship and finest jointing of the masonry, so that the building should be perfectly fire-proof and thief-proof, but he also took care that one of the granite blocks in the edifice was made capable of being *easily withdrawn*, and through this secret aperture the specie and other valuables were abstracted.

In like manner, the screw propeller mystery was eventually—but not completely—solved, by the discovery that, owing to faulty design in the screw itself, and improper formation of the "run" of a vessel, currents were created in the water, which, by impinging upon the hinder part of the ship, had the effect of increasing her speed beyond what could have been expected even under the most favourable circumstances. When this occurred, the propeller was changed, and hence the question will at once arise:—" Why discard it, after performing such good service gratuitously?"

The answer is:—"The service was only apparent, because some of the engine power was expended in making the propeller churn the water, in one sense uselessly, but in another—strangely enough—for the benefit of the vessel, by indirectly accelerating her velocity as above described."

This will be clearly seen when it is stated that the same speed with, in some cases, *less* engine power could have been obtained in a natural way, with positive slip, by means of a screw scientifically designed in pitch, diameter, and form, to suit as closely as possible the circumstances of the case, and thus allow the machinery to give out its full energy in the best manner. Many years ago, an Inman steamer lost one of the blades of her propeller, and she actually ran faster with the remaining three than she had previously done with four. This, however, was not appreciated by the Company. The screw was therefore taken off, and a new one put on, because the three remaining blades produced an unbalanced distribution of power, which was bad for the engines and dangerous for the shaft.

The correct pitch of a screw and its diameter depend in a great measure upon the proposed number of its revolutions per minute, as well as upon the lines of the vessel, which are regulated by considerations relative either to slow or moderate speed cargo ships, or to swift mail steamers. In the former case, the propeller requires to be of large diameter, for reasons which were carefully investigated as far back as the year 1846.

At that period, the S.S. "Dwarf" was experimented upon with the object of ascertaining the effect upon the speed of a ship of variously altered formation below water, in the immediate vicinity of the sternpost. When first tried in her ordinary condition, a velocity of 9.1 knots per hour was obtained; but, in the next experiments, the run of the vessel was made fuller by adding two separate layers of timber, and the result of this was a reduction of speed to 5, and then to 3.25 knots per hour. Upon removing the layers, however, it rose to 5, and then to 9.1 knots as before, thus conclusively proving the evil effect of a full run upon the screw.

In those experiments, care was taken to make each layer of timber represent as closely as possible the true lines of ordinary ships, and the results then obtained have been confirmed by subsequent practice. It has, therefore, been clearly proved that full-built cargo ships require propellers relatively larger in diameter than mail or other fast steamers, so that the ends of the blades will work in water as free as possible from current disturbance, and also on account of the slow speed of the engines.

The formation of the blades of screw propellers has been endlessly "improved" by inventors, some of whose ideas can only be treated as philosophical novelties. No doubt, real improvements have been made, as the patentees themselves declare, but the shipowners are very slow in adopting them. It is certain, however, that nothing but continued and successful practice at sea will enable any new propeller to supersede those which have been so long and so favourably known in connection with the late Mr. Griffiths.

The cheapest screws are those cast in one piece, which do very well for coasting steamers; but for ocean liners the movable blade arrangement is best, because if one blade should break, the "spare" one can be bolted on, the pitch can also be altered slightly, if required. One of the most useful modifications of this system is Mr. Bevis's feathering propeller, which allows the screw blades of a yacht, or any similar vessel, to be angularly altered, and thus prevent them from becoming a drag upon the ship when under sail only.

The materials chiefly used are cast iron, steel, and manganese bronze. The former, however, is liable to serious corrosion and pitting of the blades, which greatly weakens them near the ends, and causes increased friction in the water. Cast steel, though a much stronger metal, possesses the same objectionable quality in a higher degree; and it is by no means uncommon to find the ends of the propeller blades of ships bitten, nibbled, cracked and riddled, and broken off, on account of the mysterious and destructive process of pitting and furrowing they are subjected to. Manganese bronze is the best material for such purposes, as it possesses immense strength combined with non-corrodibility. The screw blades can therefore be made thinner than in cast steel, and this, together with a smoother surface has, in some cases, given a ship about half a knot more speed at sea.

There have been many theories concerning the cause of pitting in cast-iron and steel, but the best one appears to be that of Mr. J. F. Hall, of Messrs. Jessop & Sons, Steel Manufacturers, Sheffield. In his opinion, the evil is occasioned by the sucking action created by the blades of a screw always working in the same direction, and thus in time, drawing out of those metals the particles or molecules which have not sufficient affinity in themselves to hold together as corrosion takes place.

My elder brethren, and perhaps contemporaries in engineering, will remember the time when this plague among the propellers was unknown, owing no doubt to the great stiffness of the broad-pointed or fan-shaped blades then in use preventing the metal near the tips from being disintegrated by vibration, as it now is in those of the narrow-pointed and more elastic form. This has been proved indisputably by the fact that old broad-pointed screw blades of cast iron have been in constant use for thirteen years without shewing any sign of decay; whereas those of the modern type in steel and iron only last from three to five years. Hence we may safely consider that the vibration, which in time destroys crank and tunnel-shafts, also loosens the particles of metal near the tips of propeller blades, and that the suction at the back—as described by Mr. Hall—does the rest of the mischief.

With the view of counteracting this costly evil, Mr. Willis, of the "Specialty" Steel Works, Sheffield, has patented a method of facing the blades of propellers with various anti-corrosive metals whilst in a state of fusion in the foundry. By this process solid castings, either in steel or iron, are now made with the protective facing of gun-metal, Delta metal, etc., which in practice will probably be sufficient for the purpose.

When made of strong cast-iron, a screw-blade usually has a thickness at the root of ½″ per foot diameter, or 10″ for a 20 feet propeller, and the cost when finished may be from £20 to £24 per ton. If steel is employed, the thickness will be about 7½″, and the price from £35 to £40 per ton; but if the blades are of manganese bronze, the thickness need not exceed 7″. In this case, however, the cost will reach £130 or £135 per ton; but, even at such high rates, this material is frequently preferred for long voyage ships, on account of its superior advantages.

Owing to the imperfect knowledge which at one time existed regarding the laws which govern the propulsion of ships, engineers have sometimes been unable to obtain the desired speed for their vessels, thus giving rise to considerable disappointment to all concerned. The subject was certainly perplexing, but the late Dr. Froude, of Torquay, was so greatly interested in it, that he constructed a large water tank, of special form, for the purpose of experimenting upon the resistance of models of vessels while passing through the water. In this he was so eminently successful, that his system has now enabled engineers to ascertain with considerable accuracy the power required to drive a ship of a certain size, form, and weight, at a specified velocity.

The following particulars, taken from the log book of the Cunard S.S. "Etruria," in reference to her fastest voyage from Queenstown to New York, in July, 1888, will appropriately illustrate the efficiency of the propeller employed in that ship.

Diameter of cast steel propeller 24′ 6″.
Pitch of " " 33′ 6″.
Total area of blades 225 square feet.
Highest number of revolutions, 68¾ per minute.
Length of day on longest run, 24 hours 37 minutes.
Knots run by observation, 503.
" " " propeller, 551.
Slip " 8·7 per cent.
Mean speed of ship, 20·3 knots per hour,
Indicated horse-power of engines, 15,200.
Displacement of ship, 11,000 tons.

Other particulars in reference to the hull and machinery of the sister vessel, "Umbria," are given in another chapter, and from the continuous performances of these two ships much may be learnt regarding the high state of efficiency now attained by the marine engine. Those who wish to study the subject of screw propulsion practically and scientifically—analytically, algebraically, and mathematically, dynamically, pedantically, and conclusively—may perhaps find what they require in the literature of the past and present, and also in the books and technical journals of the future.

When ladies and gentlemen of enquiring minds stand gazing at the propeller of an enormous ship, they will now cease to wonder how it can possibly drive her through the water at a speed of eighteen or nineteen knots per hour, because there is—as we have endeavoured to show—sufficient well directed energy in the screw, and sufficient resisting power in the water, to do this, or such high results would not be forthcoming.

To non-professionals, the side wheels and boxes of paddle steamers are—as we have shewn—somewhat delusive, as they create too exalted an idea of their power, and it is, therefore, not surprising to find some people led away considerably in this respect by what they see. On one occasion, when crossing the Mersey, a clergyman said to me, most impressively, as we passed close to the "City of Rome," "*Don't* her three funnels give you *the idea of power!*" I replied, "Yes, they do," and so they did. It is said that for a similar reason a towing Company had a new tug built into which the engineers only put one funnel, because it was quite sufficient. The owners, however, objected to this arrangement, because the sailing ship people would not consider her powerful enough for their purpose. The steamer was almost finished, and could not well be altered. A dummy funnel, with the smoke leading into it, was therefore set up, and this solved the difficulty.

For the purpose of having a chat on practical science, we abruptly left Mr. Macdonald and Mr. Bouverie in earnest conversation about the diameter of the "Rosalind's" screw, and now return to our two friends who have thus been apparently neglected.

In reply to the former gentleman's opening speech, the manager gives his reason for introducing such a small propeller. If he were a pompous man, anxious to display his learning, he might unconsciously crush the superintendent at the outset, by telling him in the "hum! ha!" sort of style, that "when the variability of the eccentricity is taken into account while integrating differential equations involved in the problem of screw propulsion," etcetera, etcetera. Since, however, he is merely a practical minded gentleman of high professional attainments, he talks away fluently and confidently about "ratio of area of disc of screw to immersed midship section,"—"speed of engines,"—"fine lines" and "full lines,"—"cargo ships, and mail steamers," including some of the reasoning already given in the previous pages. The superintending engineer, however, cannot follow such arguments on account of the want of drawing office training, and as his ideas are of the empirical kind in some cases, he reasons thus:—

"My last ship, the 'Cymbeline,' had a large propeller, and she went along at a fine rate; the 'Miranda' also, did very well under similar circumstances, and what was good for them, ought to do for these new vessels. Have you ever noticed how a duck in the water increases her speed, by enlarging the area of her feet, why then, should a large screw not have more power than a small one, and be able to drive a ship faster ? "

To use a well-known quotation, Mr. Macdonald might from his appearance " be taken for forty-two in the dusk with the light behind him," and as everyone knows, when men and women attain this age, they generally hold pertinaciously to their own opinions, whether right or wrong. Mr. Bouverie has protested against the alteration, but not wishing to be too stiff at the outset, agrees to make the screw two feet more in diameter,—thus raising the centre of shaft and also the engines, twelve inches higher. He has given the best advice as clearly as he could, and if the superintending engineer for the owners rejects it, he must take the responsibility. This gentleman's last words are,—" Put two feet more on to the diameter of the screw, but keep the bulkheads as you have them, and that will do first-rate. Good morning."

For the next ten days or so, Mr. Macdonald has a lurking suspicion that what the manager said may have been right after all, but he is unable to satisfy himself on this point. His time is fully occupied with the other ships of the fleet, but he is occasionally in a "swither," or state of doubt, regarding the propellers of the new vessels, and is afraid that if any loss of efficiency should ultimately arise from this cause, he will get the blame.

A little incident, however, causes him to decide quickly upon what he ought to do. The " Miranda " is in a graving dock being cleaned and painted, so he goes down to see how they are progressing in all departments, but, on the way to his old ship, he passes the stern of one of the Atlantic "greyhounds," also in dry dock. " What a splendid model ! " he mentally exclaims, and adds, "what a small screw she has, too, for her size," remembering at the same time that, on a recent voyage, this famous vessel steamed 480 knots in one day. The "Miranda" is also carefully inspected, by way of comparison, when the disagreeable truth suddenly flashes upon him that, although she certainly has a large propeller, her lines are "full," and the build and engine power of the ship adapted for carrying a large cargo at only a moderate speed.

Here then is a discovery which prompts the superintendent to exclaim—"Good gracious! can it be possible that I am wrong after all?"

There is no time to be lost, so he goes off immediately to the works to rectify his mistake, and is delighted to find Mr. Bouverie in the erecting shop, calmly surveying everything around him.

"Good morning, sir," observes Mr. Macdonald. "I hope you haven't done anything to those screws of ours yet?"

"Well, no, we have not, as they will not be required for some time to come." What a relief!

"Well, sir, I have just been thinking that it would not be at all amiss if you made them as we had them at first."

"What! two feet less in diameter?"

"Yes."

"Why that is exactly what I proposed; but you objected to it, and now we are well on with the general arrangement in accordance with your ideas. I tried to explain to you that fine lined ships with quick running engines, such as those we are building, do not require such large propellers; whereas cargo ships do, for obvious reasons. It is a pity you did not tell me about this before letting us go on so far."

"I am very sorry to trouble you," observes Mr. Macdonald; "but, really these screws are such puzzling things, you never know where you are with them." . . . The draughtsman, in a rather unamiable humour, had to rub out all his work relating to the engines and their connections in the longitudinal and transverse sections, and begin again by lowering everything one foot. Were it not for the boilers, however, which have to be kept as they are, it might perhaps have been better to let the engines alone, and raise the ship twelve inches in those two views. This would have given exactly the same result; but the easiest and simplest way of accomplishing the end in view depended upon the judgment of the draughtsman, who, no doubt for his own comfort, used it to the best of his ability.

CHAPTER XI.

ORIGIN OF MARINE ENGINEERING—STEAM POWER ON CANALS.

Duties of Superintending Engineer—Repairing damaged Engines—Marine Propulsion among the Ancients—Blasco de Garay's "Trinidad," 1543—Miller's First Experient on Dalswinton Loch, 1788—Canal Steamer "Charlotte Dundas," 1801—Scheme abandoned—Houston's experiments on Canal Boat, 1830—Expected Railway Opposition—Fairbairn's Iron Steamboat "Lord Dundas"—Trial on the Irwell—Strange Discoveries—Perilous voyage to the Clyde—Compass Deviation and Correction—Success at low speed on Canals—Steam on Ship Canals—Belgian Cable System.

THE duties of a superintending engineer are numerous and responsible. He has charge of the whole of the engineering staff in the fleet, which requires considerable administrative ability; he has also to rectify all complaints, and see that the men in both engine and boiler room departments do their work properly. Besides this, he has to keep a vigilant watch over the machinery of all the ships, in which he is greatly assisted by the chief engineer of each vessel, who reports to him whatever alterations or repairs may be necessary to execute before she sails again.

On visiting each ship at the end of her voyage, he finds out whether the engines have worked satisfactorily, or otherwise, and whether any breakdown has occurred. If any important smash should have taken place, such as loss of part of the propeller, fracture of shaft, etc., it will be known to the owners long before the ship arrives, and prompt measures taken to countervail the damage, by having a new propeller cast at once,—if they have not a spare one at the repairing works,—or giving an order to the forge people for a new shaft, if sufficient particulars have been obtained to enable them to do so. Since time is required for these and similar operations, it is of the utmost consequence to have the repairs carried out as rapidly as possible, and thus save the vessel from protracted and expensive detention in dock. As an illustration of this, it may be added that a few years ago two steamers arrived at Queenstown the same day, each having lost her funnel. Both returned to Liverpool, and one of them was repaired in two days, whereas the other required twelve.

Steamers in general carry sufficient "spare gear" to provide for all ordinary contingencies, but occasionally disasters happen at sea which are entirely beyond the power of those on board to rectify. Minor accidents, however, can be repaired easily enough, or if they cannot, may stand over until arrival in port, as they do not interfere with the safety, or even perhaps the speed of the ship. The most irreparable breakdown that can happen is serious damage to the propeller, or fracture of the screw shaft, the latter of which has caused large ships to be towed very long distances—in one notable instance 3,700 miles, and in another 4,200 miles.

The superintendent has also to look after all vessels "now building," and this is what our friend, Mr. Macdonald, is at present occasionally occupied with. In the course of a few months, the appointed chief engineer of each ship will help him in his duties by inspecting the work in progress from time to time. It may be mentioned, however, that nearly all the alterations and improvements that are made refer to the first of the ships, but with the others, everything will be plain sailing.

It will thus be seen, that the superintending engineer has considerable authority, which he may wield successfully or unsuccessfully, generously or tyrannically, according to his disposition and temperament. Generally speaking, superintending engineers to lines of steamers are now-a-days selected from the ranks of those who are or have been at sea, instead of the professionals on land. The former are obviously more suitable for the post, whereas the latter are better adapted for the scientific branches of engineering, such as the design, construction, and supervision of marine and other machinery in the works and elsewhere.

Hence it appears to a great extent unnecessary for those who are simply and entirely practical men to interfere with the drawing office arrangements, and this will be at once seen when we consider the question. In the first place, men who are good hands on board ship very often know little of the higher branches, as practised on shore. On the other hand, a manager of works may be most accomplished in every sense of the word. He has also under his own control full and complete records and sets of drawings of every ship and set of engines made by the firm, for reference and future guidance, and thus knows exactly whether certain arrangements, or proportions of engines, boilers, etc., have been successful or not. Everything good is adopted and improved if possible, while everything faulty is eliminated.

The chief draughtsman, too, as previously explained, is one who has, through many years of close study and application, collected an immense quantity of useful information of the most varied character, all of which he finds invaluable while getting out designs, or working drawings.

These two gentlemen also thoughtfully and intelligently help each other in every possible way, in their endeavours to obtain the best results, and nothing, however small, escapes their eagle-eyed scrutiny. A superintending engineer will, therefore, find it more conducive to his peace of mind to let the eminent firm who are making his engines have their own way in the office, and direct his attention almost exclusively to inspection in the workshops and yard. He will thus prevent them from incurring unnecessary loss by the undertaking; and in proof of what has been said, it may only be added, that we have never known any superintendent who interfered with the scientific staff, as Mr. Macdonald is now doing, and as the original character actually did, through over anxiety to promote the welfare of the company he represented.

Origin of Marine Engineering.

Hitherto we have referred only to the screw as a propelling agent for steamers, but may now introduce a few remarks concerning the paddle wheel system, which, although very nearly a thing of the past, has nevertheless been greatly used from the earliest times.

The principle upon which nearly all marine propellers work is the projection of a mass of water in the direction opposite to that of the required motion. The only exception to this rule is to be found in ferryboats, and barges on some of the Continental canals, where the motive power is produced either by a steam engine or by manual labour operating on a drum on the deck of the vessel, which pulls in a rope or chain lying at the bottom of the water, a system which has been extensively and successfully used in Belgium and elsewhere. The paddle wheel still maintains its position in river steamers, and also in a few sea-going vessels of large power and light draught, similar to those so much used in America, inasmuch as the screw, to work efficiently, must be wholly submerged, and any addition to its diameter demands an increase in the draught of water, which cannot always be obtained. This difficulty, however, is sometimes got over by the adoption of twin screws of reduced size.

On the other hand, the power of the paddle wheel can be increased by making the floats longer, instead of deeper, and thus preventing the necessity of increasing their dip. These wheels may also be placed in the centre of the ship, instead of outside, or at the stern, an arrangement which is frequently adopted abroad. On the Mississippi, they used to take great liberties with their steamers, quite apart from the traditional racing and occasional blow-up of the whole machine, as it was not uncommon for those vessels, after having been run in shore at some cotton depôt for cargo, to crawl out into deep water again on their wheels if they should sink in the mud. At other times, when the river was low, and they had to cross a bar with a stern-wheel steamer, they simply turned her round, and at once got over the difficulty. The reason was that, with the wheel aft, the water receded from her, and she grounded, whereas with the wheel in front the water flowed under her, and the boat rose.

With these few exceptions, the screw may be said to have almost entirely superseded the paddle wheel, whose services, both in ancient and modern days, have been so generally appreciated, but which are now of little value on account of the great advances made in practical and economical science during recent years.

The action of a fish while swimming gave the earliest idea of marine propulsion to the ancient people of Assyria, Egypt, Babylonia, and China, who floated on bundles of reeds or inflated skins, propelled by the legs of those who sat upon them; and such methods are still in use on the Nile, the Euphrates, and in the West Indies. The Egyptians, Assyrians, and Babylonians also employed wicker boats—made water-tight by plastering bitumen inside and outside,—which were propelled by either one or two men with short oars or paddles, as is yet done in the Mediterranean.

The Chinese used a round boat driven by the palm of the hand; and Pliny tells us the ancient Britons used a similar boat worked by oars, very much like the coracles which are even now sometimes employed on the Severn and other rivers. The use of sails as a propelling power is of unknown antiquity, but the common paddle wheel on each side of a vessel was used by the Chinese very far back in the history of the world, and to them we are doubtless indebted for the idea. The screw propeller also was known to the Chinese for ages, but in Europe its conception seems to have been derived from the windmill and Archimedean screw.

In A.D. 1472, galleys were moved through the waters of the Mediterranean by means of side wheels connected by a shaft having a crank in the middle, which could be worked by manual labour, in a manner similar to that which is sometimes adopted in small yachts, or boats on lakes at the present day.

In 1543, Blasco de Garay, a Spaniard, is said to have driven the "Trinidad" at Barcelona, by having a paddle-wheel on each side, worked by an "engine," which consisted of a large cauldron of boiling water, but how the plan was carried out we are not informed. During succeeding ages other people tried various schemes of an extremely primitive character, down to the end of last century, but none of them were of any practical value, beyond leading the way to the great future which at that period was just beginning to dawn.

The first experiment which led directly to the introduction of steam navigation was made by Mr. Patrick Miller, of Dalswinton, in Dumfriesshire. This gentleman had made a fortune in Edinburgh as a banker, and having partially retired from business, devoted the most of his time to useful pursuits, among which was the improvement of agriculture on his own estate. Being also a large shareholder in the Carron Ironworks, he invented the famous "Carronade," a gun at one time most popular in the Navy, but his greatest fame arose out of his efforts to introduce steam power as a means of propelling ships.

The experiment referred to was carried out in the Firth of Forth, on June 2nd, 1787, with a little double-hulled boat. Its motive power consisted of a five-barred capstan worked by men who, however, soon became exhausted with the arduous labour, and this constituted the great difficulty to be overcome in an otherwise favourable trial. A divinity student named Taylor, who witnessed it, at once observed that "steam might possibly be used instead of manual exertion." Mr. Miller took up the idea, which he tried to develop, and meeting soon afterwards with William Symington,—a young engineer, who was exhibiting a road locomotive in Edinburgh,—entered into conversation with him on the subject as fully as circumstances would permit. "Why don't you try the steam engine?" Symington asked, shewing at the same time a working model he had made, and explaining its action. Mr. Miller was so much pleased with what he had thus seen, that he gave him an order to make a pair of one-horse-power engines to drive a little pleasure-boat on Dalswinton Loch.

The trial took place in October, 1788, when the highly satisfactory speed of about five miles an hour was obtained. This was the *first steamer* that ever trod the water like a thing of life, and proved the herald of a new and mighty power in river, lake, and ocean navigation. The hull was constructed of tinned iron plate which, we may add, initiated the now well known system of "iron shipbuilding." It was also similar in plan to the Channel steamer "Castalia," built nearly a hundred years later. After repeated and satisfactory experiments on the lake, the engines were taken out of the vessel and placed in Mr. Miller's library, where they were kept until their removal to South Kensington Museum.

Steam navigation having been thus successfully attempted on a small scale, Mr. Miller commissioned Symington to make, at the Carron Ironworks, a twelve-horse-power pair of engines to put into a larger vessel, which was tried in the end of 1789 on the Forth and Clyde Canal. During the first trial trip the paddle wheels broke down, and after having been replaced by stronger ones, a speed of seven miles an hour was obtained; but as the boat was far too light to be propelled by machinery she was soon dismantled, and Mr. Miller, who had spent upwards of £30,000 upon his pet scheme, became tired of the constant vexations and disappointments to which he was subjected, and abandoned the project just when success was at hand.

The experimental trial trip on Dalswinton Loch forms a landmark in the history of the world, quite as distinct as that of many other important events which have proved new departures in the arts of war and peace. The iron boat, the horizontal engine, and the practically useful employment of steam as a motive power, clearly foreshadowed what was to take place in future years. The Edinburgh banker may therefore be said to have touched the border land of an entirely new system of engineering, which has been developed in the most extended form by many talented inventors down to the present time.

Much has been done in this respect since 1788, but much still remains to be accomplished before marine propulsion is perfected. As it now stands, however, there is sufficient to indicate the extremely complicated nature of the science of steam navigation, which Mr. Miller so successfully introduced on a miniature scale, and which has proved so beneficial to the world.

The experiments referred to, which had been thus far successfully conducted, were resumed in 1801, when Lord Dundas,—at that period Governor of the Forth and Clyde Canal Company,—employed Symington to construct a small steamboat for towing their barges, and after considerable preparation, a vessel named the "Charlotte Dundas" was completed, and fitted with a horizontal engine having a steam cylinder 22 inches diameter, and a paddle-wheel fixed in the centre of the boat and close to the stern. The performance of this little craft was admirable so far as mere towing was concerned, but the surging motion of the water created by the wheel, and apprehended danger to the banks of the canal, caused the scheme to be abandoned. The Duke of Bridgewater, however, had been so satisfied with the result of the trial of this vessel that he gave her builder an order for eight similar ones for his own canal; but on the day the Forth and Clyde Navigation people gave their adverse decision, news was received of his death.

Nothing appears to have been done towards the development of steam navigation on canals until the early part of 1830, when a Mr. Houston, who was the principal proprietor of the Ardrossan Canal, made an attempt to increase the speed of the packet boat running between Glasgow, Paisley, and Johnstone, by experimenting with a light gig, similar to those frequently used in rowing matches.

To this boat he attached two of the track horses, and, driving them at their utmost speed, found to his surprise that, instead of a heavy rolling surge in front, it actually skimmed smoothly over the surface, and the horses worked with greater ease at the high velocity than they appeared to do at a lower one. This was so contrary to all the received theories that doubts were entertained concerning the accuracy of the results. Mr. Houston was not a scientist, and therefore could not investigate the subject for himself; in order, however, to ascertain the true state of affairs, Mr. William Fairbairn, of Manchester, was requested by the Forth and Clyde Canal Company to visit Glasgow and conduct a series of experiments on a light twin boat, which was built for the purpose. In his autobiography Mr. Fairbairn says:—

"Mr. Houston's experimental trip with the gig, and my own experiments on the twin boat appeared to bring out a new law in the resistance of fluids, which encouraged the idea of obtaining quick speeds on canals. This was a subject of vital importance to every one connected with them, as the Liverpool and Manchester railway had just been opened with unexpected and extraordinary success.

"A new principle of traction had come into operation. The flight of the swiftest bird and the fleetness of the racehorse were surpassed by the iron bones and muscles of the locomotive, the tales of the *Arabian Nights* were realised, and no wonder that such apparent magic should create fear and consternation in the minds of proprietors and shareholders of canal stock. A speed of four and a half miles an hour for passengers, and two and a half for goods, were all that they could then boast of, and a new project, which held out hopes of increased velocity, was seized upon with avidity. Hence, every encouragement was given to the new theory, as exhibited by the experiments on the Forth and Clyde, and Ardrossan canals.

"The proprietors of the former, who had great interests at stake, confirmed the report I sent in, viz.: 'That after having duly ascertained the resistance to a floating body passing through the water of a canal at from five to fourteen miles an hour, it was found that such resistance might be overcome by a light iron boat with a steam engine on the locomotive principle to drive her.' In this report I was advised not to raise hopes that might not be realised, but I considered the experiments of such importance as to recommend further trials, and was accordingly ordered to proceed with the construction of a new vessel and all the necessary machinery requisite to propel her at the desired velocity of from nine to ten miles an hour.

"The business I had now in hand was to ascertain how, and at what cost, the object I recommended the Forth and Clyde Canal Company to pursue could be attained. It was not an abstract question of practicability, but how far a very high rate of speed could be advantageously obtained, at what outlay, and what might be the comparative difference of expense between the proposed new principle and the present mode of haulage."

Fairbairn now proceeded to design and build the "Lord Dundas," which was 68 ft. long, 11 ft. 6 in. beam, 4 ft. 6 in. deep, and having a 16-inch draught of water. Her shell was of iron plates $\frac{1}{16}$th of an inch thick, strengthened with light angle and tee iron ribs, and fitted with cabins fore and aft. The engine, which was of the locomotive type — with one cylinder on each side, and equal to about ten horse power—worked a single paddle wheel 9 ft. diameter and 3 ft. 10 inches wide, placed a little aft of midships, and intended to make 50 or 60 revolutions a minute. The wheel worked in a trough, extending fore and aft to allow of the flow of water to and from the paddles. From this arrangement, it was called a "twin boat," although the general construction of the body was single.

This little boat was made of special lightness although at the same time put together in a very substantial manner, and was finished in 1831. Continuing his narrative, Mr. Fairbairn observes:—

"I waited with anxiety our first experiment, and having launched the vessel and fixed the machinery, we proceeded down the Irwell a few miles below Manchester, for the purpose of making the preliminary trial.

"During the time required for building, I had frequent opportunities of considering the nature of the engagement I had entered into with the Forth and Clyde Canal people. It was true I had made no promise to accomplish by steam what had been done by horses, but I considered it worthy of trial, and undertook to construct the boat and engines, and also to superintend the experiments. So far, the agreement was clear on both sides, but subsequent considerations and greatly matured reflections modified my hopes, and, notwithstanding the lightness of the vessel and power of her engines promised success, yet my doubts continued to increase, and I approached the day of trial in a state of nervous excitement of no enviable kind. I had certainly (as I used to reason with myself before the boat was finished) given no pledge to the company, but the public as well as the proprietary would expect the realization of their wishes, and if I did not suceed I must fail, and failure was of all things, to my mind, the most disagreeable.

"In this way I tormented myself, and passed many a sleepless night, in order to devise the best means of ensuring success. At last the dreaded day arrived, and a party of friends from Glasgow, Liverpool, and Manchester embarked for the purpose of testing the qualities of the new boat. The spot selected for the trial was a narrow straight reach of about a mile in length, and after the distance had been carefully measured, we commenced to run with and against the current, when the maximum velocity was found to average about eight miles an hour, and that with considerable surge in front. The whole day was spent in the experiments, and a faithful record was kept of the time occupied in running the distance both ways.

"Mr. Graham, of Glasgow, who took great interest in all that was done, maintained that, as a first essay, it was very successful. I thought differently, but kept quiet, since, with all the power we could obtain, we did not materially increase the speed, but raised a much greater surge before and behind than it had ever been with horse traction, and thus by sinking the vessel in a trough between the crests of the preceding and following waves we appeared to hang on the water with a persistence which no power emanating from the boat itself could overcome.

"The result was to me far from satisfactory, as I thought, even in this early stage of the experiments, I could see what was afterwards realized, that the propulsion of a vessel having the propelling power within itself is entirely different from the force employed in the shape of traction from a towing path. In the latter case, the vessel is free from the load of machinery which in the former sinks her to a greatly increased depth. With horse traction, however, the boat rises upon the surface of the water, and with comparative ease and diminished resistance overrides the wave; but when hampered by a steam engine and all connections, including coal, the vessel, from its increased weight, sinks much deeper in the water and considerably intensifies the amount of surge.

"The 'Lord Dundas' had a second trial on the river from Warrington to Runcorn, and a third from Runcorn to Liverpool in the open tideway. On the narrow canal our speed was reduced to less than *six miles* an hour, but in the Mersey the engines had good play, and we drove along at the rate of *ten miles* in the same period.

"During the trip from Runcorn I had the pleasure of the company of Mr. George Rennie, to whom I was greatly indebted for many useful and friendly suggestions. He took great interest in the experiments, and made many enquiries as to the results, which he considered highly satisfactory under the circumstances. As we steamed down the river, Mr. Rennie got alarmed about the safety of such a fragile boat and when he heard that she was to be taken by sea to the Clyde, advised all who intended going in her to wear cork jackets."

At five o'clock one fine morning in June, 1831, she sailed for Douglas, with instructions to wait for Mr. Fairbairn, who would arrive next day by the regular steamer from Liverpool; but during this adventurous trip, a discovery was made which became of great value in the navigation of the future iron ships. After crossing the bar, the captain steered what he considered the proper course, and about two o'clock in the afternoon land was in sight, which he said was the west side of the Isle of Man. For some time they kept steaming as before, but the commander could not make his course agree either with the chart or with the appearance of the land; and on nearing the shore, he found to his surprise that they were on the coast of Cumberland. This very wide discrepancy completely upset the calculations of the skipper, who had now to run for Morecambe Bay to avoid a gale which was approaching.

On the following afternoon they started again for Douglas, where they arrived in safety, and found Mr. Fairbairn waiting for them most anxiously. Upon learning the incidents of the voyage, he had the compass tested with the aid of a second one fixed on shore, and thus determined the effect of the iron hull of the boat in causing such a dangerous deviation. This is now a very well known method of treating the compasses of iron ships, but at the time referred to a boat of this material was quite a new thing, and the prompt detection of the error, the experimental discovery of its exact amount, and the immediate application of an efficient remedy, shewed great ability on the part of the young engineer. To correct this error, a piece of iron was placed in a position opposite to that of the ship's attraction, until the needle on board was brought in a line parallel to the one on shore. With this rough-and-ready correction the voyage was continued with certainty, though at considerable risk, and they all eventually arrived safely in Glasgow.

The boat was afterwards tried on a long reach of the

Forth and Clyde Canal; but these experiments not only confirmed the results previously worked out on the Irwell, but proved indisputably that high speed could never be obtained on canals when the vessel had to carry her own propelling machinery. Fairbairn adds:—

"This was undeniable, and although we had abundance of power to drive her nine and ten miles an hour in open water, we never, even in our most successful experiments, attained more than seven and a half miles an hour on the canal, with a high swell in front and a corresponding one following behind. At a speed of five to five and a half miles the 'Lord Dundas' steamed beautifully, and at that rate she carried passengers from Port Dundas to Port Eglinton for upwards of two years.

"These experiments were sufficient to convince the most sanguine of the proprietors that nothing could be done with high velocities on canals to enable them to compete with the new locomotives then in process of development on the Liverpool and Manchester railway. Strongly impressed with this conviction, I advised the Governor and Council of the Forth and Clyde Company to abandon the attempt of carrying the passenger traffic by light steamboats, and to confine their operations to a class of steamers that would act as tugs, taking the barges in fleets, and thus expedite the delivery of goods at both ends of the navigation. I further advised the construction of iron vessels adapted to canal and sea navigation, which by increased rapidity of transit would meet the demands of an extended traffic in parcels and light goods. These suggestions were acted upon, and I had the satisfaction of being the first to open the new system of transport, and at the same time to direct attention more prominently to the construction of iron ships in general.

The employment of steam as a towing power on canals, has now been found very advantageous on account of the adoption of the screw propeller. There is less rubbing of the vessels against the banks, the power being in the direct line of pull and not at an angle, as with horse traction. The wear and tear of ropes is much reduced, speed is increased, and bad weather presents no obstacles on the track, as it does with horses. Another of the advantages offered by the use of steam tugs is the cleansing of the sloping sides from the deposit of mud which, falling to the bottom, can easily be removed by the dredger.

On a ship canal with deep water as many as thirteen loaded vessels, from 50 to 100 tons register, have been towed by one tug at the rate of three to three and a half miles an hour, the speed, however, for small vessels may occasionally attain about four miles an hour, but on ordinary canals it cannot well exceed three miles without causing such a disturbance in the water as would be injurious to the banks.

A system of cable towage is much used in Belgium, and considered in that country at least, to be very advantageous. A wire rope is laid along the bottom of the canal throughout the whole length of the course, and fastened at both ends. Tow-boats are provided with engines for giving motion to a clip-drum or pulley, which is so arranged as to enable it to grip the cable in such a manner as to prevent it from slipping—an operation which is automatically regulated by the amount of the load. In working this system, the cable is raised from the bed of the canal, and placed in the groove of the clip-drum which is fitted with suitable appliances, on the deck of the tug near the bow. When the engine is started, it pulls the tug along with its fleet of boats, by "clawing" in the cable, which is delivered over the stern, and left to sink to the bottom until required again.

It may be asked, "Why is this system not used in England?" Well, what suits one country may not suit another, on account of altered circumstances. In Belgium, for instance, the land is flat, and stations far apart, whereas in Great Britain the latter may frequently be very close to each other, and therefore a more independent and generally useful system is necessary.

This is to a large extent accomplished by means of the screw propeller, which has been found to answer very well, when modified to suit the requirements of our canal traffic, and is now extensively used in England. No mechanical system, however, has yet been invented which can increase the speed of a boat economically, beyond what is now so generally allowed, in consequence of a natural law which is more unchangeable than that of the Medes and Persians, and which governs the resistance of water to moving bodies in narrow and shallow channels such as those just referred to.

The preceding remarks sketchily describe the early stages of steam navigation under the most disadvantageous circumstances. We need only add, in conclusion, that so correct was Mr. Fairbairn in his opinions derived from experimental researches on this subject, that no one has been able to controvert them. The system and style of reasoning also which he employed to enable him to ascertain conclusively the true state of the case, will furnish non-professional readers with excellent examples of the manner in which engineering problems are solved, even to the present day.

CHAPTER XII.

BAD WORKMANSHIP.

Troubles of the Engineer-in-Chief—Ambiguous Specifications—Contrary readings of the documents—Responsibilities of "The Engineer"—Reckless Competition—"Lowest Tender"—Cause of variation in Estimates—"Cheap" Machinery unprofitable—Splendid wearing qualities of high-class Machinery—The "Rosalind's" Engines—Office work far advanced—Mr. Macdonald's Improvements.

THERE is nothing, perhaps, in the whole range of the experiences of an accomplished engineer which tends to make him more irritable and anxious, and more inclined to use unparliamentary phrases, than having to superintend, survey, or be in any way associated with bad workmanship. The defects of inferior material are sometimes of such an occult character as to render their detection rather difficult, if not occasionally impossible; but bad workmanship is the curse of engineering, and indicates gross negligence or ignorance, if not premeditated dishonesty on the part of those who produce it. It includes everything that is thrown together in that wretchedly fitted and vilely finished style which is often the result of the "lowest tender" system.

It also embraces a great deal that is fair externally, at least so far as you can see, but is in many places tight where it should be easy, or what is worse, perhaps, slack where it should be tight. Joints may be dangerously reduced in strength, or weak in the fixing at some vital but apparently insignificant point, owing to rivets or bolts having been squeezed into holes which should have been cylindrical, but are, nevertheless, spherically triangular, semi-demi-circular, or of some other shape unknown to Euclid. In short, this style of work takes in the one-hundred-and-one different methods adopted by inferior hands when they execute what is libellously called, in Scotland, a "Manchestered job."

An engineer's annoyance and anxiety, which the superintendence of such work entails, may be easily explained. He acts professionally for his clients, and is expected to see that a contract is carried out in first-class style, generally from his own drawings, but sometimes from those of other people. If the accepted estimate is a fair one—though the lowest—and the people who sent it have a character to lose, they will take care, for their own reputation, that everything is properly executed, even at a loss to themselves, and this is what some of the great firms we have mentioned in previous pages have frequently done. Under these circumstances the private engineer will have no reasonable cause for grumbling.

If, on the other hand, it should happen that some rash speculator has seized the order, determined to evade in some way or other what may be legally, but not morally, a somewhat ambiguously-worded specification, then the superintending engineer may look out for himself, or he will soon get into trouble, as some of the evils we have mentioned will be secretly sowing the seeds of future disaster and loss.

Although the engineer-in-chief is responsible for the quality of the work generally, he cannot be expected to treat any firm so shabbily as to go round and try every bolt, and nut, and "bearing," and also take to pieces every detail of engines, boilers, ships, or indeed any other class of machinery, as if the builders were so many thieves and robbers. If such a state of things existed, we think the sooner this gentleman resigns his position, the better it will be for his peace of mind.

Supervision of this kind is utterly unknown among good people, where the most honourable feeling prevails on all sides. I am constrained to say, however, that were it not for careful inspection on the part of the engineer, workmanship would often be introduced which was not in accordance with the specification, simply because that document wanted clearness in its statements, and gave occasion for contrary readings; that is to say, the superintending engineer studies it from one point of view, and the contractor from another, possibly one that is more favourable to himself. Hence the necessity of great perspicuity and simplicity in describing what is required in specifications for small as well as for large contracts, otherwise expensive and troublesome litigation may arise which might easily have been avoided. So fully has the subject been written about in our scientific journals, that engineers are now much better educated on this point than they were some years ago, and know pretty well what to avoid.

Calculations may be very accurate, and working draw ings very clear and exact, but there are many instructions relating to the execution of the work shewn on the plans that may be quite intelligible to the person who originated them, although hazy in some respects to others. A good specification is very binding on all parties concerned, and a lawyer sometimes has a hand in giving force to its statements, for the purpose of securing what is desired in the fullest possible manner.

For example, the specification for great and, indeed, for many small undertakings, states what the words "corporation," "contractor," "engineer," etc., definitely mean, and also to whom they refer; what kind and quality of materials are to be used; how the work is to be done; what class of workmen are to be employed on it; and what the foremen have to do, so that no inferior methods of construction are resorted to by careless "hands." Full particulars are also given as to testing, erecting, painting, and finishing, "to the satisfaction of the engineer," who has authority to condemn everything that is not in accordance with the specification, or with his own ideas, and make the contractor rectify all faulty parts at his own expense.

"The engineer" is also the judge in all cases where disputes arise regarding "quantities," and "extras," which are allowed for, or "deductions" in the work, which are subtracted from the estimate. As the time for completion of contract is in many cases fixed beforehand, and, perhaps under a penalty, that gentleman has also to be the arbitrator for his clients, and settle what is to be done in the event of any unnecessary delay, and besides his other duties, has to apportion periodical payments to the contractor as the undertaking proceeds.

There is nothing in professional life that gives us more pleasure than to see our schemes prospering,—everything "coming in" nicely, and an air of joy and peace, happiness and serenity pervading all those we are associated with. But, on the other hand, it is extremely disagreeable either to find out that some mistake of ours has been acted upon, or that the contractor has done something which must be put right at all hazards, no matter how low the estimate has been. All engineers know this more or less, and the only protection they have is, in the first place, to send out accurate and well-considered plans, and in the next, clearly-worded and full specifications.

There is such severe competition nowadays, that the "lowest and accepted tender" may leave, mildly speaking, no room for any profit. With eminent firms, however, such as those we have so frequently alluded to, their own exalted name and character is a sufficient guarantee that, at any loss to themselves, the contracts they accept will be faithfully executed; and I am sure that people such as Napier, Denny, Laird, and Maudslay, would as soon think of eating a piece of stewed cylinder cover or fried air-pump valves for breakfast, as of sending out machinery which was not fully in accordance with their own high-class ideas of excellence.

The obnoxious "lowest estimate" is variable, even with the same people, but at different times. For instance, suppose a great bridge, or set of pumping or other engines, or even small gear of any kind in large quantities have to be made. When the estimates arrive, it may be found that Messrs. Crank, Flywheel & Co. are at the top, and Snatchblock & Pulley at the bottom of the list, and if the latter firm are considered good enough to do the work, they will get it.

Six months later, however, this state of things may be reversed, because by that time Messrs. S. & P. have received large orders, are very independent, and ask what they please, without troubling themselves much when invited to tender; whereas C., F. & Co. have finished all their work, and are glad enough to take a contract at almost any price, so that they may be enabled to keep their staff together and their establishment going.

The effects of bad workmanship and unduly low estimates on private as well as manufacturing engineers have been briefly stated, but there is another side of the question, and this concerns the clients, who are sometimes the sufferers, because they fancy that sloppy though "cheap" engines and boilers are profitable. Such machinery is indeed objectionable at any price, because it may involve loss of time and fortune through stopped factories, delayed and perhaps lost ships, boiler explosions, and other disasters too numerous to mention.

The only cheap machinery deserving recommendation is that which is carefully made by trustworthy people at a moderate price, and from its design and construction capable of doing what is required of it in the most efficient manner, and with the least outlay for working expenses and maintenance. So thoroughly is this known to those who are extensive employers of every description in mills, on railways, and in steam navigation, that they rigidly exclude everything of a second-rate nature, because the saving in first cost would be more than counterbalanced by the evils just mentioned.

It was amongst Whitworth's machinery, that I had the honour of beginning my career, and even now, when standing beside one of his early productions, great or small, I feel myself in the presence of a machine whose material is of the very highest and most suitable quality, and whose workmanship cannot even now be surpassed. It may only be added that these qualities, combined with the most admirable design, have built up a reputation of world wide celebrity. Only recently, I saw a few of these machines in a great railway establishment, and although about thirty-seven years old they were still in fair order and working satisfactorily. It would be unjust to other engineers not to mention that there are many of them now who can do quite as well in their own establishments, but some of them, at least, are indebted to the late Sir Joseph Whitworth for the education they obtained in his most admirable school of thought and practice.

The hulls, engines, boilers, and all other gear belonging to our three ships, "Rosalind," "Andromeda," and "Clytemnestra,"—now building—, are all of this high-class standard, and Mr. Macdonald is delighted with them. Only the other day Mr. Bouverie said to him in the erecting shop—

"Well, Mr. Macdonald, how do you think we are progressing?"

"You are getting on first-rate, sir; things seem to come in very nicely, and they are making a magnificent job of these engines," was the reply.

The fact is, that all the plans and details are working out splendidly, with, of course, a few small but important alterations from time to time, that is to say, a little shortening here, and a wee bit lengthening there,—a few more bolts in one place, and perhaps a few less in another. I can promise Mr. Macdonald this, however, that whether he visits the works or not, neither Mr. Bouverie, nor the firm, will let those engines out of their thoughts by night or by day, and from first to last, until they have done all that mortals can possibly accomplish, to attain the highest excellence in their arrangement and construction. Non-professionals can hardly realise this, because the machinery is of a new type, which requires a complete and most extensive set of fresh drawings, and it is only through a long and intimate acquaintance with the internal working of great marine establishments that even professionals can comprehend it.

No engineer, however talented, can grasp at once all he wishes to know. His ideas expand from day to day—things previously unseen are made manifest—general and also detail drawings, are altered in every way to suit the latest flash of thought—materials are more scientifically distributed so that strength may be combined with lightness and economy in manufacture. Indeed, nothing can be too small or apparently insignificant to escape the rigid scrutiny of men who well know that life or death, safety or destruction, so often depend upon *little things*. One of the latest examples of this was the bursting of the Royal Mail S.S. "Elbe's" main steam pipe in 1887, during her trial trip. It was only a small rent in a new copper pipe, for which no one could be blamed, and yet it killed ten people before the steam from the boiler could be shut off. This, however, is only one of the numerous side-lights of good engineering practice.

The office work is now far advanced, and whatever improvements have been introduced into the first set of engines, will be utilised without further trouble in the second and third sets. Mr. Macdonald has become quite a favourite with everyone he comes in contact with, and especially with his friends in the drawing department, who fancy themselves well out of the wood, that is to say, all the additional "eighths" in diameter to bolts throughout the engines, and extra "quarters" and "half inches" given to rods and shafts, have been put into the drawings from time to time, as well as other little alterations of a varied character the superintending engineer thought advisable.

Things are, therefore, well past the rectifying stage, but even now a discovery has been made in the "General arrangement of engines and boilers." Mr. Watt, the draughtsman, has been explaining different parts of the plan to this gentleman,—who has paid him a visit,—and showing to his own satisfaction, at least, how well all the details will work out, and how handy they will be in every respect.

"Yes," says Mr. Macdonald, "everything looks first-rate, but you have too sprawly an arrangement in that corner—pointing to the port-forward end of the engine-room—which will have to be altered."

"Well, I *could* have made a more compact arrangement, but I wished to give you a little more room for working," observes Mr. Watt.

"Very true; but suppose you had a field you wanted to build houses in, what would you do?"

"I don't know."

"Wouldn't you like to put them as close together as possible?"

"I don't think I would."

"Well, that is just exactly what I wish you to do in this case. Put that donkey more into the corner, shorten the bends of those pipes, and put these suction and delivery valve boxes a little closer together, and then you will be right."

Mr. Ellington, the chief draughtsman, is appealed to before anything previously sanctioned can be amended, and his opinion is that "the arrangement could not be better, but I suppose we shall have to alter it to please him." It is altered.

In course of the next fortnight, Mr. Macdonald is again making a tour of observation in the works, and again looks at this plan approvingly.

"That will do very nicely," he remarks, "just go on as you are doing, but man,"—he says, bringing himself up with a jerk—"what is this you are about? You have jammed everything into that corner in such a way that no one can get at it. That will never do."

"I thought," replies Mr. Watt, "that was just what you wished."

"Yes, but you have gone to the other extreme now, you surely couldn't expect men on board a ship to work these things properly."

If the truth must be told, Mr. Macdonald has found out that they were better as they were, but as it would be rather humiliating to adopt a discarded idea fourteen days old, he suggests a medium arrangement, which the draughtsman informs him "will be very awkward, as all the details are in the shops, and may be partly made by this time—pity he didn't know about it sooner, etc."

The end of it is, that every tracing referring to the disputed subject has to be sent for, inquiries made concerning what has been done, and the work stopped until the alterations are put in in crimson lake, and the tracings returned. As the superintending engineer has never made a half-inch scale drawing of this kind in his life, he has, of course, a rather hazy idea of distances on a plan, hence the unnecessary and troublesome alterations just referred to. Had he, however, seen the real work in the actual ship, he would have told you exactly, straight off the reel, whether it would have done or not, and maintained his opinions, too. It may be useful to add that there is a kind of ocular deception about drawings which has to be guarded against. This is particularly the case with full-size details, as they always look larger than the work they represent when finished. The figured dimensions, however, efficiently correct these false impressions.

As previously observed, everyone in the office engaged on the plans for the "Rosalind" and her sister ships, feels as if he were getting clear of his difficulties, and looks upon a visit from Mr. Macdonald as a source of enlivenment, as he is full of quaint narratives, funny illustrations, tales of the ocean, and yarns from the engine room to fire off when he has time to do so. On one occasion, he came in upon Mr. Ellington, when he was busy examining about a dozen tracings of details before sending them out, and also entering them in a large book kept for the purpose. He had just got as far as "Engines, No. 850; Air Pump Levers, No. 31,999, January 18th, 1889;" when the visitor arrives, and work is for a few minutes suspended, so that both may have a chat upon things in general.

CHAPTER XIII.

SYSTEM OF DESIGN AND CONSTRUCTION IN MARINE ENGINES.

Method of proportioning Engine Power to required Speed of Ships—Experiments with Steamers at various speeds to ascertain the actual Powers — Leading Dimensions and Calculations of the "Rosalind's" Engines and Boilers—Rules for determining size of Triple Crank Shafts, etc.—Arrangement of Drawings and Tracings in Office—Mr. Macdonald's Sea-going experiences—Board of Trade Examinations—Great activity in Erecting Shop—Description of "Rosalind's" Engines as they now appear—Leading principles in Machinery Construction—Lifting Gear and Tackle—Engine Foundations—Shrinking on the "Connaught's" Cranks—Modern system of finishing Crank Shafts—Serious Galvanic action in a Propeller Shaft.

WE may now briefly describe the preliminary operations that have to be performed before the sketch design for the engines and boilers of a ship can be proceeded with.

After the leading particulars and speed of the proposed vessel have been decided upon, the first thing to be done is to ascertain how much indicated horse-power is required to drive her at the intended velocity. This is accomplished chiefly by calculation, and partly by means of data referring to other similar ships, and additionally in some instances, by means of model experiments in a specially constructed watertank on Dr. Froude's system. These computations are more or less affected by the lines of the ship, which give the "coefficient of fineness"—by "the displacement in tons"—by "the immersed midship section"—by the friction of the ship in passing through the water, and by the fluid resistance at various speeds already mentioned in connection with the screw propeller.

As previously stated, the power required to drive a ship at different velocities varies as their cubes, which may be considered fairly correct in a general sense when above ten knots per hour. The following particulars, however, taken from the trial trips of well known steamers, will shew at a glance the practical utility of the above rule. The "true speeds" given are in knots per hour, and the cubes of these velocities, with their corresponding indicated horse-power, as well as the calculated powers, are added for comparison.

S.S. "Egyptian Monarch."

True speeds ...	13·26 ...	12·58 ...	11·21 ...	6.4 knots.
Cubes of do. ...	2330 ...	2000 ...	1410 ...	263
Actual I.H.P....	2822 ...	2298 ...	1498 ...	287
Calculated do....	2677 ...	2125 ...	1538 ...	—

S.S. "Taupo."

True speeds ...	12·44 ...	9·97 ...	8·2 ...	5·25 knots.
Cubes of do. ...	1911 ...	993 ...	552 ...	145
Actual I.H.P ...	1084 ...	520 ...	295 ...	102
Calculated do....	1001 ...	530 ...	388 ...	—

When the required horse-power has thus been found, the diameter of the high pressure, intermediate, and low pressure cylinders, and also the stroke of the proposed engines are calculated, having as a basis a steam pressure of about 150 pounds per square inch, and the intended number of revolutions per minute.

The empirical method of proportioning the boilers, is to allow about 2¾ square feet of total heating surface, and

·085 of a square foot of fire grate per indicated horse-power. From these leading particulars may be found the number of boilers, and also their diameter and length.

The rational science rule, however, is to ascertain the number of cubic feet of steam the high pressure cylinder will use per hour at so many strokes per minute, and cutting off for expansion at any fixed point of the stroke. Having found the quantity of steam required in the engines, and also the quantity of water from which to make that steam at the given pressure, allow in the next place for the ordinary coal consumption of fifteen pounds per square foot of fire grate per hour. Then upon this basis calculate the amount of fire grate and heating surface necessary to evaporate the water, and thus create sufficient steam to drive the engines at their highest speed. This is right enough in theory, but in practice ample allowance must be made to cover waste from a variety of causes.

As the leading proportions of the "Rosalind's" 6,000 indicated horse power machinery have now been determined in the drawing office, a few of them may be given as follows:—

High pressure cylinder, 40″ diameter.

Intermediate cylinder, 66″ diameter.

Low pressure cylinder, 100″ diameter.

Piston rods, for all the cylinders, of mild steel, 9½″ diameter.

Crank shaft, of Vickers' mild steel, in three interchangeable pieces; each bearing 21″ diameter.

Tunnel shafts, 20″ diameter; and propeller shafts, 21″ diameter, all of Vickers' steel.

Total cooling surface in condenser tubes, 11,546 square feet.

Two single acting air pumps, 30″ diameter and 33″ stroke.

Two centrifugal pumps, for condenser, each being driven by a pair of engines, having steam cylinders 8″ and 16″ diameter by 10″ stroke.

Two feed pumps, 7″ diameter and 33″ stroke.

Two bilge pumps, 7″ diameter and 33″ stroke.

Six boilers, 13′ 6″ diameter by 18′ 0″ long, suitable for a working pressure of 160 pounds per square inch.

Total heating surface, 17,640 square feet.

Total fire grate surface, 627 square feet.

Propeller, of Willis's anti-corrosive steel, 22′ 0 diameter; and pitch, varying from 27′ 0″ to 30′ 0″.

Total flat area of blades 149·6 feet.

These dimensions refer only to some of the principal parts, whose details, as well as all the minor details of engines, boilers, and their connections throughout the ship, have to be very carefully calculated and arranged as the work proceeds.

The application of a few of the rules mentioned in a previous chapter may here be appropriately introduced. For example, the areas of the cylinders of our engines—40″, 66″, and 100″ diameter—must have a certain ratio, so that the power given out by each will be nearly uniform. The ratios, therefore, of the above cylinders are 1, 2·7, and 6·25; the mean, however, of sixteen sets of engines, by as many different makers, is 1, 2·54, and 7·07, where the steam is cut off at three-fifths of the stroke.

If the piston rods had been of iron, 10″ diameter, or 100 ÷ 10, they would have done well, but as they are to be of steel, we have reduced them 10 per cent. in area, that is, to 9½″ diameter.

The crank shaft could safely be = high pressure cylinder diameter ÷ 2 = 20″, instead of 21″ diameter, but as the "Rosalind" is intended for long voyages, a fracture of that most important part might entail very serious consequences. On the Atlantic station, however, a similar breakdown would not be so disastrous, owing to the shortness of the trip, and the number of vessels in the track which could give assistance when required.

The Board of Trade formula for three crank compound engines is:—

$$\frac{\sqrt[3]{(d^2 \times P) + D^2 \times 15}}{2016 = f} \times C.$$

Where d = High pressure cylinder diameter.
,, D = Low pressure cylinder diameter.
,, P = Steam pressure in boilers.
,, C = Length of crank in inches.
,, f = Constant for three crank shafts.
,, 15 = Assumed pressure in low pressure cylinder.

By applying this rule to our own engines, and leaving the intermediate cylinder out of the question, we get $19\frac{1}{8}''$ for the diameter of shaft, which is the least dimension the Board of Trade will permit. Since, however, their proportions are in all cases taken as the *lowest* limit of strength, good engineers make ample allowances when necessary, not only to prevent the bare possibility of accident, but also to insure the highest performances of their machinery in every sense of the word, and thus it is that some ships are so wonderfully successful in speed, and also in freedom from accident on ocean voyages.

The condenser cooling surface is very nearly two square feet per horse power, or in this instance, thirty-five times the content of the 100″ cylinder, which is equal to 327·24 cubic feet.

The content of *both* air pumps is 27 cubic feet, or almost exactly $\frac{1}{12}$ of the 100″ cylinder.

The circulating pump gear is driven as already described; but in smaller ships it is generally worked by the main engines, and the quantity of water delivered through the cooling pipes depends more or less upon whether the ship is to run in tropical seas or in Atlantic waters.

The content of each feed pump—7″ diameter by 33″ stroke—is 1,270 cubic inches, and as the content of the high pressure cylinder—40″ diameter by 72″ stroke—is 90,475 cubic inches; the ratio of their capacities is therefore 1 to 71·25.

The bilge pumps are, as a rule, made the same size, and the diameters of all the pipes through which water is forced are so determined as to allow a fluid velocity of not more than 450 feet per minute. This, however, is often much reduced.

The total boiler heating surface of 17,640 square feet ÷ 6,000 = 2·9 square feet per indicated horse power, and the fire-grate surface of 627 feet ÷ 6,000 = nearly $\frac{1}{10}$ of a square foot per H.P. Therefore, the ratio of fire grate area to heating surface is in this case = 17,640 ÷ 627, or or as 1 to 28. In general, however, this proportion is about 1 to 30.

These few examples may perhaps be sufficient to indicate in a general way how the leading proportions of engines and boilers are directly ascertained, but if the reader wishes to study the subject in detail, the text-books, aided by practical observation, will no doubt prove useful. It may be added that the dimensions and particulars given above for the S.S. "Rosalind" may be safely trusted, because they are exactly the same as those of the magnificent and highly successful Orient liners "Oroya" and "Orizaba," recently built by the Barrow Shipbuilding Company, whose "allowances" — professionals must admit—have been liberal.

Mr. Macdonald's Sea-going Experiences—Marine Engine Construction.

When an engineering firm begins to make its first pair of engines, these engines are ever afterwards known as "No. 1," and the first drawing or tracing has also the same title applied to it, but every additional one is numbered in consecutive order,—as indicated in the last chapter,—and continued throughout every set of engines and boilers as long as the firm is in existence; hence, in time, very high numbers may be arrived at.

This practice not only shews how many plans have been made since the beginning, but is of great assistance when reference is made to drawings months or years back. The engines are numbered from the first set onwards, and in regular order, no matter what their size or description may be, or whether they are paddle or screw, hence "No. 750" may represent a set of twin screw machinery of 10,000 indicated horse power for an ironclad, and "No. 751" a pair of tiny launch engines you might almost carry in your arms. The boilers, too, are similarly numbered, so also are the ships, but in all cases independently of each other, and the reason is, that some firms have built very many ships before starting as marine engineers, and *vice versâ*.

Then, again, numerous engines are made for ships built elsewhere, and for old vessels requiring improved machinery. Multitudes of boilers are also in the same manner constructed either for home use or to send abroad; it will therefore be clearly seen that carefulness in numbering is absolutely necessary to prevent confusion, with its attendant worry and loss of time.

Another point of the system is the arrangement of drawings and tracings, in drawers or otherwise. Cloth or paper tracings for a set of engines and boilers are generally folded and tied up in bundles when done with, and have a large parchment label attached, giving "number," or in some cases a class term, such as "Valves," "Boiler mountings," etc. Drawings and heliographs, on the other hand, are put away in large drawers about three inches deep, for easy reference at any time. One of the best methods of accomplishing this is to let all the drawers have printed titles, such as "Engines," "Boilers," "General arrangements," "Brass fittings," and so on, but in other cases two or more "numbers" are given instead for the general details, which should be kept in the places assigned for them, or endless confusion would arise.

As previously stated in the last chapter, Mr. Macdonald has paid the chief draughtsman a visit, and both are now engaged in lively conversation.

"Yes," observes the former, "you are quite right to give plenty of strength to everything. I like in all cases to keep well on the safe side, having seen so many breakdowns in my time. One night, when I was in the 'Miranda,' outward bound, we had a terrible gale in the Bay of Biscay. The ship was deep in the water, and the sea swept our decks in awful style; indeed we never expected to reach land again.

"All hands were on watch that night, I can tell you, sir. We had reduced our speed, and were trying to make some headway with the storm dead against us, when, in the early morning, we heard a crash in the tunnel, and felt a shock throughout the vessel. Mr. Brown, my 'third,' had the steam shut off in a twinkling, and just at that moment a tremendous sea broke over us, which washed three of our hands overboard, carried away two of the boats, and came down the engine-room skylight in tons. We all thought the ship was going to the bottom in two thousand fathom water, but she weathered it magnificently. It turned out that the screw shaft had given way at the aftermost coupling, and the overhanging part had swayed about so much as to tear open one side of the tunnel, and very nearly cut a hole through the bottom of the ship. All the plummer blocks were more or less damaged and wrenched from their seats, indeed everything had gone wrong with a jerk.

"Never in my life have I seen such a divvle of a smash in the inside of a tunnel, and never in the whole course of my existence have I had such a rampagious night, both above and below. We screwjacked the shaft into line, fished, and timber-strutted everything the best way we could, and then headed at slow speed for Bordeaux, where we had a few temporary repairs, and after that we came home again at half speed, attended by a tug in case of accident.

"Between one thing and another, that business cost our Company a fine round sum of money, which would have been immensely reduced if we had had Thomson's patent coupling for broken shafts on board, as we could soon have put everything right, and gone ahead full speed as before."

Mr. Ellington has been smiling his approval from time to time, and now the two worthies have a hearty laugh over the incident, the draughtsman because he considers it an amusingly instructive narrative, and the late chief of the "Miranda" because he is now looking on the perils of that eventful night through the haze of modern antiquity, but feels, nevertheless, that in all his sea-going career he had never been in a ship which ran so close to the gates of death, simply because the screw shaft broke at a critical time.

The friction of two minds thus engaged in different spheres of usefulness has proved beneficial to both. The superintending engineer goes away delighted, and the principal draughtsman, feeling refreshed and invigorated, proceeds with the examination of the tracings before him, resolved more than ever to strengthen everything that may possibly be just a *little* too weak when exposed to great and irregular strains in heavy seas.

At another time, Mr. Burton, the foreman of the erecting shop, receives a visit from Mr. Macdonald, and both are as merry as larks, while the former relates a strange experience of his during a long apprenticeship in Maudslay's, and the latter fires off some amusing recollections of Napier's, of which place he has many happy remembrances. While thus engaged, however, he is casually surveying all the large and small gear belonging to his engines, by which he is surrounded, and trying to discover where any improvement might be introduced.

"By-the-bye, Mr. Burton"—he parenthetically observes—"don't you think these high pressure cylinder covers have rather too few bolt-holes in them? Napier would have given them more."

"Mr. Maudslay would not have put in so many. I think they will do first rate," replies the foreman.

"Very well, keep them as they are; I fancy they are not far out, after all. Ever since my last voyage in the 'Cymbeline' I have been nervous about these things."

"Indeed! How did that come about?"

"Well, you see, we had had a splendid run home, until we reached the chops of the Channel, fully expecting to enjoy New Year's day on shore. I was busy in my room making entries in the log-book. The engines were running at sixty-five revolutions a minute, with a strong breeze on the quarter, and every sail set, when all at once there was a tremendous smash in the engine room, close to my lug, and the whole place filled with scalding steam. Good gracious! thought I to myself, what's gone wrong now? and on groping my way to the starting platform, I found that Mr. Cameron, my 'second,' had shut the stop valve before you could say 'Jack Robinson,' and all danger was over.

"It turned out that the high pressure piston was broken, and the cylinder cover smashed to pieces. After disconnecting, however, we worked the other engine, and, with the help of our sails, managed to get into Liverpool all right the day after, instead of the day before, the New Year. I can tell you, sir, that ever since *that* breakdown I have been very careful about the strength of such gear. Good morning!"

It is only right to add, that Mr. Cameron is now the appointed "chief" of the "Rosalind."

As we said before, Mr. Macdonald is somewhat vacillating in his opinions, but he is, nevertheless, a man of great experience, and quite capable of giving valuable hints to those who know perhaps but little of engineering life at sea. When *he* imparts information, he does it in a way that will prevent people from ever forgetting it. Unconsciously he runs upon the lines of Sir David Brewster, who said that "Philosophy in sport is science in earnest." He follows the lead of another writer, who "gossipped pleasantly while instructing solidly," and thus it came to pass that much good was done all round wherever he went, by means of his own chatty, simple, and humourously instructive style of language. It is therefore much to be regretted that some of our learned but pedantic lecturers and authors do not similarly modify their high-toned oratory, and say what they mean simply and brightly. If they did so, it would keep the minds of their audiences from becoming torpid—their nervous faculties from getting benumbed—and would at least enable them to leave a lecture hall, or put down a book, with the feeling that they had derived some benefit.

As non-professional readers may exclaim, "These accidents on the ocean seem to educate sea-going engineers in very good and sharp practice, which is no doubt most useful to them in cases of emergency," let me inform them how the necessary knowledge is obtained.

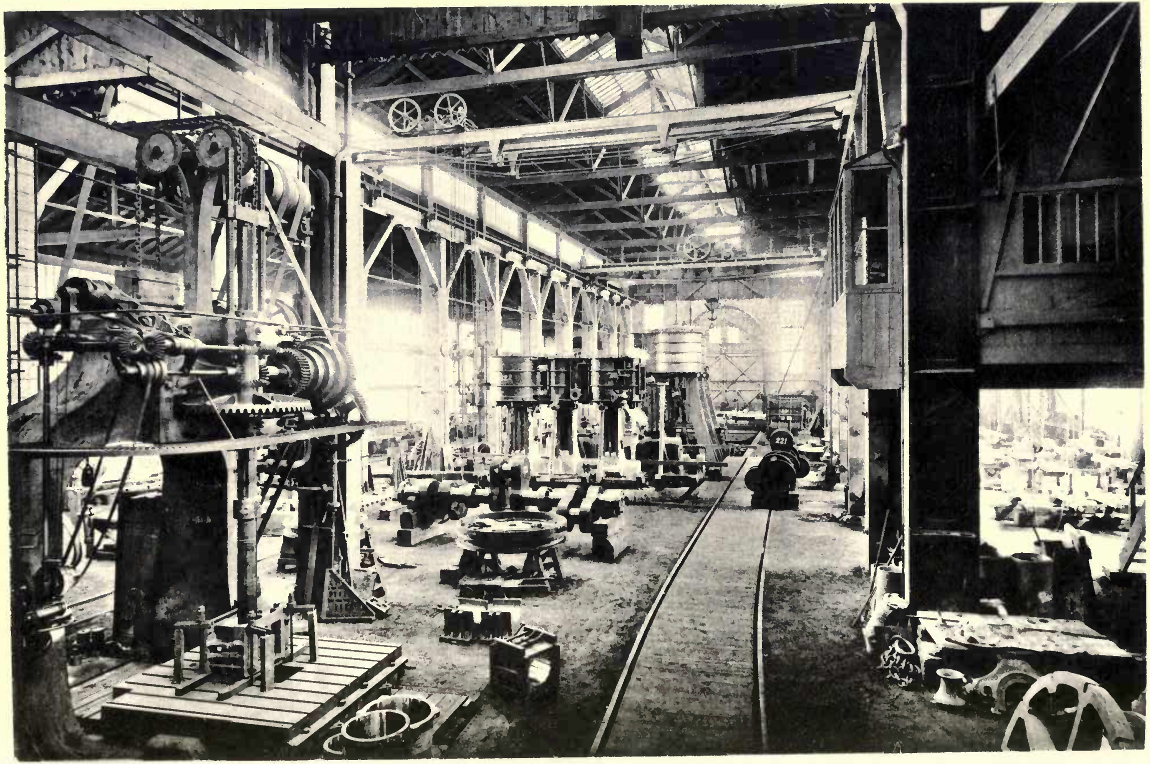
Long before the occurrence of the disasters we have mentioned, the second and third engineers of the ships just referred to had passed Board of Trade examinations in practical engineering at sea, which involved satisfactory answers to a great many questions relative to the construction, uses of various parts, and general management and repairs of engines and boilers. Among the numerous questions asked, were, for example—

"What would you do if your screw shaft broke, or how could you possibly repair it when damaged?"—"What course would you pursue if the piston gave way, and how could the remaining engine be worked when thus disabled?"—"If a boiler-tube burst, how would you remedy the evil?"—so on and so forth. What *had* to be done in these cases, and also a multitude of others, was fixed in their minds, and thus they became qualified to hold the above mentioned appointments.

The necessity of this is clearly obvious, since there is no time to think about what is the best thing to do when a breakdown occurs, and in many cases little enough to perform at once what is absolutely necessary for the safety of the vessel. All the engineers of the fleet know their duties exactly, and hence the passengers and the Company have complete confidence in those who, in the steam department, have charge of their lives and property. The same may also be said of the captains and navigating officers, whose technical knowledge has often proved invaluable at a critical time, and perhaps not more so, nor more frequently, than on board the ships of the Atlantic and other well-known Companies.

The erecting shop at this period is in a state of great activity, and would be quite a study for those who take an interest in such matters. Standing at one end, you will have in front of you a set of small twin-screw engines for the steam launch of one of the ironclads now building. Close beside them are the very handsome oscillating paddle engines, of 6,000 indicated horse power, for the "Duke of Connaught." Then you have the great engines of the British ironclad, in a forward condition, and, in their immediate vicinity, the costly machinery for another ship of war; while lying about on the floor promiscuously are brass and iron castings of all sorts and sizes, including condensers, air-pumps, slide valves, wrought iron work of every description, copper pipes, etc., etc., and which are being operated upon in various ways.

You will also observe, among much that may interest you, the great lathe, in which the "Rosalind's" propeller



INTERIOR OF NEW ERECTING SHOP, WIGHAM RICHARDSON & CO., NEWCASTLE.

is being bored. The end of the screw-shaft will next be fitted to it, then " key seated," and ultimately screwed up tight by means of a large nut at its extremity. As nearly the whole power of the engines will be transmitted to this point, it is very necessary, in this manner, to prevent the possibility of a disaster at sea.

One of Sharp, Stewart & Co.'s slot drilling machines is making cotter holes in air-pump rods, and this will be done to perfection. The same operation, even in the heaviest butt and strap connecting rods, was at one time performed by hand; that is to say, four holes were first drilled right through; the rest of the metal was then chipped away in the usual manner, and the aperture filed perfectly true for the reception of the gibs and cotters, which were accurately fitted to it.

A large radial drilling-machine is boring bolt-holes in a massive casting. Buckton's colossal slotter and planer is fully occupied with the slide valve face of the " Andromeda's" low-pressure cylinder, and the rest of the machinery is similarly engaged upon various other details. A great many fitters, erectors, and apprentices, are busy chipping this, filing that, and scraping the steam-tight faces of pistons and slide-valves to a true surface, while the labourers are lifting light and heavy gear with the overhead travelling cranes. An air of prosperity seems to pervade the whole place, and upon inquiry we are told the firm has orders in hand for the next two years, and that most of the hands are working until eight and ten o'clock every night.

The plate opposite shews very clearly the new erecting shop and part of the heavy turnery, at the works of Messrs. Wigham Richardson & Co., of Newcastle, and may be considered a very good illustration of the general arrangement of this department of a marine engineering establishment. Two sets of triple expansion engines are being constructed in a deep recess in the floor of the building, to enable them to clear the overhead travelling cranes, and a few of the details belonging to them are lying scattered about for convenience. Amongst the most conspicuous objects are the crank shafts for the aforesaid "Triples," whose built-up construction is very clearly seen, and also a piston partly finished. The large boring machine in the foreground, forms in itself a handsome illustration of the various kinds of gearing so much used in constructive work.

"Where are the 'Rosalind's' engines?"

If you come with me, I will shew you them. Let us go to the other end, beside the great lathe.

After descending a flight of steps, we find ourselves in front of the engines we are in search of. There you see the massive bed-plate in position, on one side of which are the air and circulating pumps and condenser, and, on the other, the columns which assist in carrying the cylinders. Between them, also in its place, is the steel crank shaft, and a splendid piece of work it is. Overhead you will observe the three cylinders,—high pressure, intermediate, and low pressure,—all in position and bolted down, while the piston and connecting rods, and other gear, are on the ground ready for setting up. The connecting rod is considered one of the handsomest and most costly details of an engine, and its crank end is now formed in the almost universal "Tee head" style, which was so fully developed and perfected by Mr. Penn.

Although the "Rosalind's" machinery has a somewhat imposing appearance, there is an amount of work to be done in reference to the fixing of minor details that would astonish an outsider, not only before the ship is ready for sea, but even before the erection is completed. Including the main engines, and other engines for various purposes, the boilers and their connections, shafting, and all other gear, large and small, throughout the vessel when finished, a recent writer has calculated that the number of separate parts in the machinery of a first-class Atlantic liner amounts to 103,722, counting all rivets, bolts and nuts, pins, levers, rods, pipes, etc. This may now be considered too low, but we shall take the statement as it stands.

In the erection of the engines before us, and indeed in all others, two grand ruling principles are rigorously adhered to from beginning to end, viz.:—*All vertical surfaces must be truly perpendicular, and all horizontal surfaces exactly level.* The first is obtained by means of the plumb-line, and the second through the use of the spirit-level. If there should be any deviation from the above hard-and-fast rule, the error will most assuredly have to be rectified, since this is the basis upon which not only machinery in general is constructed, but all architectural works as well, from the cathedral to the cottage.

In this department, the greater portion of the ponderous work of the establishment is built up and finished, consequently there is a large quantity of heavy lifting or moving about in some way or other. It is also towards this point that all the efforts of the drawing office, pattern shop, foundry, turneries, etc., converge, and if something has been made wrong in any of them, it will be discovered here if not previously detected. Jib or radial cranes were used long ago for erecting purposes, but for general utility nothing can equal the overhead travellers, which have superseded them. Although the lifting is performed by labourers, great care should be exercised by experienced hands in slinging the heavy weights, and the slings themselves must be well made. These consist of various lengths of chain or rope spliced at the ends, thus forming convenient attachments for the crane hooks.

Unimportant as this art may appear, a good knowledge of it helps in various ways to facilitate the execution of all engineering contracts, indeed, some undertakings have been unnecessarily delayed through the want of special information. There is a very simple, but nevertheless valuable double-loop, which is much used when lifting cylindrical objects vertically, and there is also a special kind of knot particularly adapted for sustaining very heavy strains without jamming. Both of them are admirable contrivances, but can only be explained experimentally; the latter, however, may be constantly seen at the end of hawsers connecting ships to the quays of docks or harbours.

Heavy machinery is frequently erected upon massive timber supports, but a much better plan is to have strong cast-iron plates planed on the top surface, well bedded in the floor, and set perfectly level throughout. In the Central Marine Works at Hartlepool, a somewhat similar system is adopted, but with the addition of strong movable cross girders resting on the bed plates underneath them, thus forming in each case a very good and easily adjustable foundation. Although the latter is an expensive arrangement, it has proved economical as well as useful. In many first-class establishments on the Clyde and Tyne, the old-fashioned timber system still prevails, notwithstanding the revolutions that have occurred in marine engineering during the last twenty years, but, antiquated and imperfect as it now appears, it is nevertheless simple, easily adaptable to different sizes of engines, and sufficiently well tried to enable it to hold its ground in spite of all improvements.

Do you see those men bringing in something of a dull red heat? That is one of the "Duke of Connaught's" cranks, which is going to be "shrunk on" her intermediate shaft, lying beside you. The "eye" of the crank has been bored just a little less in diameter than the part it has to fit, but the heating has expanded it so much that it will now easily slide on to its place. When that is done, water is poured over it, and the contraction in cooling causes the crank to embrace the end of the shaft so firmly that, when "keyed up," it will be practically solid, and fully able to withstand all the severe and irregular strains that will be brought upon it at sea. For marine work the above process is very popular, but for fixing railway wheels in a cold state on their axles, powerful hydraulic pressure is invariably used.

The above mentioned detail is so important, that a few further remarks in reference to it may be interesting. As we have before observed, the "Rosalind's" crank shafts were made upon Sir Joseph Whitworth's improved principle. Other similar work, however, is generally accomplished in the various forges, where all the heavy parts of ships and engines are executed in accordance with tracings sent to them by different people.

Formerly, engineers received their crank shafts in a rough state, and did all the machine work themselves, but it was discovered that flaws very often did not shew themselves until a great amount of such labour had been expended, and hence the forging of many tons weight had to be returned. This system became so inconvenient and troublesome that the forge people were allowed to complete the work in every respect, so that any fault which existed could be found out on the premises at an early stage. Visitors to these establishments will see much to interest them in the manufacture of iron and steel, and also in the ponderous machinery employed in the various processes, a small portion of which can be seen in the plate of the Mersey Forge.

Notwithstanding the extreme care adopted in all these instances, shafts frequently give way at sea most unexpectedly, and when we consider the amount of loss thus entailed, it is evident that no expense should be spared in order to obtain the most trustworthy material, and also the best contrivances for promptly rectifying such evils when they do occur, and especially so when terrible calamities sometimes arise on land and sea from similar failures.

In proof of this we need only refer to the dreadful railway accidents at Penistone in 1884 and 1889; the loss of the S.S. "American" in mid Atlantic some years ago; and many others of kindred nature but minor importance.

It is generally supposed that the main cause of so many shaft fractures is the disintegration of their particles owing to the vibration caused by quick running engines. There is another cause, however, which we had an opportunity of noting only recently in connection with a very well known ocean mail steamer that had only been eight years on her station.

The diameter of her "tail" or stern tube shaft was 24″, and, in addition to the usual brass liners at each end bearing, it had an intermediate liner which butted against both of the others, but without being watertight. This had caused galvanic action which had cut the shaft, as if by a saw, to a depth of fully 2½″ all round, and reduced its strength in the ratio of 24^3 to 19^3 or as 13824 to 6859. Owing to the sharpness of the corners of the groove at the bottom, it was also in the best condition for snapping like cast iron when exposed to sudden shocks. In the navy these shafts are cased with brass all over to protect them from rust, but every joint is made thoroughly water-tight to avoid the galvanic action above described.

From this it will be seen that the protective casing may easily become a source of grave danger, and especially on account of the great difficulty of discovering the evil. A much simpler plan is to coat the shaft with a composition which will adhere so firmly to the metal as to prevent corrosion, and this has already been done very satisfactorily in the merchant service, where the casing referred to is almost unknown.

CHAPTER XIV.

BOILER YARD, AND BOILERS IN CONSTRUCTION.

Difficulties in Boiler Design and Construction—Structural, Mechanical, and Chemical Difficulties—Peculiarities of Steel Boilers—Board of Trade Supervision—Increase of Steam Pressure, 1850 to 1889—Racing with unlimited Pressure—Awful Disaster—"Rosalind's" and other boilers in progress—Hydraulic Testing—Fatal Explosion in a Locomotive Work—Boiler Coverings and economy of Heat—Fairbairn's Experiments and Improvements—Materials and mode of Manufacture.

AND now, may I ask you to come with me and survey the contents of the boiler shop? Yonder lie two of the "Rosalind's" boilers in a far advanced stage, and also two more not so far on. Externally, they are of steel plates, double and treble rivetted, and in every other way immensely strong, on account of the high pressure of steam they have to bear. "Plebeian-looking things, compared with the engines," are they? "Not much in them," do you say?

Not at present, certainly, but they will be *full* enough in course of time. Perhaps you think anyone might design these apparently simple articles? Would you therefore be surprised to hear that there is, perhaps, nothing in the whole range of engineering practice that has more fully exercised the talents, energy, skill, fortune, and patience of practical and scientific men, for the last fifty years, than the boilers which supply our land and marine engines with steam?

Their value may, however, be best understood when we consider the important part they have to play, and the difficulties that beset the successful performance of their duties. What your lungs are to you, the boilers are to the engines, because they provide the very life of the whole system of the machinery, and without their aid the most costly and best arranged engines would be utterly useless. The difficulties which surround the design, construction, and management of boilers on land and sea are very numerous, and sufficiently powerful to have retarded for very many years their efficient application in manufactures and in steam navigation. These obstacles comprise three great classes,—structural, mechanical, and chemical,—all of which have formed the bases of patented inventions involving an expenditure of hundreds of thousands of pounds, in costs alone, down to the present time.

The first-named class refers to the internal arrangements, whose objects are to create rapid circulation of the water in the boiler when heated, so as to produce a somewhat uniform temperature throughout, if possible, and to prevent the sediment contained in the water from settling down on the flues and tubes, thereby reducing their heat-conducting powers, efficiency, and economy in maintenance, and retarding the rapid generation of steam.

The second class is most extensive, and embraces everything in reference to economy in manufacture, and ultimate safety and durability. In connection with steel plates and iron plates; single, double, and treble rivetting, ordinary draught and forced draught; staying, fitting, and mounting, of various descriptions, indeed everything which comes within the province of the engineer and boilermaker, we have such an abundant supply of valuable scientific, practical and experimental information in our professional literature, as would satisfy all, one would think; but it doesn't. The wonder is that so much has been said and written by clever people to prove or disprove theories which looked so simple, not only in this, but in every other science. One of the puzzling questions of the day has been the consideration of steel as a suitable material, which has now to be used instead of iron for the shell plates of large cylindrical boilers, as previously mentioned.

So long as pressures were about 70 to 80 pounds per square inch, iron did very well, but when they ran up to from 130 to 160 pounds, it was necessary to make the iron plates so thick that it became difficult to rivet them satisfactorily, hence the adoption of steel on account of its superior tensile strength allowing thinner shells to be used.

This was a very good arrangement, but, like everything else, it had defects, sometimes of a serious character. If the quality of the steel could be thoroughly relied on, nothing could have been better, but, unfortunately, this was not always so, as plates made by the most eminent firms, and in the most careful manner, and passing successfully the most rigid tests imposed upon them, occasionally proved failures during the process of manufacture into boilers. The cause of these failures has, however, been scientifically investigated, and the steel Companies are now enabled to produce, and the engineers to manipulate, a material which is in every respect trustworthy.

The Board of Trade is much interested in everything we do, and not only provides sea-going engineers with full instructions regarding the management of boilers, but furnishes us with an elaborate and extensive set of rules, regulations, and formulæ, for our guidance in proportioning their various parts, and further, will not "pass" any boilers which are not made in accordance with those rules, which give the lowest limit of strength in all cases. Such, however, is the leniency of the court that engineers have full permission to make them considerably stronger if they please, but subject to its official examination as they proceed.

The reason of this is no doubt apparent to everyone, and especially to those who expect to be carried safely to their destinations when travelling. Were it otherwise, we should have a lively time of it on land and sea, amongst all the dangers arising out of improper construction and bad management, some of which will be described in another chapter.

The chemical obstacles to the proper working of boilers consist of injurious substances, either existing in the water they contain, or getting into it from the condenser, through the feed pipes, and thus causing irregular and serious corrosion of the plates in course of time. The remedy for which is found more or less in the application of various anti-corrosives, such as zinc plates suspended at intervals inside the boilers, and also various fluids mixed with the water they contain.

We do not quite see at present what will be the future limit of our steam pressures. From 1850 to 1860, twenty-five pounds per square inch was quite the order of the day, and engineers jogged along very comfortably with this pressure. Great improvements, however, have taken place since those days. In 1861, Tod & McGregor received an order from the Inman Company to build the "City of New York," with boilers to have a working pressure of 30 pounds per square inch.

This was so unusual for such large ships, that Mr. William Tod took especial care that everything should have very ample strength. He told us that the cylinder covers of H.M.S. "Himalaya," by Penn, "surged like a pair of bellows, and that he would not have such things in *his* engines;" and from the working sketches now beside me, and the light of modern days around me, I have reason to believe that undue importance was attached to the additional load of five pounds above mentioned. Such was the state of public feeling at this period regarding high pressure steam, that if anyone had whispered to the passengers of an ocean steamer those awful words, "We have sixty pounds pressure in the boilers, sir!"—or "ma'am!"—no doubt the greater part of them would have jumped overboard, or taken to the boats.

All this time, an extremely high pressure was quite common in American river steamers, even of the largest class, and 150 pounds per square inch seems to have been considered of little consequence on those vessels, judging from the treatment their boilers were frequently subjected to in ordinary running. Racing used to be a favourite amusement on the Mississippi; for instance, two steamers, say the "Baton Rouge" and the "President," sighted each other on the way to New Orleans,—the former leading.

The "President's" people would not allow this, and if the captain, or that still more autocratic individual, the pilot, did not take sufficient interest in the proposed race, the passengers would spur them on to do so. The engineers received their orders in consequence; the ship began to increase her speed by degrees, and in a short time they were close to the other boat, which was also driving ahead in magnificent style. The passengers became very excited, and did everything they could to outstrip the "Baton Rouge," until at last the fuel was exhausted, but that was of no consequence when they had the cargo to fall back upon. Boxes of bacon were opened, the wood thrown into the furnaces, and the fat pork after it. The steam pressure went up with a bound, and the panting, quivering ship forged gradually ahead of her rival. The passengers and crew cheered in the wildest enthusiasm, until *something* happened, and all at once a "most awful disaster"—as the *Picayune* would call it next morning—occurred, which shook the country for miles around. . . . . .

After a few survivors, who had clung to floating pieces of the wreck, were taken on board the other steamer, there was hardly anything left to indicate the grave of what had once been a swift and magnificent floating palace.

What the bursting pressure of the steam had been we are unable to say,—probably it was 400, 500, or any other number of pounds per square inch,—as the safety valve levers were tied down, and, if that could not be done conveniently, some one would be glad enough to sit or stand on them to the last. These events were rather frequent in the early days of steam navigation; now they are not so, for obvious reasons.

If you look to the left of the "Rosalind's" boilers, you will see part of a set for H.M.S. "Vitellius." The mountings, that is to say, the steam stop valves, safety valves, main feed and donkey feed valves, blow-off and surface blow-off cocks, and other accessories are nearly all on, and will soon be tested by hydraulic pumps to double their intended working pressure of 150 pounds per square inch, so that any leaky places may be rectified, and the strength of the boilers practically ascertained. This hydraulic test is invariably adopted on account of its safety, since, if it were continued until the boiler burst, no evil results would happen to those around, and this is owing to the fact that water, when subjected to great pressure, is almost incompressible, and when the load is removed suddenly by fracture of any part, or otherwise, its expansion is practically nothing, hence its safety when applied in the manner indicated. Any failure caused by *steam* pressure, on the other hand, would be productive of very serious consequences.

As an example of this, it may be mentioned that in 1858, Sharp, Stewart & Co., of Manchester, were completing an order for forty locomotives for the Russian railways. They were large and powerful engines, and had, with the exception of the last, been started satisfactorily under steam, but, strange to say, when the test was applied to this one, the boiler burst and killed nine of the men who were around it, including Mr. Forsyth, the manager. A rigorous inquiry was made concerning all the circumstances of the case, which resulted in the discovery that inequality of strength in the fractured plate was the cause of the disaster.

All these boilers, when in the ships and completed, will be carefully covered with nonconducting substances, and finished on the outside with strips of wood neatly jointed together, and secured to the plating. The steam cylinders will be similarly treated, so will also the steam pipes, but the latter will be covered with canvas painted white, instead of wood, for convenience. The object of this is, not only to prevent a great waste of heat, and indirectly of coal, but to protect the men who work the engines and boilers from an unbearable temperature similar to that which proved so detrimental to the engineers and firemen of the "Enterprise," previously mentioned, on her voyage from London to Calcutta.

The boiler-room will also be provided with ventilating pipes, about two feet six inches diameter, having large bell-mouthed, movable cowls on deck, to catch the wind and direct a current of cold air to the regions below. In modern ironclads, however, this is frequently accomplished artificially, by means of a fan-blast driven by independent engines.

Besides all this, the heat which constantly radiates from the necessarily unprotected boiler fronts and other parts, is guided in its ascent to the casing around the funnel on deck by means of sheet iron "curtains," which are fixed outside the "uptakes" conveying the smoke and heated gases to the chimney. As everything on board a ship is utilised to the utmost, the warm air that eventually reaches the upper deck is taken advantage of in the "drying-room," where wet clothes, and boots or shoes may be left till called for.

From what has been said on this subject, it will be seen that economy of heat, and therefore of fuel, is of the highest importance in steamships, especially those on long voyage stations, and we have reason to believe that, were it not for the great reduction in coal consumption, brought about by the use of compound engines in ocean ships, it would be a commercial impossibility to run steamers to the West Coast of South America, Australia, or indeed on any other long voyage station. The term "compound" is now somewhat misleading, as it is quite as applicable to the triple and quadruple expansion engines of the latest design, as it was to the double expansion two cylinder, three cylinder, and four cylinder—or "tandem" engines—of the old type. Hence in correspondence, care should be taken to state clearly what is meant, otherwise confusion may arise, as there are many of the old engines still in use.

The boilers of the "Rosalind," as well as those of the other ships have been very carefully designed throughout, and especial attention has been paid to the staying of all the flat surfaces. Here, again, however, Sir William Fairbairn's elaborate investigations have proved invaluable to the world, because he not only determined experimentally the best proportions of rivetted joints and flat stayed surfaces, but opened out at the same time a field of scientific enquiry relating to these and kindred subjects, which has extended to the present day. He also invented the well known double-furnaced "Lancashire" boiler for land engines, which is still a general favourite, despite of all the new types that now exist.

The simplest and strongest form of boiler is the old-fashioned, externally fired, egg-ended, cylindrical type, that required no stays of any kind, but was ultimately found unsuitable. Then came the "Cornish" boiler, with flat ends and one internal flue. This, however, Mr. Fairbairn greatly improved upon in the larger sizes, by using two small flues instead of one, which gave them much greater strength to resist the collapsing pressure of steam.

The sphere, and also the cylinder with dished ends, possess in their simplest forms great powers of resistance, which engineers utilise in every possible manner. Were it otherwise, it would be almost impracticable to make the old style of flat-sided boilers strong enough to work safely with such high pressures as we are now using. A steel boiler shell for example, 12 feet diameter and 15 feet long will carry safely 150 pounds steam, if made of plates $1\frac{1}{16}$ in. thick and treble rivetted, no staying whatever being required, except for the flat ends and internal surfaces of similar form.

When the working plans have been well matured, and finally approved, the orders for the required number and description of plates are sent to one of the Steel Companies, while those of iron—if used at all—and specified as "Yorkshire," "Staffordshire," or "Lowmoor," are given to the iron manufacturers. The latter brand is of a remarkably tough quality, and commands a very high price, as it is the most suitable for internal parts exposed to great heat, and also for the flanging and bending operations it is subjected to in the boiler shop.

When the shell plates arrive, they are planed on their edges at a large special planing machine, and are next passed through a plate bending machine, which gives them the necessary curvature, say five, six, seven, or any other number of feet and inches radius. After this they are put together in place, and the rivet holes drilled, thus ensuring great exactness. Punching the plates by machinery used to be the system adopted, but it does not make sufficiently accurate work, and is considered very objectionable on account of the damage which may be done to the fibres of the metal surrounding the holes.

After all the parts are carefully rivetted, either by hydraulic pressure or by hand, and finished off with the caulking chisel, the mountings and fittings are put on, the boiler finally tested to double its working pressure, and, when painted, it is ready for shipment.

As steel is now so much used in engineering constructions, it may here be mentioned that, in order to make the ordinary metal workable by machine or hand tools, it should be allowed to cool very slowly after forging. Cast steel is somewhat similarly treated, but, curiously enough, turning, planing, and other tools may be operated upon with a second cut file, if dipped in water after being heated to cherry redness, when this colour has disappeared in the dark. The reason why "cheap" knives sometimes have such bad edges is the overheating, or "burning," the blades have been subjected to, which makes them useless. On one occasion, I had a very practical illustration of this, in a handsome and generally useful pocket knife, that came to me from Calcutta. All the blades were rubbish, and evidently the English makers considered them quite good enough for the Indian market. Steel has many peculiarities, but there is perhaps nothing that can give one a clearer idea of the value of good material than the extraordinary amount of wear and tear that screw-taps and dies will stand in ordinary use. Their tempering was at one time a secret, and justifiably so, as it is certainly the perfection of the art.

Before leaving this department of the works, we may only add that, so important is this apparently simple and uninteresting branch of engineering considered by those who practise it, that after all that has been done, its improvement is likely to go on for some time to come. And, moreover, there are few practically scientific subjects which have so fully occupied the attention of engineers, and been so largely experimented upon, as that which refers to the economical production of steam as a motive power in machinery.

CHAPTER XV.

THE BUILDING YARD—SHIPS ANCIENT AND MODERN.

"Rosalind" and other ships in progress—Precautions for giving Safety at Sea—Watertight Bulkheads—New and old style of Bow—Boats of the Phœnicians—Origin of Masts and Sails—Galleys of Greece and Rome—Modern Ships—"Lightning"—"Marco Polo"—"Champion of the Seas," and others —England to Australia in 1808, 1850, and 1889—Fastest long voyage Steamers afloat—New Inman Liners of 10,500 tons—Swiftest River Steamer, and Torpedo Boats —American Steamers—Changes in Naval Ships and Engines—Ironclads of 19,500 horse-power.

LET us now pay a visit to the building yard, and see what they are doing. Yonder, in a far advanced state, lies the "Duke of Connaught." What a handsome ship! What beautiful yacht-like lines! What paddle boxes! Beside her you will observe the Brazilian ironclad, and other vessels we need not refer to, so let us take notes of the "Rosalind," which is just before us. Her frames are all up, deck beams in place, and plating pretty well on. One special feature is her bow, which is of the handsome figurehead type, but many other merchant vessels have straight rowing-boat stems, which give them a very abrupt and unfinished appearance forward. Nearly every steamship Company, however, has during recent years adopted this form of bow for the sake of economy.

Since 1839, the attention of shipbuilders and owners of steamers has been directed to the production of vessels which would not only be fully adapted for the purposes for which they were intended, but possess, in the highest degree, the elements of safety under all the conditions of service to which they would be exposed. One set of conditions refers to the engines and boilers, which have already been described, and another set refers to the stability and strength of the ship herself and her floating powers after collision with rocks, icebergs, or with other vessels.

The use of numerous transverse watertight bulkheads has tended in a very great degree to protect ships in times of serious danger, and in many cases has prevented them from foundering. In spite however, of every precaution which the most skilful people can devise, it is surprising that, in our days of advanced practice, ships should so often sink in a few minutes after having been run into, and the inference to be drawn is that either the bulkheads are unable to save them when struck in a vital part, or that the damage done by the colliding vessel is so crushing in its effects that all the resources of modern science are of no avail.

For very apparent reasons we have no means of ascertaining what was the condition of naval architecture before the Flood, beyond the account given in Genesis concerning the ark, which was not only the first built up vessel we have any record of, but the most gigantic in general dimensions the world had ever seen until the "Great Eastern" appeared. This wonderful vessel was three hundred cubits in length, fifty in breadth, and thirty in depth, and if we take the cubit at twenty-one inches, the above dimensions will become 525 feet, 87 feet 6 inches, and 52 feet 6 inches respectively.

After the Deluge,—2,348 B.C.,—the art of navigation is justly considered to have had a beginning, and the earliest people so engaged that we have any knowledge of were the Phœnicians, who are stated to have been the first nation on the shores of the Mediterranean who were actually engaged in nautical affairs, and practiced the art of underwriting or marine insurance, but where they learnt the science of shipbuilding, or what their vessels were like, is almost unknown. There is a story, however, connected with that primitive race which may be worth repeating.

It is said that on one occasion a Phœnician went out with his lady for a row in the rudely constructed skiff of the period, which, in this case we may suppose was large enough for two, but rather small for three people. Actuated by a sudden flash of thought, and a wish to help her lover, the lady sprang to the bow, and, while standing in that position, held up with one hand the skirt of her dress to catch the breeze. Thus was created the idea of sail power, and especially the Lateen sail, which to the present day is so well known in Eastern seas, and also in the smaller sized vessels of various kinds throughout the world. The graceful figure of the lady originated the mast, and her arms, yard-arms, to which were afterwards added the studding sail booms.

That most ancient of European nations, the Greeks, who date their history as far back as the eighteenth century, B.C., paid great attention to the art of shipbuilding, but many centuries rolled away before their vessels passed beyond the rank of row boats or galleys.

Throughout the whole of Solomon's reign this style of build continued, and not until about 588 B.C., do we arrive at the first distinct mention of a "sail" Ezekiel xxvii, 7. From this period until the Christian era, the progress of shipbuilding was very slow, and the compass still unknown. Even the rudder was not invented, and the motive power was chiefly the oar, made of oak; heavy, cumbersome, and capable of application for even moderate distances only by the forced labour of slaves, who, when at work, were driven by cruel task-masters with long whips. It is not to be wondered at, then, that the ancients never ventured out of sight of land—were totally unacquainted with the art of navigation,—and that the type of vessel for coast service remained unaltered from age to age.

The ships of war of ancient Greece and Rome were, for their class, of a very powerful and formidable nature, a remnant of which is still to be found in some of the vessels in the Mediterranean. They consisted of the galley, with one row of oars on each side, the bireme with two rows, trireme with three rows, and the quadrireme with four rows, the three former of which were very clearly illustrated by the beautiful models recently lent by the Venetian Government to the Exhibitions of Liverpool and Glasgow.

In the Peloponnesian war, a trireme's crew consisted sometimes of 170 oarsmen, exclusive of the other hands, and her speed was equal to that of our racing boats, or even some quick steamers. By St. Paul's time, the art of shipbuilding seems to have improved very much, since the ship in which he was wrecked at Melita had 276 people on board, besides a cargo of wheat, and that famous vessel was capable of running the distance from Rhegium to Puteoli, 182 miles, in one day. It is also recorded, that the Alexandrian corn ships of this period had a capacity varying from 500 to 1,000 tons.

Within the last two or three centuries, the shape of vessels' hulls has been very much modified. At one time they had extremely lofty poops and forecastles; indeed the word "fore-*castle*" owes its origin very naturally to the huge constructions which once adorned the forward part of a ship; and the after part was still higher, as may be seen in many old engravings of such vessels. Their rig has also been altered from time to time, in accordance with the dictates of changing opinions in naval architecture, and the sails arranged and proportioned so as to act most efficiently.

Many years ago, a Mr. Cunningham invented an arrangement of gear for abolishing the old-fashioned system of reefing, which was accomplished simply by lowering the yards from the deck, and allowing them to revolve upon their axes. By this process, the sail was automatically coiled up, and a great deal of time and trouble were saved. In the model experiments, the apparatus worked admirably, and so it did also in practice. In course of time, however, yards originally straight became slightly bent, which prevented them from turning as they should have done, and thus the improved system was gradually relinquished.

Double topsail yards were next introduced, the lower one being fixed in position, and the upper one being made capable of rising and falling in the usual way. But here a great mistake was made at the outset. Shipbuilders thought that, because the lower topsail was so much smaller than the full-sized sail would have been, the yard could be made lighter, quite forgetting that a close-reefed topsail in a storm strained it quite as much as the ordinary sail would have done at other times. The yards broke; they were then strengthened, and thus they have remained to the present day.

These two examples clearly indicate that people who invent improved mechanical appliances for ships should study simplicity to the utmost, and bear in mind that an apparatus which works beautifully when everything is in *complete order*, may fail at a critical time through some unforeseen defect, and perhaps cause the loss of the vessel. The same thing may also happen with other good inventions whose practical value depends upon the perfect arrangement of their surroundings, and which certainly deserve success, if they cannot command it.

The hulls of vessels, which in former days were of the bluff-bowed or "tub" species, have been gradually improved, and, as time rolled on, the "clipper" type became a favourite, and perhaps reached maturity among the "sixties," when timber-built ships of the "Lightning" class made such wonderful voyages, and ran, in some cases, at least four hundred miles a day. I remember seeing this vessel occasionally in the Coburg dock, Liverpool, where at that period some of the famous "White Star," "Black Ball," and other liners used to lie. She gave one the impression of a ship that would cut through anything under heavy sail pressure, and attain very high speed, and looked in every respect what she really was—one of the fastest ships afloat. On one occasion this vessel ran the distance from Melbourne to Liverpool in the wonderfully short period of sixty-three days. She has sometimes made fully 18 knots an hour with her lee rail under water, and actually logged, on her greatest run, 436 knots in 24 hours. The "James Baines," however, exceeded this on her famous 12 day 17 hour voyage from Boston to the Mersey, when by the log, she was at one time running 21 knots an hour, under a crowd of canvas, which included all the starboard stunsails and main skysail.

However much, from a professional point of view, we may admire the steamers, and in however great a degree they may win the brotherly love and sisterly affection of all those connected with them, it is certain that, in one respect, they will never equal the sailing ships. Everything that constitutes magnificence in masts, and spars, and sails, is fast disappearing from the former, and in vessels of the "City of Paris" class they are hardly required, owing to the use of twin-screw machinery. A great ocean liner in a stiff breeze is, therefore, a somewhat uninteresting object, when compared with some of the splendid three and four masted sailing clippers of London and Liverpool. And when tearing along at sixteen or seventeen knots an hour, under a crowd of canvas, the passengers of the Indian, Australian, and Cape of Good Hope mail steamers will see in these vessels the highest order of beauty among the white-winged descendants of an ancient race, who perpetuate the art of practical seamanship as it used to be long before the introduction of steam navigation.

The famous "Marco Polo" was not at all inferior to the "Lightning" in speed, but the contrast between them was striking, especially when lying together, as the comparatively full-shaped bow of the former could not lead any one to suppose she was so finely modelled below water. Her commander, Captain Forbes, was then in the zenith of his fame as a skilful navigator and inventor of the system of circle sailing; indeed, his name was "well up" both at home and abroad. It is said that one wet day he tried to get into an omnibus, which was completely occupied.

"No room, sir, we're quite full," said the conductor.

"Oh! but my good man, I must get in; I'm Captain Forbes."

"I don't care who ye are, sir, ye ain't the captain of this 'bus!" was the unexpected reply.

Fully twenty years ago, we had some of the largest and most magnificent wooden sailing ships in the world. There were, for example, the "Morning Light," the "White Star," the "Champion of the Seas," and many others, all of which have now disappeared. Then came the rage for steamships, which went on increasing until it attained such gigantic dimensions as almost to extinguish whole lines of what used to be sailing passenger ships of the class just mentioned; and at no time has this been more marked than in the ocean traffic during the last few years.

In 1808, the convict-laden vessel did well if she reached Botany Bay within 150 days from Spithead. In 1850, the eager gold digger considered himself fortunate if he landed in Melbourne in 90 days after leaving the English Channel. Then followed the age for clippers, when 75 days was thought a rapid passage, but a new era dawned on the history of Australian navigation, when the "Orient" line, which led the way, enabled passengers to reach the colony in the short space of 32 days, including stoppages. In other words, the S.S. "Austral," in 1883, ran the distance from Plymouth to Melbourne, via Suez, 11,162 miles, in 32 days, 14 hours, 49 minutes. In October, 1887, however, the "Ormuz" landed the mails in King George's Sound, Australia, in a little under 24 days from London, which gave an average speed of 18⅓ statute miles per hour for the whole voyage.

Amongst the quickest steamship runs for long voyages were two races with cargoes of tea by the "Stirling Castle," which at one time belonged to Skinner's China Line. This vessel was built by Elder, and though not exceeding 4,500 tons gross register, had engines of 7,000 indicated horse power.

At 4 a.m. on May 22nd, 1883, she started on her second voyage from Shanghai with 5,400 tons of the first of the new season's tea, and arrived at Singapore on the 29th, at 1 p.m. After fifteen hours coaling she sailed for Suez, where she arrived on June 12th, at 1-30 p.m. Upon taking in coals again at Port Said, she started on June 14th, at 6-30 a.m.; passed Gravesend on the 22nd, at 1 p.m.; and entered the London Docks an hour later, thus performing the voyage from Shanghai, including all detention, in 31 days 10 hours, or 29 days 2 hours' steaming time. The average speed of 16 knots an hour was maintained for the whole voyage, but the ship sometimes ran 19 knots, and her daily runs against the South-West monsoons ranged from 371 to 401 nautical miles.

A new system of construction has recently been introduced into Atlantic steamships, which has been fully developed in the latest vessels of the Inman and White Star Companies. The "City of New York" and "City of Paris" belonging to the former, are each 560′ 0″ long, 63′ 3″ broad, 42′ 0″ deep, and 10,498 tons gross, which makes them the largest steamers in the world. They are built of steel, and, from the numerous watertight bulkheads, and other important improvements that have been introduced, may be termed "unsinkable." The engines are of the twin screw triple expansion description, having cylinders for each set, 45″, 71″, and 113″ diameter, stroke of piston 5′ 0″, steam pressure 150 pounds per square inch, and indicated horse power 20,000. Many other engines are also employed for driving the circulating pumps, and for electric lighting, hydraulic hoisting, refrigerating apparatus, steam steering, steam haulage, pumping water throughout the ship, and for other purposes. The speed of each vessel is fully 20 knots an hour, and the internal arrangements are in every respect quite equal to those of the highest class hotels.

Some of the swiftest steamers afloat are to be found on the Clyde and Mississippi. The "Columba" and the "Lord of the Isles," previously mentioned, run 21 and 23 miles an hour respectively, on their usual daily trips, but even this is exceeded by the performances of torpedo boats on the Thames, which have attained the astonishing speed of 24 knots, or 27½ statute miles per hour.

As we have frequently used the words "knots" and "miles" in reference to a ship's velocity, it may be well to mention that the former is the sixtieth part of a degree at the Equator, or 6,082 feet, and is therefore called a nautical mile or knot, whereas the English statute mile on land only amounts to 5,280 feet. For simplicity in calculation, we usually take the number of knots run per hour by a ship, and add one-seventh, which reduces them to miles, that is to say, 21 knots are equal to 24 miles.

The American river steamers are very different in every respect from ours, but are nevertheless well suited for what is required of them. Their leading features are light draught, high speed, curiously trussed and tied framings in ship and engines, and magnificent hotel-like interiors. The following are the dimensions of one of the largest, named the "New World." Length 468 feet, breadth of beam 50 feet, and over paddle boxes 85 feet. The hull is of timber and flat bottomed, with bilges nearly square, and draught of water 5 feet 6 inches. In such a shallow vessel the trussing is immensely strong, and although the great high pressure engine, with its huge "walking beam" and other peculiarities may not be in accordance with our ideas, the Americans nevertheless obtain results which are quite satisfactory to themselves.

Some of the greatest changes in engineering and iron shipbuilding have taken place in the Navy, and so sweeping and rapid have been their character that one eminent authority in such matters stated, a short time ago, that we were "most extravagant people, because every few years guns and ships that had cost millions were put aside to make room for some improved system of construction costing a few more millions, which superseded all that had been previously accomplished." To so great an extent has this been carried that uncharitable individuals might feel inclined to say that gunnery engineers, such as Sir William Armstrong, Sir Joseph Whitworth & Co., and others, had formed a conspiracy with the shipbuilders and armour-plate people for their mutual benefit, and practically directed all their efforts towards neutralising each other's improvements.

This may appear to have been the case, but the truth is, that practical science has made such rapid strides in recent times, and so overwhelming have been the changes, that really we can hardly tell what the next movement may be, or how it may affect us. Among the "fifties," the greater part of our naval ships were built of timber, and heavily masted to enable them to sail well. The introduction, however, of good horizontal engines, such as Penn's double trunk, and Ravenhill's and Maudslay's return connecting rod types, created a great demand for them in these vessels, because both engines and boilers could easily be kept below the water line, and out of danger from shots penetrating the sides.

These engines were chiefly used at first as auxiliaries to help the ships on in calms or against head winds, and, to render them still more serviceable, the propellers were made with only two blades, so that, on being disconnected from the end of the shaft, they could easily be lifted by winch gearing into a recess which was made for them in the stern. This gave the ship full scope for the use of her sails, and prevented her from uselessly dragging the screw through the water.

In course of time, ironclads came into use, with full powered machinery, and with magnificent masts and spars as well. Of this class may be mentioned H.M.S. "Black Prince," "Warrior," and others. The next movement consisted in cutting down the masts until hardly any were left, thus throwing the whole work of propelling the ship upon the engines, and the result has been the introduction of a class of vessels which, though well suited for modern warfare, are as devoid of every element of beauty as it is possible to conceive. Within the last few years, the vertical compound engine, and latterly the triple expansion engine, have been adopted, because the armoured sides form a sufficient protection from shot.

All this time a struggle was persistently maintained between guns and armour plates, and every now and then an improved and more powerful gun was invented for the purpose of smashing all opposing ironclads in existence. This, in turn, led to considerable strengthening of the sides of these vessels, which, however, was neutralised by a great increase in the power of the artillery, and thus the friendly strife was maintained, until wonderfully constructed steel ordnance, and ships something marvellous to behold, were ultimately arrived at. A first-class ironclad of this description now costs about £750,000; the

110-ton guns she carries, cost £19,500 each; a single charge £55 10s., and a single cast steel shot £135.

The machinery used in the manufacture of these guns, includes 200 ton hydraulic cranes; lathes costing £6,000 each; boring machines, £4,000; combined gun-boring, turning, rifling, and lapping machines at £7,000 each; and a great variety of powerful engines, tools, and appliances suited to the work they have to perform.

The largest and most powerful war vessels in existence are the Italian ironclads "Sardegna," "Italia," "Lepanto," "Sicilia," and "Re Umberto." The dimensions of all but the first-named are, length 400′ 4″, breadth 76′ 9″, and mean load draft of water 28′ 8″. Their engines were designed in 1884, by Maudslay, Sons & Field, as ordinary twin screw compounds of 19,500 horse-power; and with a displacement of 13,298 tons, the speed of each ship will be 18 knots. These vessels have excited much criticism at home and abroad, as their machinery is now out of date, and the ships—as Herr Spiridion Gopcevic himself declares—are neither useful as ironclads, nor as unarmoured cruisers. He further states that, for the cost of the "Re Umberto"—which will not be finished till 1892—four ships could be built which, in a variety of ways, would be much more serviceable. As the "Sardegna" is 22,800 I.H.P., she has at present reached the limit of power in marine machinery. The last named vessels, however, in the naval and mercantile services, clearly indicate what has now been attained in at least two branches of practical science.

We have with extreme brevity run over the peculiarities of ships from the time of the Phœnicians to the year 1889; those, however, who wish to study the *History of Merchant Shipping and Ancient Commerce*, will find very interesting information in the late W. S. Lindsay's exhaustive treatise in four volumes, bearing the above title. Great changes in land engineering may be anticipated in the future as time rolls on and the powers of nature become better known, but what those changes are likely to be no one, perhaps, can predict with any degree of accuracy. So far, however, as we can discover at present, steam, as a motive power, will continue to be employed in ocean navigation, on account of its general suitability.

The marine engine of to-day will, on the whole, remain pretty much as it is now—at least for some time to come—but we may expect changes in the boiler department which will economise fuel in the furnaces, and also weight in the ship; thus directly decreasing her coal expenditure, and enlarging her cargo earning powers, to the delight of shipowners in all parts of the world, and for the benefit of shipbuilders and engineers at home and abroad.

CHAPTER XVI.

FINISHING THE ENGINES IN THE WORKS.

Modern Types of Engines—Cycle of operations in working Triple Expansion Machinery—Errors detected by the "Turning Gear"—Finishing touches, past and present—Painting of Machinery—The Engines taken down—Boilers completed—All ready for the Launch of Ship—Distinguishing Marks of Ships—"House Flags"—Funnels—Names—Preparations for Launching—The Chairman's Daughter—Visitors and Officials—Launch Failures.

THE "Rosalind" is now so far advanced as to enable the builders to fix a day for her launch; the engines, too, are receiving the finishing touches in the erecting shop, before being taken to pieces; and, as this is the best opportunity we shall have of seeing them all round, let us inspect them a little.

There they stand, with all their gear in position, with the exception of various attachments which will be added to them when in the ship. The main difference between this improved type of engines and the now obsolete "compound" arrangement of machinery is, that the latter consisted of one high pressure and one low pressure cylinder, except in the case of very large engines, when two low pressure cylinders, of unitedly equivalent area, were employed, chiefly with the object of reducing the risk of an unsound casting, and also for the sake of greater convenience.

The largest mercantile engines of the two cylinder class, that have been made, were those of the Inman ships "City of Berlin" and "City of Richmond," having, in each case, steam cylinders of 76 and 120 inches diameter, and 5 feet 6 inches stroke. Valuable practical lessons were learnt from them which induced engineers to adopt the three cylinder type already mentioned, and also the four cylinder or "tandem" arrangements, at one time so popular in the White Star and other companies. In this instance, however, the high pressure cylinders were placed on the top of the larger ones, thus producing a very lofty, but nevertheless good working set of engines, the working pressure of which seldom exceeded 75 pounds per square inch.

In the engines before us, a very important modification, of the most recent date, has been introduced, consisting of a three cylinder arrangement, which includes one high pressure cylinder, worked by steam of 160 pounds pressure, which escapes at greatly reduced pressure into an intermediate cylinder of much larger size, and then—in a very expanded state—passes into the low pressure cylinder of still greater diameter, and from that to the condenser, where it is changed into water by coming in contact with a large number of small brass tubes, through which the sea-water is driven by means of a circulating pump.

The cycle of operations from this point is exactly the same as in ordinary engines; that is to say, the condensed steam, now at the bottom of the condenser, is drawn off by the feed pumps, and discharged into the boilers as partial compensation for the water which is evaporated to supply the engines with their motive power. It may be mentioned, however, that on these points everything that skill and science can suggest is freely made use of to prevent the possibility of any accident happening at sea.

The air, circulating, and bilge pumps, with all their gear and attachments, have duties to perform just as usual, with the exception of a few modifications to suit the requirements of the case.

A variety of platforms, ladders, pipes, valves, and other connections with the ship's side and bottom, cannot be seen here, because some of them are fixed in the vessel, and others will be put in afterwards. There is no danger of any lurking mistake now remaining undiscovered, because the engines have been turned round by hand and critically examined to see if the "clearances" are all right, such as the pistons when at top and bottom of cylinders, etc. The setting of the steam slide valves, upon which the proper working of the engines so much depends, has been adjusted in the same way. These movements are effected by the turning gear, which, though slow in its action, is very powerful, and in many engines is arranged so as to be worked by steam power. If the machinery passes successfully through this operation, all is well, and those in charge of it may rest in peace.

We have referred already to the manner in which errors in drawings are made, and also discovered in the works, but there is nothing more surprising perhaps than the grave and most unaccountable blunders which are at rare intervals committed,—even by the most experienced engineers,—and which will escape every one's notice until the engines are erected, and passed through a revolution as described. Three of these costly mistakes come to my remembrance now. The first happened in Denny's to a pair of trunk screw engines for China, which were so urgently required that we were working at them till ten o'clock every evening.

When they came to turn the cranks round, it was discovered that the connecting rods, at one point of their vibration, cut into the trunks. There was no remedy whatever in this case except by making new cylinder covers, cutting the trunks off the pistons to which they were cast, and making the second set oval instead of round, so that the required clearance could be obtained. This operation was troublesome and expensive, as it involved a great deal of difficult turning and planing, indeed the trunks were perfect master-pieces of art of the latter kind, since they had to be finished as truly as if executed in the lathe. The alteration was ably carried out, and the office mistake satisfactorily rectified.

On another occasion, a pair of oscillating engines were being made by a firm on the Tyne, when the turning gear revealed a serious error. In this instance, the cylinders cut through the bed-plate, new castings for which had to be made at once, which considerably reduced the profits.

The third of these curious events happened some time ago in a large establishment on the Mersey, where a set of powerful twin screw Government engines were building. The foreman of the erectors was revolving the machinery in the usual way, and fancying everything was right, when lo! the connecting rod of one engine—which meant the whole of them—fouled a large casting con taining the air pump valves. This also had to be remedied in the most efficient manner, and as quickly as possible.

And now it may be asked how such things occur, when experienced draughtsmen prepare the drawings, when the manager is gazing at them every day for many months, and when foremen and workmen fail to see anything wrong until too late, the answer is, "I really cannot tell." Cases of this kind only prove the necessity for great vigilance on the part of those who design complicated machinery, to prevent even the possibility of mistakes existing.

In the engines before us, everything has "come in" splendidly, and Mr. Macdonald has expressed his great satisfaction to Mr. Burton, who is delighted with the compliment. After being thoroughly overhauled with the object of finding out any lurking defect, the machinery receives a coat of slate-coloured paint, and when that is dry it is taken to pieces, and each separate detail,—previously type lettered for reference,—receives the finishing touches. Until within the last twenty years, this operation was a most important one; it meant that everything upon which high art could he displayed was carefully polished in the lathe, and all the other parts were filed and drawfiled, and then burnished with emery cloth, until not a scratch however small could be seen, and every joint was so beautifully true as to be almost invisible.

This style of doing things is now changed, for commercial reasons, but the fitting of machinery is as faultless as ever, because its very life depends upon the way in which all the parts are put together. As superfine polish is not necessary, from a practical point of view, the various machines execute in a perfectly satisfactory manner, nearly all that is required, thus saving a large amount of expensive manual labour. When therefore the engines in front of us are taken down, they will only get touched up here and there, because all that is needed has already been accomplished.

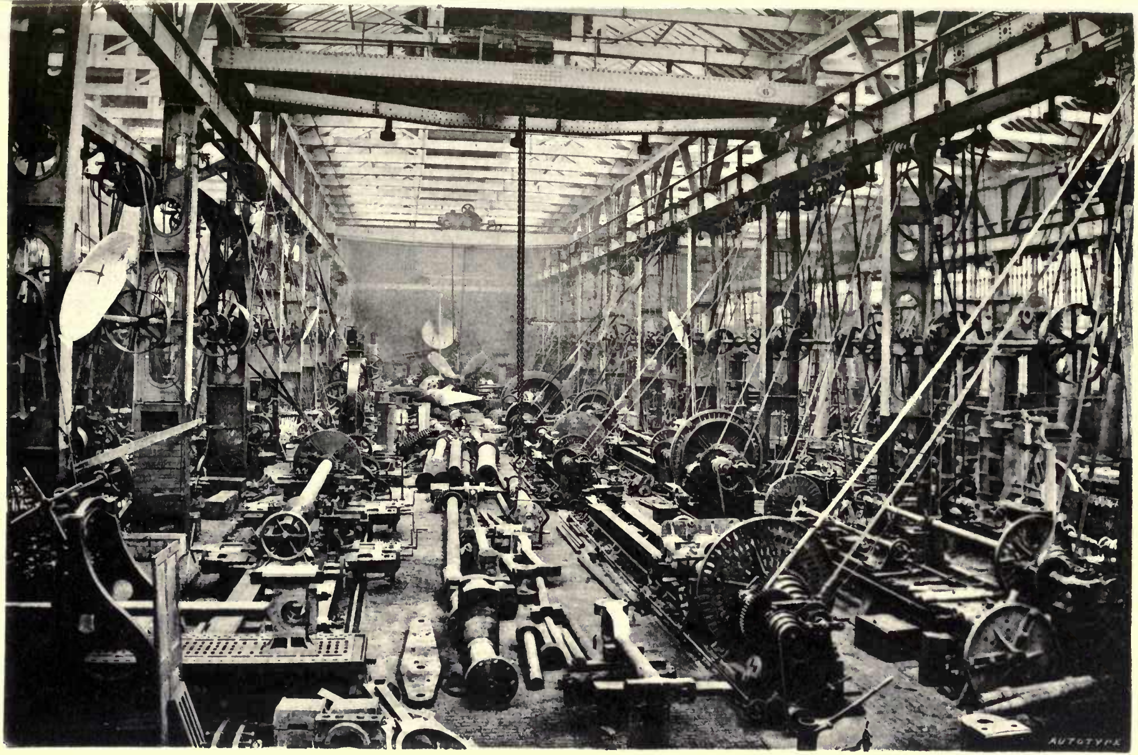
Painting and colouring generally prove most attractive when tastefully arranged and harmoniously blended with a view to usefulness as well as ornamentation, but nowhere is this more necessary than in engineering structures. The "Rosalind's" engines are of a dark grey or slate colour, because it harmonises with the polished work and impresses one with their solidity; but, if scarlet, or bright blue, or brilliant green had been used instead, it would have given them a paltry appearance. The same may be said of nearly all other kinds of engines, and of constructive machinery in general. Roofs and bridges, however, are treated very effectively in a lighter style; but in agricultural engines and machines, and also in American locomotives, etc., a different system is employed.

The farm labourer is fond of gaudy colours, and if he is thus treated liberally in the implements he uses, will take greater pleasure in them. Since also a love of the beautiful, in some form or other, pervades the various races of the earth, those who live in the prairie and other states, will be induced to travel more frequently when taken in tow by a brilliantly illuminated and pictorially treated locomotive and tender.

In high class work the castings are carefully scoured, and, after several coats of paint have been laid on, a beautifully smooth finish is given to them. Proper attention to such matters is very important, because, in addition to the preservative qualities of good oil colours, a certain amount of elegance and cleanliness is conferred upon all kinds of constructions, which—as we have shown—does good in various ways.

The annexed plate is a view of the heavy turnery at Messrs. Clark's marine establishment at Sunderland, and clearly illustrates the interior of similar places.

There is no machine in engineering establishments



INTERIOR OF HEAVY TURNERY, CLARK'S MARINE WORKS, NEAR SUNDERLAND.

that holds such high rank as the lathe, owing to its extreme usefulness and economy of labour. It executes work that no other can accomplish, and performs much that is done by drilling, boring, screwing, planing, slotting, and milling machines. It is also capable of cutting screw threads of all sizes out of the solid metal. This invaluable machine is of endless varieties, and ranges in size from the amateur's foot lathe to those with 6 feet centres and 60 feet beds, employed in the manufacture of the 110-ton guns previously referred to, and its cost will run from about £5 to over £6,000. Some of the machines mentioned above are shown in the plate opposite.

If you were to look into this part of the erecting shop, say next day, you would see a heterogeneous collection of cylinders, also the condenser, air, and other pumps, crank shaft, and other gear, lying in every direction upon the floor, the bright parts of which will be painted with a mixture of white lead and tallow, to prevent them from rusting. This, however, can easily be wiped off with cotton waste when required. The massive bed-plate of the engines will be first taken down to the fitting-up basin, to be in readiness for putting on board as soon after the launch as possible. The boilers, too, are also ready to be lifted into the ship when she is alongside of the great crane. This, however, only forms part of the system which prevails in engineering establishments, and assists in no small degree to facilitate the economical execution of a contract.

I cannot at present remember a single instance of a ship having been launched on a Friday. My good friend, the late manager of the Barrow Works, however, informed me that they "did not consider what day they launched a vessel on," and perhaps that is the most sensible method. As it is now definitely arranged that the "Rosalind" is to glide into her native element on Thursday next, we may in the meantime have a little to say about the distinguishing marks of ships, or in other words, those special features which enable people to ascertain at a distance what Companies they belong to.

The salient points referred to, include the names of vessels, their "house" flags, the colour of the funnels, and to some extent, at least, the rig. The first is not only the oldest and best known, but in our day is capable of great expression, and indicates, in all parts of the world, the ownership of a large vessel. Take for example those of the Inman line, they are all "cities"—"City of Berlin," "City of Paris," etc.

The Cunard Company adopt the names of countries, and call their steamers "Servia," "Gallia," and so on, whereas the Allan line pursuing a similar course, alter the last syllable slightly, as in the names "Sardinia*n*," "Peru*vian*," &c. Solomon used to say that "a good name was more to be desired than great riches." A good name! Well, who would not prefer being called a Vandeleur, a Farquharson, or a Seymour, in preference to Snooks, or Bludd, or Bugge? And so it is with ships. Give them handsome titles, classical or modern, and people will think all the more of them, and this will no doubt help to increase the revenue of their owners. Favourable *first* impressions are most important, and every legitimate method ought to be used to obtain them since unsuitable designations create false ideas, and this will be apparent if we suppose the "Etruria" to be called a "Lily," and the "Mirzapore" a "Violet,"—pretty little titles in themselves, but only suitable for river steamers.

Anything will do for canal boats and mud punts, from "The Pet" upwards, and yet not quite, because a name that is popular with the ladies and gentlemen who work them, may command their admiration for the ships they sail, and thus produce the best results. This principle seems to permeate, in some form or other, all classes of society, but in too many cases it is unwisely disregarded. If you wish to see at a glance the impropriety of giving unsuitable names to ships, try the *reductio ad absurdum* style of argument and you will succeed.

For example, suppose the largest vessels of the Peninsular and Oriental Company were re-named the S.S. "Flea," "Cat," "Dog," "Brotherly Love," "Sisterly Affection," "Polly," and so on, those magnificent steamers would become lightly esteemed by people who had never seen them. And it is also probable that if passengers were to head their letters "S.S. Flea, at Sea," or with any of the other names mentioned, their friends at both ends of the line would fancy the Company had chartered a three hundred ton coaster for their own especial use, and for the sake of variety.

And thus it is all through the shipping world. A well-selected name wins admiration from the public, and the affection of officers and crews, whereas unsuitable ones do no good. Upon looking over the extensive list of P. and O. ships, and also those of other Indian lines, we find many handsome titles, the best of which are of three and four syllables. Such names, however, as "Rome," "Clyde," &c., cannot do justice to floating palaces. They are too short—they want massiveness—and are deficient in that euphony which is to be found in such words as "Golconda," "Massilia," "Navarino," &c.

The names of rivers, lakes, mountains, and cities, are very popular amongst shipowners, who generally give handsome appellations to their vessels, taken from the foreign countries to which they sail. This is only natural, because in a pleasant way it helps in some degree to win the kind consideration of the inhabitants of distant climes. Indeed, we may add that a gentleman who ran his ships to Bombay named them after Hindoo Rajahs, and so pleased were those personages with the graceful compliment, that they presented the enterprising owner with a handsome amount of rupees for every vessel thus designated.

The branch of literature just referred to may, perhaps, appear trivial to some people, but it is nevertheless of more importance than many would suppose, and of an antiquity considerably greater than that of the celebrated ship of Alexandria whose sign was "Castor and Pollux."

"House" flags form another good distinguishing mark. That of the Cunard line consists of a golden lion rampant, on a scarlet ground, carrying the world in his arms; and all the other Companies arrange their colours and devices to suit their own ideas.

Flags of this kind are not only very useful, but, if tastefully designed, highly ornamental appendages to a ship, and whilst in every case they should be as distinct as possible from all other flags of similar nature, they ought to be clearly legible at a distance. This is accomplished by means of striking contrasts in various ways, and when initial letters are used, by making them of large size and bright in colour, say red on a white ground, or white on a blue field. The latter being most expressive and tasteful when contrasted with each other, as in the simple and well-known "blue peter," or sailing signal. From sunrise to sunset these flags are carried at the main when a ship is in port, thus indicating at a glance the Company to which she belongs, and enabling people at a distance to find out the vessels they are in search of.

Amongst the most suitable and distinctive house flags are those of the Peninsular and Oriental and Anchor Companies. The former consists of red, blue, yellow, and white triangles, whose bases form the sides of the flag. The latter is simply a large red anchor on a white ground, which expressively tells its story. The Allan Company carry the red white and blue of France, under a red pennant. Floating at the stern of their ships, and without the pennant, this would signify French nationality, but when at the main it indicates the private colours of the firm. If, however, the foremasthead of an incoming or outgoing steamer is decorated with the same flag, or indeed with that of any other country, say the United States, Chili, or Brazil, it effectively announces that the ship is either arriving from or departing to a French, American, Chilian, or Brazilian port.

While admiring the good taste displayed in the selection of the Allan house flag, it is only natural to suppose that the originators of the line intended it as a delicate compliment to the French Canadians whom they hoped to receive as passengers; and this, like many other polite attentions in ordinary life, has, no doubt, in a pleasant way, done much more good all round than some would imagine.

Another very expressive distinguishing mark is the colour of the funnels, which are variously painted,—red, with black tops; black all over; cream coloured, as in the Navy; and in other ways too numerous to mention.

The rig is the last, and also the least important, because there is so little room for diversity, as a two-masted, three-masted, and four-masted brigantine are the styles generally adopted for large steamers. The Inman people, for very many years, appropriated the full ship rigged masts and spars, by means of which their vessels could be distinguished, even when the hulls were below the horizon. Now, however, they have taken the yards off the main and mizzen masts, because they are not required.

We admire the names "Rosalind," "Andromeda," and "Clytemnestra," given to our three ships now building, the first of which is, however, a compliment paid by the Chairman of the Company, not only to the original lady, but to his eldest daughter, who is also a "Rosalind," and the engaged queen of the launch. And now the day has arrived when the noble vessel is, in newspaper language, to "glide gracefully into her native element." The hour fixed for the event is twelve o'clock, that is to say, just a little before high water, because the steamer when launched will swing with the tide up the river, and thus avoid all vessels which are likely to be in the way lower down. About eleven o'clock the works are thrown open, and visitors begin to arrive, but during the whole morning the ship-building authorities have been completing their arrangements.

At 11–40, the representatives of the owners, the invited guests, and the members of the firm, are all assembled on a raised platform, which is placed at the bow. First and foremost among them, is the Chairman's daughter, who is to have the honour of naming the ship. What an elegant and charming young lady; so tastefully and simply attired, and all smiles and sweetness to those around her! Although the centre of observation, she nevertheless tries to look quite unconscious of the attention bestowed upon her, just as if a launch was a sort of everyday amusement. She has been taught to *think* a good deal, and to suppress every heartfelt or enthusiastic emotion. In spite of this, however, she is full of sympathy and good wishes towards the noble vessel which is very soon to bear her own name, and which will be a substantial addition to her father's splendid fleet.

The Bishops of Chester and Liverpool have been invited, and it is quite possible that if either or both of these gentlemen can get away for a short time they will favour the company with their presence, and derive much benefit by the change. Amongst the visitors are an admiral, two military officers, and numerous friends of the owners and builders, with their wives, sisters, cousins, and other ladies.

The partners of the firm are actively employed in bowing and smiling, smiling and bowing to every one, and making themselves generally useful and agreeable. Mr. Macdonald is there too as happy as a king; he has however to restrain his enthusiasm, in deference to the people he is among, but will make up for it afterwards. Mr. Bouverie is also there, with gloves on, and looking quite like a gentleman at large. His cares are lightened, and all responsibility for the present has ceased, as the sole management of affairs has been transferred to the shoulders of the shipbuilding manager, who will have to look out for squalls if the ship should stick on the ways, or topple over altogether.

Twice within my own knowledge have each of these disasters happened. When everyone thought that the "Great Eastern" was fairly off at the Isle of Dogs, she suddenly came to a standstill, owing to the enormous friction of the rough iron launching ways which were of novel construction, and her builders had to expend nearly £120,000 before she could be pushed into the water. The worry and anxiety thus brought upon the responsible people was very great, and it is said that Mr. Brunel's health was so much injured by the constant strain that he never recovered from its effects.

Many years after this event, the Brazilian ironclad "Independencia," stuck in a similar manner, near the same place, and it cost about £22,000 to get her off. In this case, however, the disaster was caused by the sinking of the foundations under such a tremendous load. Then again one of the great Galway liners fell over in a Birkenhead graving dock, and was so seriously damaged as to be of little use. And who does not remember the launch of the "Daphne," on the Clyde, and her sudden overturn, which caused the drowning of a large number of workmen.

Not one of these evils we have mentioned can happen to the "Rosalind," because she is built on rocky ground, and is well ballasted. The ship herself, taken as she is, looks well. Her lines are fine, and the model very pretty throughout. The stern is elliptical, and handsomely finished, and the bow is terminated with a beautiful figurehead, in white and gold, of Shakspeare's heroine.

The bottom of the vessel is painted a strong flesh colour, and her sides black, but, had she been an Indian troopship, they would have been painted white, because in a hot climate the heat is not absorbed so much by that tint. As great preparations for the launch have been made during the last two days, we shall briefly refer to a few of them in the next chapter.

CHAPTER XVII.

LAUNCHING A SHIP.

How it is done—Launches of H.M.S. "Black Prince" and S.S. "City of Rome"—Method of undocking a great Ironclad—Captain Henderson—The Captain in charge of a Launch—Launch of the "Rosalind"—Newspaper comments—Ship in Dock—Machinery on board ready for Trial—Starting the Engines.

A SHIP is usually built upon a piece of ground called a slip, which slopes towards the water, and which should have a very rigid foundation, not only to prevent any irregular strains upon a vessel while building, but also to insure her safety during the launch. The keel is supported upon a row of temporary blocks of large sized timber, placed about five feet or so apart, centre to centre, and wedged upon both sides, so that they can be easily removed from below when required.

Previous to a launch, the sliding ways, on which the ship will move when once started, are carefully prepared, and have an inclination given to them which ranges from about 1 in 12 to 1 in 24, the latter slope being more suitable for the largest vessels, as it will prevent them from acquiring too great a speed when entering the water. This, however, is largely regulated by the amount of water space available. To enable the ship to maintain her equilibrium while being launched, a strong frame or cradle of timber is built upon these "ways," and sufficiently wide to give the requisite steadiness, otherwise she might capsize. Guide pieces of timber are also securely fixed in such a position as will keep the cradle from moving from side to side.

As the whole weight of the ship rests upon the keel blocks during the time she is building, a system of wedging is employed, by means of which the vessel may be slightly lifted, and thus caused to rest upon the cradle alone; but if the blocks are capable of being easily lowered, this process is unnecessary. These sliding ways and cradles are completed a day or two before the launch is to take place; the ship, however, still rests upon the keel blocks, and is kept upright by props and shores.

Shortly before this, the sliding ways are rubbed over with hard tallow to stop the pores of the wood and give a smooth surface, which is afterwards well lubricated with soft soap. Just previous to the launch, the props which kept her steady while building are removed, so also are the keel blocks, now relieved of the ship's weight, the whole of which is therefore borne by the cradle and sliding ways. The former, however, is held in check by two dogshores, which are protected by triggers, otherwise the great event might come off prematurely.

When all is ready, the dogshores are released, and the ship is named as she glides into the water; but, if she will not go of her own accord, the action of screw-jacks or hydraulic presses will give her a start, and the force of gravity will do the rest. The reason she moves at all is that the launching ways have had given to them an inclination slightly in excess of the "angle of repose." Among the immense collections of memoranda possessed by engineers and shipbuilders are a few which have been based upon experiments made to ascertain the angle at which bodies of different kinds will slide—by gravity alone, under various circumstances,—upon each other, and also their frictional resistances; that is to say, iron upon iron or brass, smooth, dry, wet, or oiled; wood upon wood, and so on in great variety.

If you were, for example, to put a smooth block of ice upon a table, and tilt it gradually on one side, an inclination would soon be reached which would cause the ice to slide, but if this slope were slightly reduced the ice would stop. This is called the "angle of repose," which for obvious reasons varies greatly under different conditions. In launching a ship these conditions are, "smooth timber upon wood well lubricated." It is this, however, which guides the shipbuilder in the choice of inclination of the launching ways suitable for vessels of different sizes.

I have seen many a launch, big and little, but consider those of H.M.S. "Black Prince" from Napier's, and the S.S. "City of Rome" from the Barrow Works, as the two finest. I was also present at the launch of H.M.S. "Agincourt" from Laird's, but it was somewhat uninteresting when compared with the other two, as this enormous ship was built in a covered dock, and floated out at the last. The attendant circumstances, however, and the dinner in honour of the event in the evening, delighted us all. The gigantic hull of the "Rome" entered the water in magnificent style, so also did the "Black Prince," but the difficulty of getting the latter safely into the Clyde was very great.

In the first place, the river was so narrow at Govan, that a vessel, much less in length, could easily have blocked the passage broadside on.

Secondly, the "Black Prince" was very heavy, and in the last place, the ship, angled as she was on the sliding ways to get as much water space as possible, was cramped even in this respect, owing to a bend in the river, which could not be avoided. The result of these combined evils, was an elaborate and carefully calculated system of cables and checking gear, for the purpose of bringing the vessel well up after she entered the water, and to keep her from running into the opposite bank. The day was very wet, nevertheless many thousands of people went to see her off, and really nothing could have been more splendidly carried out than the launch of that magnificent ironclad.

The other system of "launching" referred to, is in reality only the simple process of undocking; the ship which is subjected to it, having been built under cover of a large roof. The shed thus formed contains all necessary appliances, including a powerful travelling crane, which sweeps the building longitudinally and transversely, and assists very materially in the construction of the vessel. By means of this arrangement, not only are the workmen protected from the weather at all times, but the engines, boilers, and all connections, can be fixed in position *before* launching, thus leaving as little as possible to be accomplished afterwards.

The dock in which the vessel is built is closed by a caisson having tapered ends, which fit watertight into grooves in the sides of the entrance. When everything is ready for launching, the sluice valves in the caisson are opened for the purpose of admitting water gradually, until the vessel is fairly afloat, and all the props which kept her steady while building have been removed.

The ship is allowed to rise with the tide until her keel will safely clear the dock sill. And after the caisson is floated out, the attendant steam tugs tow her to the fitting-up basin, where the masts are put in and the vessel completed in every respect. If we wished to know *approximately* the total weight of the vessel now before us—which for example, may be called the Italian ironclad "Italia"—the process would be a very simple one.

This ship—already mentioned—is 400 feet long, 74 feet broad, and the draught of water is 27 feet 6 inches. Her displacement at this depth amounts to 13,900 tons, and according to a well known law—which can easily be proved by experiment—is exactly equal to the total weight of the vessel as she now lies in the water.

Let us suppose, for the sake of simple illustration, that her hull has been built in the form of a rectangular water tank, having the same length, breadth, and draught as above, and is floating in sea water, 35 cubic feet of which weigh one ton; 36, however, being required for *fresh* water.

Then $400' \times 74' \times 27\frac{1}{2}' = 814{,}000$ cubic feet, which, if divided by 35, will give 23,257 tons.

This formula is beautifully simple for calculating the weight of all *floating* structures of rectangular form, but if the same information as to a ship were required beforehand, the weight of plating of every description, frames, deck beams, woodwork, engines, boilers, shafting, and everything throughout the vessel, would have to be ascertained, thus involving immense labour, and forming a very striking contrast to the simple process just mentioned. In addition to this, the shipbuilder has to perform many more calculations before he can ascertain the draught of water, the stability, and other important questions relating to the proposed ship he has in hand.

The "Italia's" hull is supposed to be of box form, for convenience, but we must now make allowance for its actual shape, and if the above mentioned 23,257 tons is multiplied by ·6 a constant varying slightly according to the shape of vessel, the product—13,954 tons—will approach very closely to the actual weight, or "displacement," as it is generally termed, already given.

This grand principle in hydrostatics, although applied chiefly to ships, is nevertheless frequently employed in other branches of engineering, and with the most advantageous results.

Besides the finishing touches which have been given to the outside of the hull of the "Rosalind," a large number of flags are most effectively displayed throughout the vessel, while two or more steam tugs, similarly ornamented, are lying in readiness in the river. There are also a few men on deck, who will be required to work her when afloat, and who are under the orders of a captain who directs their movements. Who that commander now is, I cannot tell, all I wish is, however, that it could be Captain Henderson.

There was in Laird's, in my time, a gentleman who was well known to all of us. He had spent some of his best years at sea, and was a good specimen of the ancient mariner—one of the old school of ship commanders who could "chew baccy," and swear, and scorned to wear gloves. He also seemed to have but little regard for the refinements of polite society, and in this respect presented a striking contrast to the aristocratic navigators of some of our modern mail steamers. The gentleman referred to, was Captain Henderson. The day before the launch of the "Agincourt" took place, he put his head inside of our office door and shouted out, "Now then, all you fellows! you're to come down to-morrow morning, and give us a hand to get the ship out of dock."

Everyone of us went of course at the hour named, but I rather think we were more ornamental than useful. The machinery was stopped, and a great number of people had assembled in the yard to witness the event. The captain was quite equal to the occasion, and I verily believe crowded into that one hour of active service the energy of a whole week of his past life upon the ocean. It would now be rather difficult to state, with any degree of accuracy, what he actually did on that eventful day, but I think I shall not be far wrong in saying, that he was *everywhere* on the deck of the great ironclad. One moment he would be at the after end, the next at the bow, and then amidships, putting one in mind of the Corsair, when he exclaimed :—

> " Who would not brave the battle fire—the wreck,
> To move the monarch of her peopled deck ? "

Captain Henderson was in his element while thus employed, and no doubt considered it a high honour to have the opportunity of shouting his commands to the right and to the left, about "hawsers," "bow ropes," and all the rest of them. His professional position in the Birkenhead Iron Works was that of superintendent of the riggers, and no one knew better how a ship's masts and yards ought to be stayed and braced than he did.

I regret to say, however, that my remarks only apply to one who will never again be associated with such animated scenes, as our good friend has long since departed this life. May he rest in peace !

It is impossible for me to describe, from actual knowledge, the characteristics of the present commander-in-chief of the "Rosalind's" launch, I must therefore imagine that the late captain is in charge of the vessel. There he is again as he used to be, high up at the extreme end of the quarter-deck next the river, and his figure standing out in bold relief against the sky.

The tide is just about full, and he is anxious to be off, but obstacles are in the way, vessels are coming and going, because this is the busy time for docking, etc., on the Mersey, and it would never do to run into any of them. There goes the African Royal Mail steamship "Teneriffe," outward bound to the West Coast, and here comes the Cunarder "Etruria," steaming up to her moorings off Rock Ferry, to be in readiness for Saturday's departure. Highly respectable people both of them are, dip your ensign to each, and be quick about it, as this is the first opportunity of doing so. Other vessels are paddling, screwing, and sailing about, much to the captain's annoyance. At last the course is free, the supreme moment has arrived, and the order is given :—

"Stand by! all clear below there?"

"Aye, aye, sir."

"Let go!"

"Hi! hi!! HOLD ON THERE! HOLD ON, WILL YE!! Drat it all, if there ain't a dirty little beast of a Runcorn flat just entering upon our course, whatever we do we must not run her down."

There she comes, crawling along at the rate of three miles an hour, and trying to beat out to sea against the tide, and with little wind.

The captain is wild, and waves his hat frantically, but she still carries on as if she had as much right to be there as anyone else. At last those on board recognise the gravity of the situation, and head for the opposite shore. When this is sufficiently done, the order is again given :—

"Now then! all clear below?"

"All clear, sir."

"LET GO!"

Word is passed to the bow, where all the visitors and officials are standing, the dogshore men are signalled to, the chairman's daughter is requested to dash the bottle of champagne,—which has been hanging by a silk ribbon,—against the bows, naming the ship the "Rosalind" at the same time, and immediately, a space which up to this moment measured 15½ inches, has become 16 inches, and is rapidly increasing in the accelerando style. Down goes the splendid vessel, amidst the cheers of the multitude, until her rudder touches the water, then the stern sinks deeply into it, and raises a large wave.

The bow next crashes through the floating timber of the cradle, the hull oscillates fore and aft for a minute or so, then steadies itself, and runs far out and up the river, as was intended. The tugs in the meantime are after her as fast as their wheels can drive them, and eventually capture the runaway, which they unitedly tow to the entrance of the fitting-up basin. The "Rosalind" is now warped in, and finally brought to rest under the great crane, where operations are at once begun for putting her engines and boilers on board.

While this movement has been going on, the guests and others, now assembled in the model-room, have been partaking of a handsome cold lunch, and inspecting, at the same time, the numerous and beautifully finished models of naval and mercantile ships built by the firm, and the paintings with which the walls are adorned. The visitors seem to be highly pleased with their morning's performance, and are delighted to learn something about ships and steamers they had not known before. The conversation is most animated. Everyone is charmed with everybody else, and soon afterwards the party breaks up and they all disperse.

The newspapers of the following day take care, while describing the event, to give as much information as possible. The chairman's daughter is complimented upon the elegantly successful manner in which she performed *her* part of the ceremony. The "graceful gliding of the ship into her native element" is commented upon. The number of ships built by the firm for the same owners; the number, tonnage, and horse power of all the vessels they have now in hand, are fully given. In short, everything is mentioned that may be interesting to the general reader, involving, perhaps, one or two technical errors, which the initiated smile at, and ordinary ladies and gentlemen cannot quite understand.

Having got the "Rosalind" safely into dock, the next thing to be done is to set a small army of workmen upon her. These consist of engineers and boiler-makers, shipwrights and riggers, carpenters and joiners; and, when the vessel is far enough advanced, plumbers, painters, upholsterers, and decorators will be added to the number. Everything is now being pushed forward with rapidity all over the ship until sufficiently near completion to enable the engines to be started. This is an indispensable operation, and forms a prelude to the official trial trip. Briefly described, it is as follows.

After the engines and boilers have been fixed in place, and all connections formed between them and the sides, bottom, and other parts of the ship; when the propeller with its line of shafting has been fitted, as well as all cooling and lubricating gear, and ladders, handrails, gratings, etc., are in position, steam is got up, and the machinery set in motion, the vessel having been previously secured fore and aft to the quay.

Upon rectifying all defects which may now appear, such as leaky piston and valve-rod stuffing boxes, and bearings which may require easing a little, the engines are allowed to run, in some cases for hours. During this preliminary trial, everything is carefully watched, both in the engine and boiler rooms, and all stiffness in the working parts, which is incidental to new machinery, gradually reduced. In course of time, a highly polished surface is given to the main bearings, and piston and other rods. The insides, also, of the steam cylinders, air and circulating pumps, etc., acquire a glassy surface, which is much desired, as it contributes greatly to the success of the trial and to their future working at sea.

With small engines, such as those for launches and torpedo boats, the speed of the working parts is so great as to prevent one from following their movements, but with great engines, such as those before us, the motion is comparatively slow, and you have time to look at and admire them; but whatever size the machinery may be, the operation we have mentioned has invariably to be performed.

CHAPTER XVIII.

SHIP AND ENGINES COMPLETED.

Vessel in the river—David Kirkaldy—Ferry passengers' remarks—General Survey of the Ship—Boiler Room and Appliances—Engine Room and Fittings—"Larboard" and "Port"—Pumping Machinery—Watertight Compartments—S.S. "Arizona" in Collision with an Iceberg—The Tunnel and contents—Materials used in Engines—View from Starting Platform—Different kinds of Engines—How controlled from Deck—Complicated modern Machinery—Economy in Working and Maintenance—"Crisp word of Command."

DURING the interval between the "start" and the official trial trip, everything throughout the vessel, fore and aft, below, and aloft, is being touched up here and titivated there. The painters, decorators, and upholsterers are in full swing; the grand-saloon begins to look noble; the masts and yards are all up, and the "Rosalind" is at last almost finished.

Another event in her early history has now arrived. The ship is in the river, just a little above the track of the Birkenhead boats, and is getting up steam previous to departure for the open sea, on her first run, which is to test the speed of the vessel, also the power and other qualities of the engines and boilers.

One evening, more than a quarter of a century ago, I paid a visit to the Glasgow Art Gallery, and after gazing at the pictures for some time, came at last to a place where an exquisitely beautiful drawing of the Cunard S.S. "Persia" was exhibited. As I stood admiring it, one of the visitors said politely to me, "Let me give you this hand-glass, and you will see it better."

"Thank you very much," I replied, and immediately added, "What a splendid drawing! so exquisitely shaded and coloured; so minute, and in so many views, too! What taste and patience the engineer who made it must have had!"

"Yes," observed the gentleman beside me, "although it is *my own production*, I must say it does look well."

Little did I think that my kind friend was Mr. David Kirkaldy, who at that period flourished in Robert Napier & Son's Lancefield works, while I at the same time was in the employ of Neilson & Co., at their adjacent Hyde Park Foundry, with only a brick wall between us. Since those days, however, Mr. Kirkaldy has acquired quite a world-wide reputation in an experimental branch of engineering he then practised very successfully at Messrs. Napier's.

I have mentioned my art gallery experience, because the idea it conveys may be utilised in similar cases. If, for example, the builders of a great ocean liner on the Mersey or the Clyde wish to learn what the public think of her, they could not do better than place the ship in a position where passengers on the river steamers can easily see her to advantage. After this is done, those gentlemen may cross as often as they please, and observe the remarks of people around them, which may be somewhat in the following style:—

"What a magnificent vessel!"

"Dear me! what power those funnels must have!"

"I do like that rig," observes a "White Star" or "Cunard" captain. Such a beautiful model, too; quite equal to any of ours. 'Pon my word, those people know how to build a ship!"

"Oh!' says one lady, "what a handsome bow!"

"What a lovely stern!" is the remark of another.

So on, and so on, in great variety. Many similar observations have I heard on board these old familiar ferryboats of the Mersey, and, indeed, have not been backward sometimes in contributing my own share. It will therefore be seen that ships so situated are exposed to an amount of criticism from all classes that might gratify, if it did not quite instruct, their builders who overheard the remarks.

But here comes the tender with the "select company" of visitors, who have been invited from Liverpool, London, and perhaps the Clyde. The representatives of the owners are among them, as also are those of the builders and engineers; some ladies may perhaps be added, and in a few minutes all are on board. It will be a little time before everything is quite ready; may I, therefore, ask you to accompany me on a tour of observation below, as this is the last opportunity I shall have of describing the mechanical interior of the ship. Let us begin at the boiler-room, in what is called the "stokehole."

This deserves our first attention, as it is the centre of that life-giving energy without which the machinery will be useless. The arrangement of the boilers varies greatly, according to circumstances. Sometimes they lie fore and aft, along the sides of a ship, and are fired in a transverse direction, but in large vessels they are generally placed transversely in rows of two or three each, and fired longitudinally, but whatever their position may be, economy of space is the first thing aimed at. There you see the furnaces giving out their fierce heat, which is immediately transmitted to the water covering them, and also to the numerous tubes, which give the name of "tubular" to all similar boilers. If steam has to be raised quickly, the furnace doors will be shut, and those of the ashpit opened, thereby causing a rush of cold air under the fire bars to assist combustion and cause intense heat. If the engines are at rest, and you wish to check the supply of steam, all that is necessary is to reverse the operation.

"Where is the forced draught part of the business?" do you ask? Well, we haven't it in *this* ship, whatever we may do in others. Some people seem to admire it, especially the inventors—others don't like it. For the present, at least, we shall be content with the natural draught arrangement you see before you.

The coal bunkers are furnished with sliding doors, through which the coal is taken when required, while the floor we stand on is of iron plates, on which the ashes are raked previous to being discharged overboard. This is accomplished by means of iron buckets, which are hoisted when filled by a little engine at the top of one of the ventilators you see overhead. When the water in the boilers becomes too salt, owing to the evaporation constantly going on when the ship is at sea, some of it is discharged through the "blow off" pipes to make room for a fresh supply. "Surface blow off" pipes are also provided for the purpose of clearing away any impurities that may float on the surface, and both of these most useful appendages deliver overboard.

The steam stop valves, with their connections for each boiler, are all overhead, and join into one large main, called the "main steam pipe," which conveys their united contents to the high pressure cylinder of the engines, but before the machinery can be fully started, the main stop valve, and also the throttle valve for regulating the supply of steam instantaneously, must be opened. In addition to the above, small auxiliary or "starting" valves are provided for convenience in handling the engines.

The safety valves are on the top of the boilers, and are of great value, as they allow the superfluous steam to escape through the waste steam pipe at the back of the funnel. They act much in the same way as volcanoes,—which by their eruptions prevent a whole country from being blown to pieces,—and thus the possibility of a disastrous explosion is at once averted.

There are other appliances and connections you will see around you, to which, however, we need not refer, beyond merely adding that they also are indispensable, and conduce greatly towards the safety of the boilers, and their economical working.

Besides the main boilers, there is a "donkey-boiler," of small size, which is used when in port to supply steam to the winches for unloading the cargo at each hatchway, and in addition to all these, are numerous ladders and gratings, fixed at different levels, and in the best position for getting up and down from the deck, and working at everything. Gear and tackle of every description for general use are also liberally provided.

Let us now take a turn in the engine room, and see what is to be seen there. As we have already described the engines in the erecting shop before being taken to pieces, it may only be mentioned that, as this lowest platform has no particular name, we may call it, for the sake of distinction, the "mezzanine floor," because it corresponds to the floor bearing the same title, which lies underneath the stage of a theatre, and also because all the pumps, crank shaft, and some of the valve and other gear, are here congregated. Before us, in the port forward corner, stands the donkey engine, whose position

Mr. Macdonald curiously altered on the plans. It looks right enough, but it would have been better if—well, well! as Lady Macbeth used to say, "What's done, cannot now be undone."

This useful little engine is named after the well-known animal, because it does so much slavish and dirty work, and is chiefly employed in feeding the boilers with sea water when the main engines are at rest. It also pumps from the bilge any water that may get there,—either through the ship leaking, or from any other cause,—and discharges it overboard. Another of its duties is to take water from the sea for washing down the ship, and deliver on deck through ordinary hose pipes. By means of "communication" boxes containing a number of valves, any of which can be opened or shut at pleasure, the donkey's sphere of action may be greatly enlarged.

Previous to the year 1845, the terms "larboard" and "starboard" were used on board a ship; now, however, the former is styled "port," because the similarity of the words was too great, and led to confusion, perhaps, at critical times. Since that date the altered phrase has been applied to the left-hand side of a ship when looking towards the bow.

In the event of a serious leak occurring, not only will the services of the donkey engine be utilised, but the circulating pumps for supplying the condenser with cooling water from the sea will be made to draw water from the bilge. Various other pumps throughout the ship can also be used for the same purpose, and thus an immense quantity of water can be thrown overboard in a short time.

Over our heads is the starting platform, which may be called the seat of government of the engine department, because every movement of the machinery is controlled from that commanding position. We shall be on it before we leave, so let us in the meantime go through the tunnel. At its very entrance is one of the watertight bulkhead doors of the ship, which are worked by screw gear from the main deck. This vessel is divided into numerous watertight compartments, for the purpose of localising any water that may enter during a collision, or otherwise, a plan which, we may say, has been the means of saving many ships from foundering, especially the "Arizona," when, steaming at 15 knots an hour, she ran into an iceberg some years ago. It may be added that the foundering of the magnificent Cunarder "Oregon" after collision with a ship—to this day unknown—was entirely due to the jamming of one of these bulkhead doors with a block of coal, which prevented it from being closed as the water rushed in.

The tunnel itself is strongly made of plating, and arched on the top, as all kinds of cargo will be placed over and around it, and is only wide enough and high enough to allow the engineers to walk up and down comfortably, and attend to the bearings of the screw shaft which runs through it.

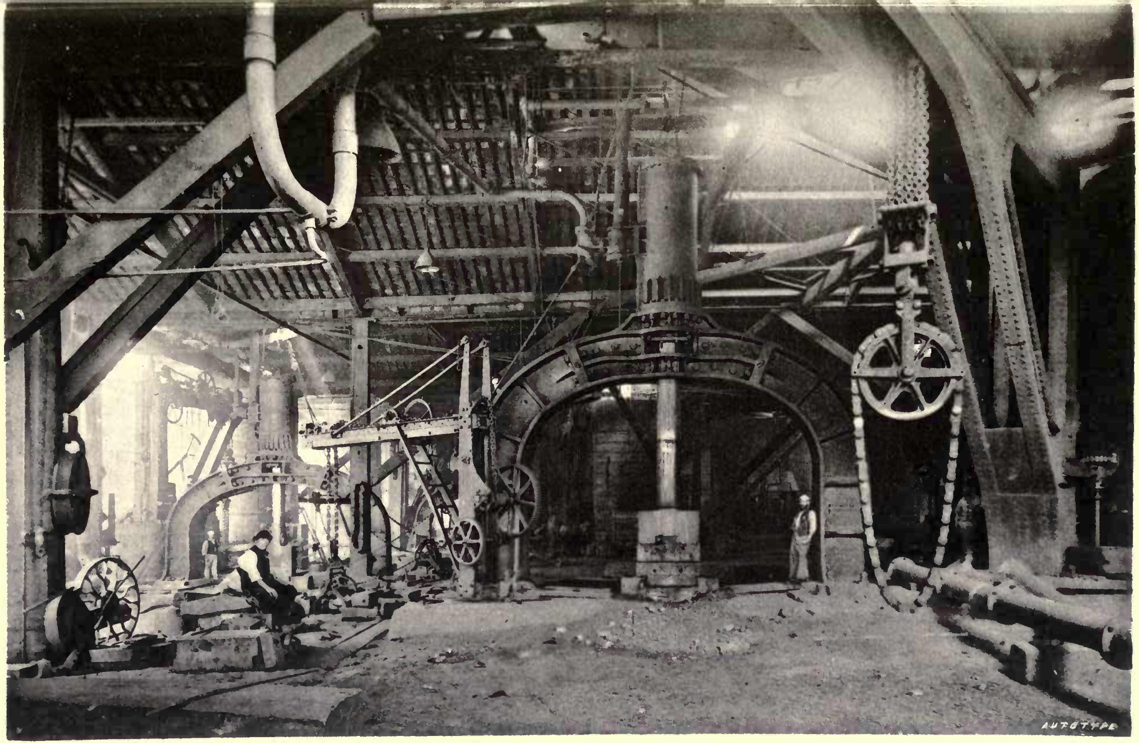
At the entrance to the tunnel lies the "thrust block," very securely fixed in position, as it will have to sustain the whole thrust of the propeller in driving the ship; and going aft, we pass several "plummer blocks," whose duty is to carry the shafting, which is bolted truly and rigidly together, in several lengths, by means of flange couplings formed on each. It is also rough turned all over, and painted white, except at the bearings, where a high finish is necessary. A line of copper pipes is carried near the roof of the tunnel and throughout its whole length, for the purpose of supplying water for cooling these bearings when heated.

Oil boxes are also provided for effectually lubricating all the working surfaces. The same system is applied to the crank shaft in the engine room, and it may here be observed that, without a very complete arrangement of lubricating gear connected with the whole of the machinery, it would very soon be cut up, and perhaps smashed to pieces, through extreme friction and the great heat caused thereby. It is only within a very recent period that the scientific laws which regulate perfect lubrication have been even partially comprehended, and, although the subject is too frequently treated in an empirical manner, it is now well known to engineers that a careful selection of lubricants, and their judicious application to machinery of all kinds, produces highly satisfactory results.

We are now at the end of the tunnel, and close to the last bulkhead in the ship; the shafting, however, is continued through it, and also through the stern post, outside of which the propeller you saw in the great lathe has found a resting place for the present. Between the screw and the bulkhead just named, the shaft is encased by what we call a "stern tube" of cast iron, which contains two most important bearings, the inner one being of brass, and the outer one of lignumvitæ. It was discovered many years ago that, when a steamer sailed in muddy water, the earthy matter contained in it quickly cut up the outside bearings of brass upon brass, as the shaft itself had "liners" of this material shrunk upon it. To remedy this defect, Mr. Penn experimented upon lignumvitæ similarly in contact with brass, and, as he found out that these materials could safely bear a working pressure of 2,000 pounds per square inch, when, at the same time, the two metals had their surfaces seriously abraded at 200 pounds per square inch, the wooden bearings have been used ever since.

Having gone as far as we can towards the stern, let us return to the engine room. I may now tell you that all the parts about these engines which could not possibly, or even economically, be made of wrought iron,—including the steam cylinders, condenser, framing, and a great variety of other gear,—are formed of cast iron, or cast steel, on account of the great suitability of these metals for work of this character. Those details, however, of a simple nature, which require great toughness and lightness, are made of wrought iron or steel, but all the internal working parts of pumps and valves, exposed to the corrosive action of water, must be of brass, gun metal, or phosphor bronze. Steam, and other pipes throughout the ship, are made of copper for lightness and convenience, but those directly in contact with bilge water in the bottom of the ship are of lead.

People in general imagine that brass and iron are somewhat uniform in quality; their variations, however, are so diversified that these materials require great circumspection and rigid testing on the part of engineers who turn out machinery of a high class. As the great forges occupy a very important position in the manufacture of every kind of heavy ship and engine work, part of which we have already seen, the annexed view of the interior of a portion of the Mersey Forge, Liverpool, will shew clearly the arrangement and system of working the powerful steam hammers and their connections. The view of the forging department at Messrs. Wigham Richard-



INTERIOR OF MERSEY FORGE, LIVERPOOL.

son & Co.'s Newcastle Works—introduced further on—will also prove interesting.

Let us now go up the ladder to the starting-platform, which, as you see, consists of an iron floor, having gratings of an open diamond pattern for the purpose of admitting light to the lower regions. There is Mr. Bouverie examining everything carefully, trying this, and inspecting that, and Mr. Macdonald is looking on. "Off at last?" "Oh no! we are not off yet, thank you; they are only warming the engines previous to our departure."

When steam comes into contact with cold iron, as the cylinders now are, it becomes condensed, and the water which is formed has to be drained off, otherwise internal accidents would arise, as the pistons have very little clearance at top and bottom of stroke, and might thus strike with great force an incompressible fluid. When the cylinders, however, become hot enough, full steam may be admitted with safety, and the ship started on her voyage. As all the hands are busy above and below, the sooner we go on deck the better. A hasty glance, therefore, at what we can easily see, will be quite sufficient for our purpose.

The view from this position is considered very interesting, as we have before us the handsome valve gear, including quadrants, eccentric rods, starting wheel, and small engine for working the gear; also numerous levers, rods, and a great deal of other beautiful work. This type of engine is the extremely popular and practically useful "inverted cylinder direct action" species, but there is one thing I don't like about them.

"Now then, haven't you got these bolts screwed up yet?" Mr. Bouverie shouts to some of the hands on the mezzanine floor.

"Very nearly finished, sir."

"I wish you would be quick about it."

As I said just now, there is one thing I do not like about these most admirable engines, and that is, they have very little to shew when gazed at from the deck, as the cylinders on the top shut out everything from view, and obstruct the light very much for those below; but we cannot have all we wish, and this is only one example out of multitudes, where a great benefit is obtained at the expense of perhaps several minor advantages. The practice of an engineer abounds with similar instances, and the highest skill and judgment are often displayed in the selection of what is really best, out of much that only appears so.

Horizontal engines can easily be seen from the deck, and they also admit of a very light and spacious engine room, but nothing in this respect could have equalled Tod & Macgregor's steeple engines, such as those of the P. and O. S.S. "Simla," a handsome three inch scale model of which stood for many years in the Crystal Palace. This machinery was completely under view from the deck downwards, from which point you could take in the whole of it at a glance, including highly finished piston and connecting rods, crossheads, cranks, shafts, and all other gear, right to the bottom of the ship.

For screw propulsion, however, nothing can be better than these engines of the "Rosalind," on account of the practical and important advantages they possess. Powerful as they are, the whole of the machinery is entirely and instantaneously under control from this platform, as every improved invention that science could devise has been utilised for the purpose. The officers on the bridge, for example, telegraph their orders direct to the engine room, and these requests are musically recorded on that apparatus before you, which by the striking of a gong, supplemented by index pointers, tells the engineers in charge to "stop," "stand by," and "go ahead," or "go astern," "slow," "half speed," "three-quarter speed," or "full speed," as required. Such an arrangement, we need hardly say, is in times of danger of the most vital importance.

Overhead is a very compact travelling crane, for lifting the cylinder covers and pistons, or anything else not too heavy, and conspicuously fastened to one of the bulkheads you will observe a handsome brass plate, backed with teak, which in Egyptian block letters informs all who look at it, that the engines were made,—let us suppose,—by "Laird Brothers, Birkenhead Iron Works, 1889," and that their "number" is 810. This statement also conveys as true an idea of the excellence of the machinery as "Collard and Collard" does on a grand piano, or Noel Paton's signature on a picture.

"What is all this wonderful and complicated mechanism for?" do you ask?

Let me tell you.

In days of yore, marine engines were much more simply designed than they are now. They were, however, very inefficient, and also expensive in maintenance. In other words, they were not economical in fuel consumption, and this induced engineers to consider some improved method of construction, and very many advantageous modifications were the result. The surface condenser took the place of the jet condenser. High pressure steam superseded low pressure steam. The old fashioned box boilers were exchanged for those of cylindrical form, and a host of minor alterations were made from time to time, which unitedly and extensively increased the complications of this most important class of machinery.

The principle adopted by shipowners was this. If you find that £100 per annum can be obtained by investing £1,000 in engines, and also discover that £300 may be safely made in the same time by increasing your outlay to £2,000, then by all means expend the last named sum. The secret, the mainspring, we might say, of all these modern complications is *economy*, or saving in coal, in management, in maintenance. I hope you will therefore not be surprised to hear that all this costly machinery I have had the pleasure of explaining to you is for no other purpose than that of turning a shaft with a screw at the end of it, in the least expensive manner.

There are wonderfully simple steam and electric engines for yachts, and others driven by gas, water, and compressed air, etc., for land purposes, with extremely few parts, but such an arrangement cannot possibly exist in the machinery before us.

"Is that circulating pump Kingston valve open?" Mr. Bouverie now asks.

"No, sir."

"Well, then, open it!"

"Rather a blunt man," did you say? Just wait till you know him, and you will change your opinion. He is going to a dinner party this evening, and, if you were there, you would find him one of the most accomplished gentlemen, in every sense of the word, you ever met. If any one remarked—

"I hear you had a very successful trial trip to-day, Mr. Bouverie," his reply would be—

"Yes, we have every reason to be satisfied with the 'Rosalind's' performance," and then—delicately avoiding all professional talk—he would drift away into an animated discussion about astronomy, vulcanology, music, the fine arts, or any other kindred subject, to the delight of everyone,—so happy is his manner, so brilliant his conversation. When you join the ladies in the drawing-room, you will hear one of them remark—

"What a charming man Mr. Bouverie is!" another—

"How refined and intelligent!"

"Yes," adds Lady Bareacres, "and how modest and unassuming, too!"

This gentleman's style of speech in the engine-room—that of the Captain when on duty—and similarly, of all officers in the Army, Navy, and Mercantile Marine, is simply what Mark Twain used to delight in so much when among the Mississippi pilots, and which he termed the "*crisp word of command*." No one is offended, or has his feelings hurt by such plain language, and a great deal of time, and probable danger, are saved by its use.

Just fancy what we should come to, if those gentlemen blandly observed, "I am very sorry to trouble you, but would you mind porting the helm a little?" or,—"I shall esteem it a favour if you would stop the engines," or,—with a squall coming down on the ship,—"I'll be obliged to you if you would kindly let go all sail."

If this state of things unfortunately existed, we should soon hear of a Cunarder being lost because the captain was so polite to his officers and men when on duty, or a magnificent clipper thrown on her beam-ends because the sails could not be taken in before the blast was upon them. The Roman centurion set a good example when he said "Go!" "Come!" and "Do this!" and we who follow in his footsteps, by adopting his style of language, are saved from much tribulation.

CHAPTER XIX.

SHIP'S APPLIANCES—TRIAL TRIP.

Steering Gear in small and large ships—Control of ship from bridge—The "Quartermaster"—Clyde and Thames boats—Steam winches—Steam windlass—View of ship from bow—Official Trial Trip—Duties of Staff in Engine and Boiler rooms—Scene in Grand Saloon—"Running the Mile"—"Indicated Horse Power"—Successful Trial—Unsatisfactory Trial Trips—Flag Signalling in the Navy and Merchant Service—Cunard and other Atlantic Captains and officers—Sea-going Engineers—Description of the "Rosalind" just before sailing—Her departure on First Voyage—Farewells.

THEY are all busy getting ready for a start, and here come Mr. Macdonald, and Mr. Cameron, the "Rosalind's" chief engineer, so we may now go upstairs by this main entrance ladder. As we mount the steps you will have a fine view of the cylinder covers, tail rods, escape valves, hand railing and other small gear, but that is very little indeed compared with what is underneath them, which we have already seen so much of.

I may mention that this ship, like others of her class, has her steering apparatus worked by machinery, and this I will shew you. In little coasters, the ancient "tiller" is quite sufficient for steering purposes; larger vessels, however, require to use the "wheel," which is much more powerful; but modern monsters need some superior agency, on account of the tremendous strain thrown upon the rudder, especially in bad weather. It has, therefore, become necessary to introduce steam, or hydraulic power, for the purpose of overcoming such a force, and in our case, the result has been the installation of these pretty little engines just in front of us, which perform all the work, and leave the steersmen nothing to do but turn the wheels.

There is no such thing known now-a-days, in a great liner, as the captain shouting to the men at the wheel, "starboard," or "port your helm," since everything that relates to the guidance of a ship is done systematically, silently, and instantaneously from the bridge amidships, and this is how it is accomplished.

The commanding officer, in that post of honour, by night or by day, is keeping a good look out ahead, so also are two men at the extreme end next the bow. If, say in a pitch dark night, the vessel is steaming 17 knots an hour, and comes suddenly upon an iceberg, or another ship whose lights could not be seen, the forward look-out reports at once to the bridge, when the officer in charge, standing perhaps between the engine and compass telegraphs, signals with one hand to the engineers to "stop," and then "go astern full speed," and with the other, orders those in the wheel-house to put the helm "hard-a-port," or "hard-a-starboard," as the case may require, and all danger is averted.

A relative of mine was on one occasion coming into Liverpool by steamer, and when off the Welsh coast encountered a gale of wind and dense fog. The ship got out of her course somehow, and those in charge suddenly discovered that she was running straight upon a precipitous wall of rock. Not a moment was to be lost; bang went the helm hard over, and as her head swung round the spray from the rocks fell on the quarter-deck, and the vessel was saved by a hair's breadth. Under, we believe, somewhat similar circumstances, and at about the same place, the S.S. "Dalmatian" was lost a few years ago, but not one escaped to tell the tale.

In the handsome and admirably arranged steering department of an ocean liner, the quartermaster stands in front of the wheel, with the helmsmen on each side, and a telegraph apparatus before him, similar to one of those on the bridge, and fitted with a gong, and pointer which indicates on a dial plate, "course," "steady," "port," and "hard-a-port," and also "starboard," and "hard-a-starboard." If, then, in the event of threatened danger such as we have mentioned, or indeed at any other time, the officer on the bridge wishes the course of the ship altered, he simply transmits his order direct to the wheel-house official, who instantly acts upon it. These arrangements will clearly shew that modern steam vessels, even of the largest size, are at all times under the most complete, and we might say instantaneous, control.

Steering gear, however perfect it may be, is occasionally liable to derangement in stormy weather, either through the fracture of a steering chain, or through a break-down of the steam machinery. Either of these disasters will cause the rudder and quadrant tiller to sway about in a dangerous manner, and any attempt to connect the hand gear at such a critical moment may create another break-down, and render the ship helpless.

To prevent the possibility of such an evil occurring, Messrs. John Hastie & Co., of Greenock, have fitted the steamers of some of the principal ocean lines with a very simple and efficient "safety rudder brake," of their own design, the object of which is to control, at a moment's notice, the action of a rudder when the steering gear is disabled, and hold it in check until the necessary disconnection is made, or repairs are effected.

In small coasting steamers the wheel is generally on the bridge, and the captain is therefore his own quarter-master; but, on the old Clyde boats, the commander, by means of a sliding rod, hammers his orders smartly on the roof of the engine-room to those below, in the *one*, *two*, *three* style, and takes the helmsman under his own immediate care. On the Thames, however, the captain of a little river steamer has a small boy for his lieutenant, whose duty is to stand at the open skylight, and shout to the driver of the machinery the well-known words, "easa, tobacca, stop-a-a," which appear to be quite sufficient for the purpose.

If we now go towards the bow, you will see, at the after and forward hatches, those most useful little engines called steam winches, by means of which the ship is loaded and unloaded with wonderful rapidity, but, like many little people we meet in life, they make a great clattering in the performance of their duties. In high class steamers it is a pity that so much noise, and dirt, and objectionable steam should thus be created. The use of grooved frictional gearing—such as they have in a few vessels—would much reduce the noise, but the wheels are apt to slip when wet, or when lifting heavy loads. Hydraulic apparatus is the best, but it is not always convenient. Taking one thing with another, therefore, we are generally compelled to adopt the present system of hoisting and lowering cargo; but, at the Royal Albert, and other new docks, hydraulic wharf cranes are employed which perform all that is required in a beautifully simple and expeditious manner.

The last portion of the "Rosalind's" mechanical appliances I shall have the pleasure of shewing you is the steam windlass and capstan, which simply run the anchor in by means of the powerful engines in front of us. They are doing so now, and if we go to the bow, you will see it arrive, with a piece of Mersey mud attached to one of its flukes. The roaring of the steam through the waste steam pipes is gradually subsiding, and we are off at last. From this elevated position we have a splendid bird's-eye view of the vessel, which will be still more beautiful when under full sail; at present, however, we have before us the masts, spars, the whole of the rigging, and the two black funnels smoking away, the bridge, with the officers and pilot on it, in short, everything great and small that constitutes a well-found and highly finished ocean liner.

The docks are passed, one after the other, as also is the Rock lighthouse. Under easy steam we reach the bar, and then putting on full speed, a course is taken which will include a run of twenty miles or so down the coast.

While all this is going on, the utmost attention is being paid to everything in the engine and boiler departments. The furnaces are carefully fired, and steam pressures noted, all the bearings are watched, well lubricated, and cooled if necessary. "Indicator cards" are taken, which record the highest, intermediate, and lowest pressures of steam in the cylinders, and vacuum in condenser, the number of revolutions of the engines per minute is also carefully observed, and from all these, the indicated horse-power is calculated. The speed of the ship is registered from time to time, in short, there is nothing that great experience can suggest or avoid, which is not acted upon so as to insure a successful official trial trip. The vacuum will be about "26 *inches of mercury*," which is equal to thirteen pounds pressure on piston. May we ask why such a misleading term is still in use, when we only wish to know the *pressure*. To tell anyone that this is equal to so many inches of mercury, is worse than giving a price per ton when the cost per hundred-weight is desired, and, therefore, a real improvement may here be easily introduced.

Mr. Bouverie, Mr. Macdonald, and Mr. Cameron are *everywhere*, but neither the superintending engineer for the owners, nor his lieutenant, will give any word of command, as it would not be etiquette to do so. The ship is still in the hands of the builders; the others are merely visitors, though, of course, interested ones. At the same time, however, Mr. Bouverie will not neglect any little mild proposal in the "Don't you think?" style the superintendent or his "chief" may make. He must be more than mortal if he did so, and we may also add that one of the characteristics of an accomplished engineer, is that he will never despise good professional advice, no matter how humble the person may be who gives it.

There is another scene of activity to which I must refer, and that is the grand saloon amidships, where the upper ten of the ship's company, and also the visitors, are now having lunch. This most handsome apartment is in the very waist of the vessel, where pitching motion is least felt, where the greatest breadth exists, and where everything that can minister to the comfort and luxury of the future passengers is utilised to the utmost. The saloon extends the full width of the ship, and is amply lighted and ventilated by the spacious side ports and skylight, and also in the evening with electric lamps. At one end stands a piano, and, at the other, a handsome library. In some liners, however, a separate and most elegantly decorated "music-room" is provided. In addition to this, the ladies have their own boudoir, and the gentlemen a smoking-room. A modern steamship thus becomes a floating hotel, and, on a long voyage, such as to Valparaiso or Melbourne, presents a very striking contrast indeed to sailing ships.

If you could now take a glance at the "Rosalind's" saloon, you would have before you a scene where happiness, and good humour prevailed. The representatives of the owners are very glad to find the ship all they wished. Mr. Macdonald is brim full of enjoyment, because he has in his own way helped to bring this about. The builders and engineers are serenely contented with the performance of the vessel, because it proves that all their calculations regarding her speed, power of engines, size of boilers, and diameter and pitch of propeller have been correct.

The ladies must, however, excuse me for not mentioning them sooner. This I regret, but the truth is that, although first in social rank, they are last in *official* position; but if we had been out in any other way, or in any other steamer, they would most certainly have had the preference. Our fair companions are delighted with everything and everybody, and after a few speeches have been made, somewhat in the mutual laudation style, the company separate, and preparations are made for running the "measured mile."

Two tall posts, exactly this distance apart, are permanently fixed on the beach in a suitable locality, and some distance inland other two are placed at right angles to a line drawn between the first two posts. Now, if those on the deck of a ship running the mile note the exact moment the first pair are in line, and drive the vessel to her utmost until the next pair are similarly sighted, they will then know, from the time occupied in doing so, and with the help of a little calculation, what her speed has been. This, however, is not enough, because they may have been going either with or against the wind or tide, and with only one run a false impression would have arisen. To prevent the possibility of such an error, several trips are taken each way, the *mean* of which gives the true result, and thus the official trial is declared satisfactory or otherwise.

The Clyde is a favoured place for trial trips, as they are generally made between the Cloch and Cumbrae lighthouses,—a distance of sixteen miles,—which gives a more correct idea of a ship's capabilities than the forced run of one mile on the Gareloch.

What the stethoscope is to the physician, so is the "indicator" to the engineer, as this most useful instrument enables those in charge of engines to ascertain with considerable accuracy what is going on inside, that is to say, what the varying pressure of steam in the cylinders amounts to in pounds per square inch at each part of the piston's stroke, and whether the slide or other valves are efficiently working. The vacuum in the condenser is also faithfully recorded, and thus full information is given on vital points which could not otherwise be obtained, and the method adopted to accomplish this consists simply in attaching a piece of paper or "card" to the indicator in such a way as to enable it to trace a curvilinear diagram upon it. By means of ordinates drawn across this diagram, which are measured by scale and taken in connection with other particulars already mentioned, the indicated horse power of each engine is ascertained.

And now, the "Rosalind's" official trial is over. The indicator diagrams are all that could be desired, and declare a total horse power of 6,441, whereas the contract only allowed for 6,000. On the other hand, the average result of several runs gives a speed of 17 knots, instead of 16½, as originally specified. Those concerned may therefore congratulate themselves upon having obtained such very satisfactory results. All that now remains to be done is to head for the anchorage, and, if the river is clear of ships, won't they just enter the port of Liverpool for the first time in grand style, as Laird's Peruvian iron-clad "Huascar" did when her trial was over; and, upon my word! won't the visitors at New Brighton make a rush to the end of the pier to see her come in, and comment upon and admire the magnificent vessel which is now passing them. I well know how the thing is done, and can almost fancy I have the scene before me.

The moorings are reached; the temporarily cat-headed anchor is down again deep in Mersey mud; the "select party" are landed in the tender, and everyone goes home delighted with the day's proceedings.

Trial trips are not always successful; indeed some have led to expensive litigation, and others to great disappointment. That of H.M.S. "Iris" was of the latter description, since they could only get a 16½ knot speed at first, but, after giving her new propellers two feet less in diameter, and two feet more in pitch, the desired velocity of 18½ was obtained, with almost exactly the same engine power.

When I was on the staff in Tod and McGregor's we built a fine little twin-screw steamer for Dr. Livingstone's use, named the "Lady Nyassa," but, when she started on her first trip down the river, it was discovered that, although the engines were all right, the vessel would not go at the proper speed. This was very annoying and inexplicable,—the first mistake apparently of the kind the firm had ever made. Upon returning however, a careful examination of her hull in dock disclosed the fact that one of the launching ways had stuck to her bottom. When this was removed the ship did all that was required, and the speed contracted for was realised.

The admiral of a fleet has now such an effective system of signalling as would enable him to convey his innumerable commands to the other ships of his squadron with almost mathematical exactness. The signal-staff on board the flagship consists of about twenty persons, divided into three watches, who keep a vigilant look-out, by night and by day, on every vessel in the squadron. On being commissioned, every ship is provided with a "General Signal Book," "Vocabulary Book," and a "Semaphore." For use at night, a flashing lamp, and an electric apparatus, are supplied; and by an ingenious arrangement any of the signals contained in the books can be made during foggy weather by means of a steam whistle or foghorn.

The instructions contained in the General Signal Book are varied and comprehensive, and contain upwards of a thousand separate signals, adapted to every probable change of circumstances in times of peace or war. The Vocabulary Signal Book is a sort of dictionary, and contains signals of a more homely and social character, such as "Admiral intends," "Admiral desires," and also the happy announcement, "Admiral requests the pleasure of your company to dinner."

This system so nearly approaches perfection that the Board of Trade have adopted it as a basis for the International code of signals, which is now used by nearly all the maritime countries of the world, so that ships of every nation may easily converse with each other on the open sea, and at long distances. For general purposes, eighteen flags and a copy of the Code are required, and the combinations which are possible with these flags amount to the extraordinary number of 78,642, using two, three, and four flags at one hoist. We remember the time when the captain of one ship, wishing to "speak" to another, ran his own vessel close up to the stranger, and then, holding on to the lee or weather rigging with one hand, and supporting the "trumpet" with the other, bellowed forth the questions, "Where from?" and "Where bound to?" "What latitude and longitude?" and perhaps the awful statement, "We are starving; send—beef, and—biscuits."

The latitude and longitude were given in great chalk figures on a black board, but the other questions and answers were very indistinctly heard in many instances. On the voyage home we spoke several ships in this manner. One magnificent, calm, moonlight night in the tropics, a vessel was sighted all at once on our starboard bow, which, curiously enough, no one saw at sunset just a short time before. Our captain shouted out, among other things, "Send a boat," but the visitor, who had backed her sails for the time, immediately braced her yards round, and was off again.

The signal system we have briefly described has abolished this most inefficient arrangement, and the necessity of doing so will be at once apparent, when two ships running in opposite directions at twenty miles an hour, may sight each other three miles off, and perhaps collide in four and a half minutes.

The bunting of which flags are made is of the best wool, and although flimsy looking and open in texture to offer as little resistance to the wind as possible, it is nevertheless tough and strong. An ensign may not quite withstand the breezes of a thousand years, but it is amply capable of long and trying service. With the price of the material at 8d. a yard, 18 inches wide, an English flag, of the best quality, 12 feet by 6 feet, will cost about 14s., and a blue peter, 7 feet by 5 feet, about 5s. 9d.

The Cunard captains have been so long before the world, that their names have almost become household words on both sides of the Atlantic, and this is not to be wondered at when we consider the immense number of passengers who have sailed with them during a long series of years. There have been numerous portraits from pen and pencil, of well-known commanders in various Atlantic Companies, a few of whom may here be referred to. It is by no means unusual for intending passengers to call at the Cunard office and ask, "What captain sails on Tuesday?"

"Captain Blanque, ma'am."

"What! that horrid man? Catch me sail with *him* again!"

"Who leaves on Saturday?"

"Captain Dashe."

"Ah! he's a nice fellow; I'll wait, and go in his ship."

There are natural reasons for this. The Atlantic commanders are not all alike in social qualities. Some are reserved and blunt, or, at least, have been; while a few, in various ways, combine the art of pleasing with the highest professional attainments. Perhaps the most celebrated of them all, at one time, was Captain Judkins, who, although highly esteemed by the Company, was not admired by passengers in general, because he possessed an amount of bluff straightforwardness which his profound knowledge of ocean navigation does not appear to have subdued. Many stories are told of him in illustration of this, including the following.

On one occasion, the "Scotia" was carrying on full speed, tearing through and over everything on her way to New York, in a mist. The commander was leaning over the side, anxiously looking out for the banks of Newfoundland, when a lady ventured to say to him—

"Oh! captain, do tell me, is it *always* as foggy and nasty at this place?"

"How the devil do I know, madam? I don't live here!" was the disappointing answer.

Captain McMickan, of the "Umbria," or the "social captain," as he is called, is a great favourite, because he is brimful of stories of the ocean, tales of the sea—of fire and flood—of storm and tempest, on the element which through life-long associations has become almost a part of himself. The "Umbria's" chief may at times be found with some of the passengers in his private saloon, for whose benefit he fires off enthusiastically some of the aforesaid tales, and if anything can exceed his delight in doing so, it is the pleasure of listening to the general conversation of those around him.

The commanders and officers of the ships of the different Companies are variously gifted, and esteemed by those who sail with them in a greater or lesser degree, according to circumstances; but whatever their social qualities may be, their professional attainments are of such a high order as to command universal admiration and confidence. There are people of both sexes constantly travelling by these liners who no doubt sometimes expect too much from those occupying such important official positions. A little consideration, however, will shew the true state of affairs.

In the first place, these modern floating palaces cost, say, from £200,000 to £350,000 for hull and machinery alone; they are driven across the great highway between two worlds at a speed of eighteen to about twenty-one miles an hour, through storm and fog, iceberg and ice-field, and occasionally run the risk of annihilating some vessel, as the "Oregon" did. What with the ship herself, her cargo, and crowds of passengers, the prestige of the Company, and his own reputation as a skilful navigator, the captain of a great ocean liner has immense responsibilities, and, when on active duty, has his mind so intensely preoccupied that he is seldom inclined to be disturbed in his thoughts, and this, we fancy, is the chief reason why some commanders are so unsocial, and perhaps at times discourteous, when they are expected to be otherwise. The junior officers have their own share of responsibility, and if they, too, did not exercise sound judgment and extreme carefulness when on duty, we should hear of many appalling calamities on the Atlantic station, for the reasons just given.

The engineers, whose efforts greatly conduce to the successful working of steamships, much resemble—in mind and manner—the navigating officers with whom they are so closely allied. As a class they are extremely varied. Some are highly accomplished—others not so. Some are most courteous and affable—others the reverse, which, however, may occasionally be owing to some annoyance hanging on their minds that cannot easily be dispelled. And while many of them are students of general literature, there are a few who would hardly read a gift book of any kind. In short, there is to be found amongst those who direct the steam department of ocean liners, an extremely diversified set of men, whose constant aim is to perform their duties faultlessly and happily. Those duties are responsible and arduous. When a ship is at sea, the whole of the management of the steam department, for weal or for woe, devolves upon the engine room staff, and when the vessel comes off a voyage, the engines, boilers, driving gear of all kinds, and connections throughout the ship, are carefully examined and put in the best condition for continuous working during the next trip.

Socially speaking, the gentlemen I am referring to possess a marked and very creditable peculiarity of their own. They frankly say what they mean, and mean what they say, without any of the sophistry so frequently to be found amongst those in other pursuits. I have, however, been much disappointed with many of them—pleasantly so, it may be added. This book was originally written with the object of benefiting all classes *on shore*, and as I did not then think that sea-going engineers read much of a non-technical character, I naturally concluded that my treatise would not quite suit them. I have since discovered, however, that none could have appreciated its contents more fully than they did, as I have had very many opportunities of knowing. For this I sincerely thank them, and hope that the present edition will prove still more acceptable to my professional brethren at home and abroad, who run their ships across the seas, and throughout the world.

When you wish to see a mail steamer to perfection, never unconsciously hurt the feelings of your engineering friends by asking them to take you over one of their pets whilst in a state of semi-undress. That is, when the carpets are up, the handsome cushions turned over, the berths dishevelled, and everything in disorder. We all like to put our best feet foremost, and would never permit anyone to form erroneous opinions of our floating beauties if we can in any way avoid it.

If you will therefore allow me the honour of being your conductor, I shall endeavour to show you a splendid ship in full costume, and just on the point of sailing. Before this can be done, however, we must obtain a card from the office of the Company for permission to go on board the S.S. "Rosalind" which is again in the river, but on this occasion with a full cargo, which has sunk her quite deep enough in the water to give her a good appearance. The card which is kindly given to us, states that "Mr. Dashe and party of three, are to go out with the Tender which leaves the landing stage at noon with the first class passengers and mails, and receive the usual courtesies from the officer in charge."

Upon reaching the "Satellite" steamer, we find ourselves amongst many people of various nationalities, the letter bags, and heaps of passengers' luggage. There lies our vessel, a thing of beauty, fresh and clean from stem to stern. The steam is again blowing off at the funnels, the blue peter is flying at the fore, the house flag from the main, the "Royal Mail" flag—red letters on a white ground—at the mizzen, and the ensign floats gracefully over the stern; but here we must disclose the name of her owners, and also her destination, which have hitherto been kept secret, but not for State reasons.

From the character of the Cunard Company's latest acquisitions in the mercantile marine, it is very evident that the "Rosalind" will not suit them, because nothing under 10,000 tons and 20,000 horse power now appears to be acceptable. Our new ship will certainly not do at all for the White Star people, because their own vessels are so exactly suited to their requirements that it would be almost impossible to induce them to try any others, unless, indeed, of the most gigantic size.

In the next place, the National Company would not have her at any price, because their's are all Atlantic liners, whereas the "Rosalind" would do better as a Pacific cruiser, or an Australian mail steamer. She might, however, with considerable internal alterations, be greatly prized by the public if handed over to the Inman and International Company, but even in this case, she would be much too small for them. The Orient people would be delighted to have her, and we are sure of this on account of our intimate acquaintance with many of their present ships in past years. The owners of them, however, are located in London, whereas those of the "Rosalind" are in Liverpool.

After she has got her name "well up" on the ocean, I fancy Messrs. F. Green & Co., or Anderson, Anderson & Co., will carefully consider her capabilities, and ultimately make her their own, for the purpose of running the letter bags to Melbourne and Sydney. For the present, however, we have much pleasure in handing the ship over to the Pacific Steam Navigation Company—whose initials you will find in each of the four corners of her house flag—and start her at once for Valparaiso. It is most probable that some handsome Chilian or Peruvian name has been given to her in place of the one she has hitherto possessed, but to me she has been, and ever will be, the "Rosalind."

After walking the plank—or rather the gangway—we find ourselves on deck surrounded by numerous passengers who have previously arrived. The Company's representatives are on board, and so also is Mr. Macdonald, who is busily engaged looking after things in the engine department—where Mr. Cameron is now the presiding deity—and all the rest of the staff are at their posts. The captain and officers of the ship are also at their's, and the pilot is amongst them for the purpose of taking her to Bordeaux, and returning, as usual, with the owners' next inward bound steamer.

We gaze admiringly at the deck, so beautifully clean and white—at the steam winches now so silent—at the boats and their attachments—and mentally note the exquisite order which prevails around us, as well as in all the gear and tackle above us. After looking at everything and everybody in the upper regions, we descend to the saloon, which is in a state of bustle and excitement. Friends and relations are saying their last few words to those now on the verge of an 8,795 mile voyage. Hat boxes and band boxes, sticks, umbrellas and parasols bundled up together, along with cloaks, shawls, and mantles, and heterogeneous collections of small gear, are lying on the tables, on the floor, on the seats, and in the sleeping berths.

What a spacious, elegantly decorated, and luxuriously furnished saloon this is to be sure! And how charmingly the carpets, the floors, the walls, and the ceilings, harmonize with each other.

"Lovely, is'nt it, Miss Oliver?"

"What exquisite flowers, too, they have overhead in the hanging garden, pensile paradise sort of style!"

"Babylonish idea! did you say, Miss Rhineveldt?"

"Quite so. The Queen of Babylon certainly originated it, and it is equally certain, that if we cannot create ideas for ourselves, we are glad enough to utilize those of other people—however ancient they may be—so long as they are good. The state rooms, music room, ladies' room, and other apartments you see, are all that could be desired for comfort, compactness in detail, and tastefulness in every particular. Heating, ventilation, electric lighting throughout the ship, bathroom accommodation, sleeping berths, and everything else that can make this vessel a floating palace has also been carefully attended to."

As we cannot now ask for the passenger list, let us have a look at the names on the luggage which is lying around us.

Ah! here is our old friend, "John Smith, Esq.," bound for Valparaiso. When he gets to his Chilian home, he will be known as "Mr. Smith of London."

"The Macnab." I wonder where the *other* Macnab is?

"Miss Emily Vandeleur." Now what can be taking her so far away from home?

"To change her name perhaps."

Very likely, but she will never have a better one.

"The Marquis of Toddiemains!" Dear me, how amusing! His father was a director of the famous Glenmutchkin railway, twelve miles long, six of which were to have been through tunnels.

"Baroness Schlippen Schloppen," and "Count Periwinkoliski." It is very evident that he is not of much account, or he would'nt write his name in such a scribbly style for people to gaze at.

Well! well!! well!!! Upon my word! this is *too much.* Who would have thought of finding my charming Italian friend Angeletta Fourdrinier amongst the outward bound?

"Excuse me, ladies, but I *must* see her before she sails—Steward, where is Miss Fourdrin— ?"

At this very moment we all heard a furious bell ringing outside, and also the harsh and most unwelcome voice of someone inside, asking if there were—"Any here for the shore?—Tender just going off."

We rushed on deck at once, and, threading our way amidst groups of passengers, and others connected with the ship, reached the gangway just as they had hauled it in. We sprang, however, to the top of the "Satellite's" paddle box, and the hawser was at once cast off. The "Rosalind's" anchor appears above water with the last piece of old England it will touch for some months to come adhering to a fluke. The tender falls off a little, and as she does so, the passengers crowd the side of the ship to have a last view of us, and amongst them is Angeletta, joyously waving her handkerchief to me, and looking positively radiant!

The moment of departure has arrived, and just as the "peter" disappears from the masthead, and the handsome Chilian flag takes its place, the screw begins to revolve, slowly at first, but gradually faster, and the noble ship moves off on her first voyage, amidst cheers and waving of hats and handkerchiefs, and perhaps tears from those who have parted with relatives and friends—it may be for years,—it may be for ever. To her, and all on board, we, too, say—good-bye! good-bye!

Although this closing scene refers to the Mersey, it is equally applicable to Southampton, Plymouth, &c., and also to the ships of the Peninsular and Oriental, the Orient, and other mail lines. A slight modification however, is necessary in the case of the P. & O. steamers, whose passengers largely consist of military officers of all ranks with their wives, Governor-Generals and civil service officials, attended by their ladies, and occasionally, perhaps, a sprinkling of Oriental potentates, such for instance, as the Rajah of Travancore, the Sultan of Zanzibar, the Nizam of Hyderabad, and all the rest of them—*without* their wives.

Another most interesting time to visit a mail steamer is the day before sailing, during the drill and inspection of officers and men, and also women, whose total number may range from 150 to about 300. In the Indian liners, this performance—previously described—is made picturesquely attractive, owing to the presence of so many Hindoo attendants and Lascars in full native costume.

The passenger traffic from the Mersey has now attained colossal dimensions, and during the season some of the Atlantic steamers have carried at least 1,400 people at one time. Accommodation for 1,800 is provided in each of the new vessels, "City of New York" and "City of Paris;" and the S.S. "Umbria" and "Etruria" have frequently carried upwards of 600 saloon passengers each during one trip.

The Atlantic voyage is not deficient in amusingly interesting and sometimes tragic events. For wit, humour, and romantic incidents of various kinds, however, nothing can exceed what is so often to be found amongst the upper strata of society when out upon the ocean sailing in one of those magnificent long voyage ships I have delightedly referred to.

And now, having taken my kind reader through the cycle of operations from first to last which relate to the building of steamships, it only remains for me to say that a very great deal more might have been added, had it not been for a desire to keep this book in a somewhat compact and readable form. What has been said will perhaps be sufficient for the purpose, and however incomplete it may be in many respects, it will still represent, from the author's own experience, the inner life of first-class shipbuilding and engineering establishments when actively employed.

Let me, therefore, in conclusion, bring together, for the last time, my good friends, Mr. Bouverie and Mr. Macdonald, to express to them the great pleasure I have had in their society, and also the hope that long life, health, happiness, and prosperity, may be theirs, and to say—Farewell!

CHAPTER XX.

"BREAKDOWNS," AND MYSTERIOUS LOSSES AT SEA.

Meaning of the Term—Their Causes—Experience gained by them—Great Safety of Railway travelling—Protective System in Cunard Ships—S.S. "Atlas" on Fire—Drill in Mail Steamers—Original Advertisement of "President" and "British Queen"—New Captain of "President"—Departure on Last Voyage—The Storm—Arrival of "British Queen"—The Missing Ship—Theories concerning the Lost Ship—Disappearances of S.S. "City of Glasgow"—"Pacific"—"City of Boston."

HAVING put the "Rosalind" on her station, we now propose to make a few observations concerning the dangers she, or indeed any other steam vessel, will be exposed to at sea, and also to extend our remarks to the subject of accidents and disasters on land, so far at least as engineering is concerned.

When people read in the evening papers that the "top floor of Messrs. So-and-so's mill has given way," they may discover next day that this simple phrase means that through the failure of a column, or girder, not only the top floor, but all the others as well, containing machinery, have fallen in, killing perhaps twenty or thirty people, and reducing the whole inside of the building to a mass of ruins. When these same individuals learn at another time that "the engines of the S.S. 'Messalina' have *broken down*," some of them may naturally enough conclude that there has been a general smash-up of everything; that, in fact, her cylinders had burst, connecting rods doubled up, condenser crushed to atoms, bed-plate fractured in several places, and the whole of the machinery lying like a heap of rubbish on the floor, the only redeeming feature being that it had not gone through the bottom of the ship and sunk her.

Such people may hardly believe that the same words occasionally mean something of a very different nature, and sufficiently trivial to cause only a few hours' detention. In reality, the word "breakdown" may either refer to a trifling event of this description, or an appalling disaster which may cause the loss of a vessel, with many, if not all, on board, and this latter case is not by any means unknown. For instance, something may have gone wrong with the valve gear, which could easily have been rectified at sea by the aid of the "spare" details, and without much trouble, or, on the other hand, as happened some time ago, one of the connecting rods of a great and almost new ocean steamer might break through the middle, and cause the fracture of the cylinder and cylinder cover, piston, framing, and condenser, to such an extent as to cause the ship to lie up for repairs for several months, involving the re-erection of the engines, with heavy loss to all concerned.

The importance of a breakdown also depends greatly upon circumstances, as the valve gear derangement just mentioned, simple as it is, might possibly bring about the destruction of a ship, if trying, like the "Royal Charter," to keep off a lee shore in a storm.

In the same manner, how often do we find that on railways, and in land engineering generally, the old saying, "great results from trivial causes flow," is too frequently and unhappily verified. From this it will be seen that careful attention to the most minute and apparently unimportant things is of vital consequence, thus bringing to our minds the old story of "the nail, the shoe, the horse, the man."

Accidents to machinery arise from one or more of the following causes, (1) unskilful design or arrangement of parts; (2) bad materials; (3) bad workmanship; and (4) improper management; and this last may be said to neutralise the engineer's best efforts. Hence when everything is executed in first-class style, we have the very elements of the success which has greatly distinguished so many commercial and manufacturing firms. In addition to this, we may state that another reason for the prosperity of those who employ machinery of any kind consists, not only in using every possible means of preventing disaster, but in possessing the art of rectifying it speedily when it does come. In the case of ships at sea, all the skill available will sometimes not avert a catastrophe, but when it does overtake them, in spite of every precaution, it may still be robbed of its power by the promptness and energy with which the evil is met, and this forms part of the discipline on board ocean steamers to which we have previously referred.

Ever since steam navigation began, engineers and shipbuilders have gained their experience in the most practical and impressive manner by a long series of breakdowns, disastrous and otherwise, and the same may be said, to some extent, at least, of railway engineering.

For instance, when a terrible calamity overtakes a mail steamer or a passenger train, the whole of the circumstances connected with it are investigated as far as possible, and the cause is frequently discovered to have been a hitherto unobserved weak place in the engines or ship, or something that required amendment in the rolling stock, signal apparatus, or even the road itself of a railway.

All this proves most valuable, though costly, information, and has resulted in building up a gigantic system which has made railway travelling the safest of all occupations on land. Indeed, we have the authority of Mr. F. S. Williams for stating (*Our Iron Roads*, page 438) that "nearly as many persons are slain in the streets of London every fortnight as there are passengers killed on all the railways of Great Britain in a year, from causes beyond their own control."

Further, it is said that "2,000 people are lost in London every year, and only half of them are found again, and also that above 1,000 lives are lost annually in the mines of the United Kingdom. It may still further be added that about 500 lives are destroyed every year upon the coasts of the British Isles by ship and boat wrecks."

At the half-yearly meeting of the London and North Western Railway Company in August, 1882, the chairman stated that "for 3½ years only one passenger had been killed, and that one a lady."

"I have in this room proved," said Sir E. Watkin on one occasion, "that railway travelling is safer than walking, riding, or driving; than going up and down stairs; than watching agricultural machinery, and even less dangerous than eating, because more people choke themselves in England than are killed on all the railways of the United Kingdom."

From these statements, the only logical inference to be deduced for the benefit of those who wish to live to a good old age is, *that if they continually travel by rail, their object will most likely be attained;* and this will no doubt be confirmed by all the great Companies, and by railway people in general.

The perfection of our railway system at the present time has been, we need hardly say, the result of painstaking care and ever watchful vigilance on the part of the engineers who design, as well as those of all ranks who practically work this class of machinery. Ocean traffic, however, though infinitely safer than it was in early days, is far from being so free from disaster; indeed, slightly altering well-known words, it might be observed that

> "Much has been done, much more remains to do;
> Our railways flourish, why not our steamships, too?"

A great variety of stories from the sea have supplied shipowners, shipbuilders, and engineers with much valuable information, of which they have not been slow to avail themselves; and this, taken in connection with a most complete and admirable system of management, gave the Cunard Company total immunity from fatal disaster to any of their Atlantic ships, from the year 1840, until the S.S. "Oregon" was lost by collision in 1886, and this is all the more remarkable when we consider the terrible losses sustained by some other Companies in a very much shorter space of time. Accidents to the machinery of the Cunarders have occurred, but even these have been extremely rare, and, when they did happen, the only result was a temporary delay of the ship, without endangering the safety of those on board.

Many things have conspired to protect these vessels from serious disaster. In the first place, the Company have always insisted on having them built of the very best materials, and with the most thorough workmanship. They have also kept their ships under such careful supervision as to ensure the discovery of the slightest defect in strength or seaworthiness, and they have never allowed a steamer to start on a voyage unless they have been satisfied that it was complete, perfect, and efficient in every department. In the next place, they have marked out separate routes for outward and homeward bound steamers, somewhat apart from the direct course—those on the outward voyage crossing the meridian of 50° at 43° N. lat., while homeward bound ships cross the same meridian at 42° N. lat. By adopting this plan, the trips have been lengthened slightly, but the loss of time has been fully compensated by the greater sense of security which has been created.

Mr. Fraser Rae tells a little story in connection with a voyage of the Cunard steamer "Atlas," a few winters ago. The ship had reached mid-ocean, and one night, while the passengers were amusing themselves in the saloon by reading, playing cards, chess, or draughts,—the weather being too rough for promenading on deck,—the boatswain came down, and whispered the awful words, "The ship is on fire, sir," in the captain's ear. The commander at once went on deck, and was followed by others to whom he had communicated the intelligence. There they saw a large volume of dense smoke rising from the forward hatch. One of them returned to the saloon, and told the dreadful news. Anxiety was manifested as to how soon the flames would be extinguished, but there was little excitement, and no sign of panic, most of the players resuming their games, and the readers returning to their books. Confidence was evidently felt that everything that could be done to avert a terrible calamity would be performed.

In the steerage, on the contrary, there was ignorance without self-possession; women shrieked, while men rushed about in aimless despair. Some of the first-class passengers, offering to aid the crew, were asked to help in carrying the terror-stricken men, women, and children, from the steerage to the cabin, where they would be out of the way and give less trouble. These people, however, refused to be comforted, or even to be quiet.

All this time, the officers and crew were as cool and reticent as if nothing unusual had happened. The officer on duty walked the bridge, giving his entire attention to the navigation of the ship; the men on the look-out were at their posts; the engineers were in their places in the engine-room; the stewards were at their usual employment; indeed the business of the ship went on uninterruptedly, while a fire was raging in the hold, and all were in peril! At the end of half an hour from the time the alarm was given the danger was over, and the fire thoroughly mastered.

The cause of the accident was the ignition of some combustibles which had been shipped contrary to the company's regulations, and as an instance of the excellent order and discipline which prevails on board these ships, and also the readiness with which any emergency can be met, this incident forms a very good illustration.

On another occasion, while the "Russia" was steaming along at the rate of fourteen knots an hour, with a strong breeze blowing, the cry went forth that a man had leaped overboard. The next moment a second splash was heard—a sailor had jumped after his unhappy shipmate, in the hope of saving him. The vessel was stopped and put back with amazing promptitude, but it was found that the gallant attempt at rescue had failed. This daring swimmer was taken up and a purse of one hundred sovereigns, subscribed by the passengers, was presented to him for his conduct. Subsequently, as "Captain Webb," he gained great celebrity at the Straits of Dover, and ultimately, but fatally, in his attempt to swim across the rapids of Niagara in the same manner.

Before the passengers are allowed to come on board an outward bound mail steamer lying in the Mersey, the crew is assembled for drill in the presence of the captain and officers, the marine superintendent, and some representative of the company, who make a full inspection of the ship, boats and crew. All the boats are manned, lowered, and replaced to prove they are in complete working order; the firemen are put through their drill, the pumps are manned and tested, the rockets and signals are examined, the steering apparatus is tried, the store-rooms are inspected, and every part of the vessel is thoroughly looked into. When this is done, the ship is reported upon, and, if everything is satisfactory, the passengers are admitted at the time announced, and sail at the appointed hour, every possible precaution having been taken to ensure the safety of all on board.

"The British and North American Company's steamship 'President,' 2,366 tons, and 600 horse power, Lieutenant Richard Roberts, R.N., commander, is intended to leave Liverpool on 10th February, 1841, and New York on 10th March next, and to continue running each alternate month during the season, until the 10th October.

"And the 'British Queen,' 2,016 tons, and 500 horse power, Lieutenant Edward Franklin, R.N., commander, is to leave London on 1st March, and Portsmouth on 10th March.

"For freight, application may be made to Joseph R. Pim, Derby Buildings, Liverpool."

Such were the newspaper announcements of the period regarding these ships. The "President" sailed as advertised, arriving safely in New York, and starting on her return voyage on the 11th March, 1841. Previous, however, to leaving England, Captain Fayre, who was then in charge of the vessel, was asked to retire from the service of the company because he could not accomplish the mechanical impossibility of driving the ship faster, and he was at once superseded by Lieutenant Roberts, from the "Sirius." The former no doubt felt quite disappointed, and the latter gratified at finding himself promoted from a steamer of 700 tons to another fully three times her size, and yet, could both these gentlemen have had the power of foreseeing the awful event which was soon to follow, how changed their opinions would have been!! The dismissed captain on the one hand rejoicing in his safety, the other horrified at his approaching doom.

If the passengers, too, in New York could have had the same gift of prescience, how they would have stood appalled on the deck of the vessel in harbour, and, disregarding the loss of passage money, fled from her as from a plague ship! But no, the impenetrable curtain which hides from everyone what is to happen even in the next half hour, hid also from them their inevitable destruction.

This is an old and well remembered story, but it nevertheless awakens in my own mind many similar circumstances, which the reader may be familiar with in various forms. Just before the S.S. "Dalmatian," previously referred to, left the dock in Liverpool for the last time, her chief officer was superseded by another, for no fault of his own; this saved his life, as a few hours afterwards the ship was dashed to pieces in a gale on the rocky coast of Wales, and not one escaped to say how it came about.

Immediately before the S.S. "Austria" sailed from Bremen for New York on her last voyage, a gentleman who had taken his passage was much annoyed to find that his berth had been previously engaged by someone else. The company were very sorry for it, of course, but could not give him another, so he had to go by the next steamer, leaving his luggage, however, which was on board, to proceed in advance.

In mid Atlantic the ship was destroyed by fire; about 400 persons lost their lives, and he might have been one of the number had he not been left on shore.

People may go with so-called "charmed lives" through fire and flood, and storm and tempest. Even in the midst of many battles, soldiers have been exposed to such a hail of bullets, shell, and cannon shot, that hardly any around them could exist, and yet they themselves have been untouched, and after living to a good old age, died at home comfortably in bed. This unconsciousness of the future on our part is a wonderfully beneficial arrangement, because if we had the power of accurately anticipating our prospective joys, sorrows, and end, the result would be a grand upheaval of the very foundations of social happiness and advancement. Therefore it is better to be in blissful ignorance and know not what awaits us.

There is also a still more important and visible reason, which is, that all may be thereby stimulated to shape such a course through time as to be enabled to turn an apparent disaster into a victory, and to look upon death only as the "Gate of Life."

To return to our story, the "President" sailed from New York for Liverpool on March 11th, 1841, with 136 passengers and a valuable cargo, everyone on board fully expecting a favourable passage. Her previous runs between the two ports had occupied about fourteen days, but on this occasion she was so long overdue that the greatest anxiety was felt concerning her safety, and all the more so, because ships had arrived and reported dreadful weather, indeed some old navigators declared they had never seen it so bad in the Atlantic. There was also an immense quantity of field and berg ice floating about. In the face of this, and in spite of prolonged delay, people still hoped that everything would yet be well.

It was stated that a large steamer of similar rig had been seen under sail alone, and of course everyone thought she must have been the "President." This hope was soon blighted however, because the disabled ship turned out to be another. In the meantime the "British Queen" arrived, and brought no tidings of the missing vessel, indeed, she had such a fearful time of it herself on the voyage, that none expected to reach land again.

The storm she passed through lasted ten days—her sails were blown to rags, and the lee paddle floats were stripped off—in short, nothing saved her from foundering but the inherent strength of the hull, and good seamanship. Time rolled on, and every scrap of supposed information was seized with avidity, but in every case it proved delusive. Hope gave way to despair, and at last the terrible truth came home to all, that the ship they so eagerly waited for was lost—but how?

This was the next question, and all sorts of theories were put forward in support of certain statements regarding the cause of the disaster, some saying one thing, and some another. Wise people shook their heads and said, she "struck an iceberg," or "broke in two," or "was overwhelmed by the sheer force of the sea," but who the correct theorists were we have no means of ascertaining.

One fact alone remains, which is, that a noble steamer sunk in mid Atlantic, taking with her all on board, and leaving behind not a vestige of anything which from that day to the present could shed a ray of light upon her mysterious disappearance. If one engine had broken down, she could still have used the other, and carried on at reduced speed. Probably she ran into field ice, and sank immediately; perhaps she broke her back on a mountain wave, and gave her passengers an awful awakening; but it is not unlikely that the sea overpowered her, and sent her to the bottom like the S.S. "London" in the Bay of Biscay.

All these theories are good and sound, but their proof is beyond our power, and ever will be. When people read in the newspapers—"The Cunard Steamer 'Servia' arrived at New York yesterday, being three days overdue. During a heavy sea the boats, the bridge, and the funnels were carried away, and the saloon was flooded," and when those who have read this see for themselves the immense vessel, and also her great height out of the water, it will give them a much better idea than words can convey of the force of those vast Atlantic waves, and the dangers weakly built, badly engined, and unskilfully navigated ships are at all times exposed to.

In the summer of 1852, when passing through Glasgow, I had the pleasure of going on board the Liverpool, New York, and Philadelphia S.S. "City of Glasgow," and accustomed as I had been to see the old-fashioned Leith and London paddle steamers "Royal William," "Royal Adelaide," and "Royal Victoria," I could not but admire the beauty and finish of this ship. She was of 1,087 tons and 330 horse-power, and had recently left the hands of Tod & McGregor—her builders. Her engines, her hull, and general appearance were therefore objects of great interest to one who gazed at them for the first, and as it proved, for the last time.

On March 1st, 1854, this fine vessel sailed from the Mersey for New York, with 480 people on board, including officers and men; but, strange to say, during all these intervening years no one has been found who could give a single scrap of information respecting the mysterious disappearance of the ship during that memorable voyage.

In the same manner did the Collins liner "Pacific" vanish from sight. This vessel, of 2,707 tons, 1,000 horse-power, and commanded by Captain Asa Eldridge, sailed from New York for Liverpool on January 23rd, 1856, with 46 passengers and 141 of a crew, but since that time nothing has ever turned up which could throw any light upon her sad story. During a previous voyage, the side lever crosstail of the port engine broke, and, before they could stop the machinery, nearly the whole of it on one side of the ship was hopelessly destroyed. This, however, had been repaired upon her arrival in the Mersey.

The last of these unaccountable losses to which we shall refer is that of the Inman steamer "City of Boston." It is now about seventeen years since she sailed on her fatal voyage, and I well remember the conflicting newspaper reports which first cheered and then depressed those who read them; the hopes, the fears, and blighted expectations, and the wearing anxiety of people who had relatives on board, which in some cases proved too great a strain for them. It may be added that sailing ships and cargo steamers are still being lost from causes which can only be conjectured. In mail steamers, however, the discipline is so perfect, and their construction and internal organisation so complete in every respect, that not one of them has mysteriously disappeared since the "City of Boston" vanished from sight.

CHAPTER XXI.

LOSS OF WEST INDIA MAIL STEAMER "AMAZON"—ENGINEERING SMASHES ON LAND.

Farewell to Southampton—First Night at Sea—"Heated Bearings"—Alarm among the Passengers—"No Danger of Fire?"—Strong Gale—Neilson's vigilance—The Little World asleep—All's well—*Fire*! FIRE!!—Wild excitement—Swift destruction—Awful scenes—Ungovernable Engines—A Flying Inferno—The End—Spontaneous Conflagrations—Cause of Safety in Travelling—Death of a Railway Engineer—Promotion by Influence—The New "Chief" and his "Improvement"—The smash on the Line—National disaster through bad Engineering—Stage Coaches and Sailing Packets reinstated.

WE naturally expect to find the greatest disasters happening to ships and steamers when out on the wide ocean, exposed to hurricanes and cyclones, and also when dashed by the sheer force of the tempest against a rocky coast. Strange, however, as it may appear, those which have involved the most serious losses of life have occurred in *smooth* water, such as the loss of H.M.S. "Royal George" at Spithead, when Admiral Kempenfeldt and "twice four hundred men" went down with her in a few moments. Second only to this was the destruction of the river steamer "Princess Alice" on the Thames, a few years ago; but the disaster which above all others involved the greatest accumulation of horrors at the same time, was the burning of the new and magnificent West India Mail steamer "Amazon," in the Bay of Biscay.

Never can I forget the awful scenes that attended the last moments of that ill-fated vessel, nor the profound sensation they caused at the time throughout the country. Briefly told, the story of her loss is as follows:—

The "Amazon" was a timber-built ship, of 2,250 tons and 800 nominal horse power, and cost, when completed, £100,000. Her commander, Captain Symons, who had been temporarily appointed for the voyage, as his own steamer the "Orinoco," was not quite ready, had, for some inexplicable reason, a superstitious feeling towards her, and objected to have his name associated with the new vessel. She started on her first trip from Southampton at 3.30 p.m. on Friday, January 2nd, 1852, with a crew of 113 and 50 passengers, also a cargo valued at £100,000, while crowds of people came to see her off, and wave, unconsciously, their *last* adieus to those on board.

Everything promised well. The splendour of the ship, the magnificence of the engines, the prestige of the Company, and the general surroundings, all seemed to forebode a happy and prosperous voyage to those sunny climes of the Spanish Main so interestingly described in Charles Kingsley's book, *At Last.*

Soon after starting, the engines began to give trouble on account of the paddle-shaft bearings heating considerably, and this increased so much that, notwithstanding all that could be done to cool them, the machinery had to be stopped twice—in the latter case for two and a half hours. This, as well as the whistling of the steam, caused some alarm among the passengers, which the captain quieted by telling them that they were new engines, and would work easier in time, but the saloon people were still anxious, and one of them observed, "I hope there is no danger of fire?"

"No chance of *that*," observed a Mr. Neilson, "or it would be a terrible business in such a night as we are likely to have."

During the next day, the ship had a strong wind dead against her, which continued to rise until it became a perfect gale, but with the engines reduced to three-quarter speed she made 8½ knots an hour. So far as the knowledge of the period went, the vessel was well cared for, and had plenty of boats—nine in all—for saving those on board in the event of danger arising. She had also able and experienced officers.

This, then, is a picture of the splendid steamer on her voyage. But let us pause ere we lift the curtain and shew in all its hideousness a transformation scene worthy of Dante or Doré, which has never been exceeded even by the wildest writers of fiction. On the deck outside, everyone on duty was navigating the ship as usual, and the engines were working more easily at the reduced speed. Up to a little past midnight, this state of things continued; the sea was high, the night dark, but all was well.

The passengers were in bed, dreaming sweetly, perhaps, of past scenes in England, the home of the happy and the free, or probably the anticipated events of the future, but certainly not *the* event so close at hand. Eliot Warburton, the talented author of *The Crescent and the Cross*, was among them, on his way to the Isthmus of Darien as a diplomatic agent to the Indian tribes of that region. Mr. Neilson, one of the passengers referred to, who had taken great interest in the working of the machinery, had left the engine-room at 12.30, and gone to bed—for what proved to be only a five minutes rest—quite satisfied with the improved state of affairs, and all was peace and safety to the little floating world thus "rocked in the cradle of the deep." Even those who were awake heard nothing but the natural creaking of the ship, and the splash of the waves against her sides as she sped onwards.

At a quarter to one on Sunday morning, January 4th, just as the "Amazon" had reached a point about 110 miles W.S.W. of Scilly, the awful cry of *Fire!* FIRE!! burst upon the ears of the affrighted sleepers. Hark! to the shouts of horror and despair—the clanging of the alarm bell—the rush of many feet along the deck—the crackling of timbers, and the belching forth of dense clouds of smoke that stifle all who approach it. Such, almost in a few moments, was the dreadful change that had come like a flash upon the amazed and awe-stricken crowd.

The fire had burst out apparently in the store room adjoining one of the forward boilers, and so swiftly did it spread aft owing to the strong head wind, that the engines could not be stopped, nor, indeed, were they ever, until all was over.

Imagine, if you can, the scene inside the theatre at Nice, or the "Ring" Theatre of Vienna on the night of their destruction. Change it from dry land to the raging seas of the Bay of Biscay, and shrouded in pitchy darkness, let it be driven over them by a power no human agency could control, and then you may have a somewhat approximate idea of the sight which greeted the eyes, and paralysed the minds of the half-naked and bewildered passengers on the quarter-deck, for whom a terrible death awaited.

Before they had time to think of any chance of escape by the boats, which were soon afterwards nearly all burnt, or swamped by the surge of the wheels, the flames were in upon them, crashing through the glass and woodwork of the saloon, and then followed scenes no language could adequately describe or pencil sketch. A gentleman was observed shielding his wife from the fire until the last moment. Another couple were seen with their arms clasped round each other's waists, and walking slowly along the deck, when all at once it gave way beneath their feet, and both fell into the raging furnace below; and amongst other horrible spectacles, was that of a man utterly destitute of clothes, walking about with one entire side a mass of burns and enormous blisters, some of which had burst, and left the flesh hanging in shreds.

Owing to the immense volumes of smoke and flame that now invaded the quarter-deck, the ship had become totally unmanageable, Captain Symons therefore cried out, "For God's sake! put her before the wind."

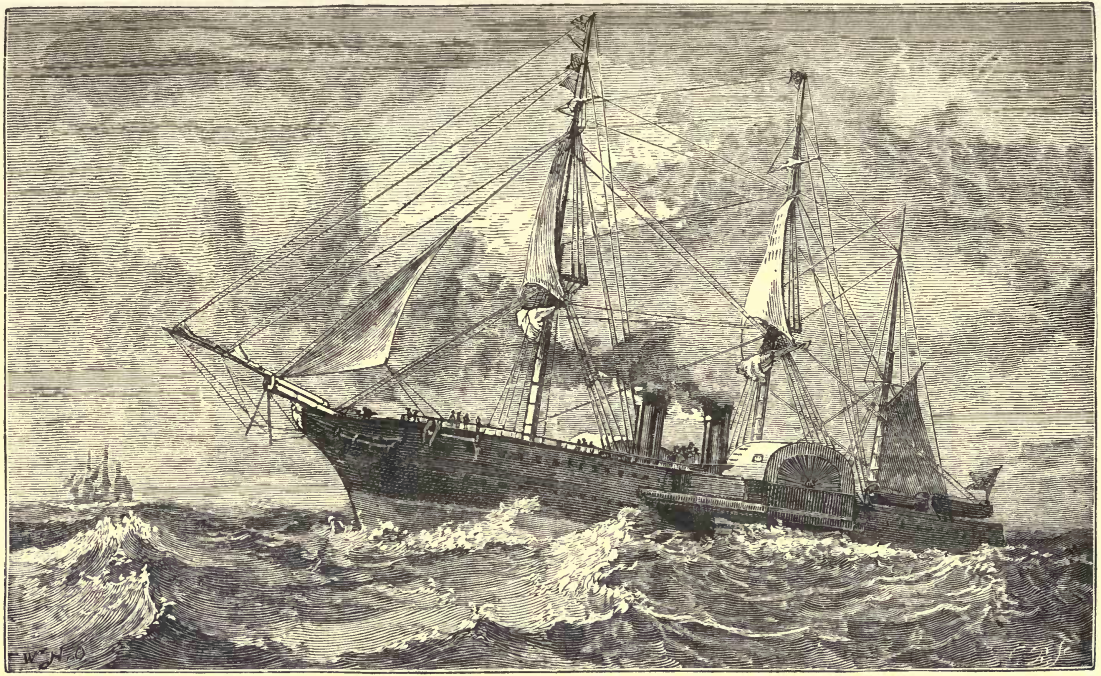
This was done as quickly as possible, but another evil arose, which was, that the speed became so greatly increased as to render it almost impossible to launch a boat in safety. It was tried, however, with the remaining ones, two of which, while being lowered full of passengers from the davits, fell end on into the water—owing to the tackle not working properly—and their shrieking occupants were thrown into the sea and left far astern. Onward rushed the flying Inferno, but ultimately two of the largest boats were safely launched, one of which was commanded by Mr. Vincent, a midshipman, and the other by Lieutenant Grylls, R.N., who was one of the passengers.

Everything that could possibly be done by the officers and men to save life was attempted, but from the first the case was seen to be hopeless so far at least as the ship was concerned, and "faithful unto death" may be said of many. Lieutenant Brady, the officer in charge of the mails, was seen enveloped in flames while trying to save the mail bags, and the last scene witnessed by those in the departing boats was the captain and officers standing by the wheel awaiting their dreadful end, and the last passenger also observed in the same position was Eliot Warburton. The annexed plate is a view of the P.S. "Amazon" making signals at sea, and is a good example of a style of ship which at that time existed.

Soon after the boats left, the main mast, which had previously fallen, was succeeded by the fore and mizzen, then the funnels fell hissing into the water, then the magazine exploded, and, after a pause, the vessel went down. Just before this, however, a barque, close reefed, passed between one of the boats and the ship, and within 400 yards of the former, which hailed her several times with the energy of despair. She brailed in her spanker and appeared to answer them, but nevertheless sailed round the wreck and left them to their fate, because, as it turned out afterwards, she had not seen the boat, and was anxious to do what she could in giving assistance.

The cause of the disaster has never been discovered. One theory was that spontaneous combustion among the coals had originated it, but it has been much more generally supposed that the store-room was to blame, as it was full of combustibles such as oil, turpentine, &c., and was moreover greatly heated by being too close to one of the boilers. The woodwork of the ship also was in prime condition for firing, as the vessel had been very hastily finished, and it had been saturated with turpentine for cleaning purposes previous to painting and varnishing.

Subsequent events have shewn that the origin of this, as well as of many other unaccountable conflagrations, may have been the spontaneous combustion of oily cotton



WEST INDIA MAIL P.S. "AMAZON" SIGNALLING.

waste, &c., when exposed to certain atmospheric influences, and, for this reason, I am induced to mention a circumstance which happened in the works of Messrs. Neilson & Co., Glasgow, when I was on their staff.

One portion of the old and well known Hyde Park Foundry consisted of a large turning shop, filled with machinery, and occupying the first floor of one of the buildings, in a corner of which lay a quantity of dirty waste that had been used for cleaning purposes. On the occasion referred to, the foreman had arrived a little before six a.m., and, to his surprise, found the pile of waste in a smouldering state, and on the point of setting fire to the floor. It is very probable that half-an-hour later the whole building would have been in a blaze, and without any apparent cause, as the works were closed at six on the previous evening.

Long afterwards, I mentioned this circumstance to a friend, who informed me that the same thing had taken place in his own house, owing to some oily cloths having been stuffed into a kitchen drawer, but fortunately discovered in time to prevent mischief. It may also be added that, so fully do the Lancashire insurance companies recognize the danger of fire from spontaneous combustion, such as we have mentioned, that they will not allow refuse cotton waste to remain during the night in the mills over which they have control.

Out of the 163 people who sailed in the "Amazon," 104 were lost. The rest were picked up in the remaining boats by passing vessels, and landed in safety, and amongst them was one lady—a Mrs. McLennan—and Mr. Neilson, who afterwards wrote a long and interesting letter to the *Times*, giving a full account of the destruction of the ship.

Thirty-seven years have rolled away since this event, and so many terrible losses have occurred during the interval that we ought to be somewhat seasoned to them by this time, but really, as I hunted through the columns of the above newspaper, and also the pages of a little book, *The Loss of the Amazon*, for facts connected with the case, I felt the scene rising again before me in such hideousness, and without a single ray of light, or one ameliorating circumstance attending it, that all the other disasters of a life time sank, comparatively speaking, into the shade. I may further add that, although other calamities at sea have involved a much greater loss of life than this one did, those who recollect the burning of the "Amazon" will remember an event which for accumulated and relentless horrors, has never been equalled in the history of steam navigation.

Even at the worst, I should have been able to modify this statement considerably if the engines could only have been stopped, but *why* they were not I have never been quite able to understand, as it is difficult to see how the flames or smoke should have so swiftly overpowered those in the engine-room as to prevent them from shutting off the steam at a moment's notice, as we can now do in all our ships, and under all circumstances.

A friend of mine was one day travelling by rail, when an animated conversation arose on the subject between himself and another passenger. They were soon joined by a third, who proved to be the Rev. William Blood, one of the survivors, who gave them a graphic description of the scenes he had passed through during the fire, and added that what he had witnessed had given him the idea of a never-to-be-forgotten hell upon earth. The intense excitement of the scene must have drowned reflection in many cases. It is quite possible, however, that in that last dread hour, as in the foundering S.S. "London," there may have been some, and perhaps weak ladies too, who, "after life's fitful fever,"—after everything possible had been accomplished,—could stand serenely under the influence of a silent, secret, wonderful power, and as the ship went down, sink with her—to rest.

From the loss of these two vessels engineers have learnt many valuable practical lessons, and among them may be mentioned the extreme danger of placing a storeroom containing combustibles, and also woodwork of any kind, too close to what may be the exposed parts of hot boilers, and at the same time, the necessity of having high and strong engine room skylights, which prevent the possibility of their being washed away in stormy weather, and thus causing the ship to be flooded till she sinks. Such calamities as those we have mentioned,—even in a mitigated form—are now almost unknown. The experience which has produced such happy results has been gathered from a great variety of sources, and has developed on the one hand the art of avoiding such dangers, and on the other the power of remedying them promptly if they should happen.

After all that has been done, however, it is astonishing how frequently the most dreadful disasters occur to ships and steamers by collision with each other. This year of 1889 supplies numerous examples of vessels thus going to the bottom as if they were made of tin, instead of being built of steel, and as if they had not a single protective bulkhead to save them from foundering. The recent "Princess Henriette" collision in the English Channel, certainly eclipses all others in its unique characteristics. Such an event as one vessel cutting another right through paddle box and engine room, from side to side, and at the same time causing the boilers to explode, has never happened before, and probably never will again. The "Amazon" story stands pre-eminent amongst the fiery disasters at sea, but this Dover and Ostend Packet calamity must remain unparalleled in the records of similar catastrophes upon the ocean. Infallibility on railways can by no means be expected, but if collisions at sea through careless navigation are to continue, they may, however, be robbed of their fatally destructive power by strengthening the bulkheads already referred to.

This chapter, as well as a portion of the last, has been somewhat down among the dismals, but as lights and shades are appropriate in a picture, so are they also necessary and natural in a book, the object of which is to describe in a simple manner the practice of engineering, which contains some of the most melancholy records to be found in the history of the world. And another reason for raking up so many sad stories of bygone days is to show to the general reader how engineers—step by step—have worked the profession up to its present high position in so short a time.

It is to be regretted that the time honoured, and geographically distinctive title of the "West India Royal Mail S.S. Company" should have been changed to that of "The Royal Mail Steam Packet Company," which is confusing to some at least owing to the existence of so many other *Royal Mail* liners. As there is a West India and Pacific fleet of steamers owned in Liverpool, and also the P. S. N. line sailing from the Mersey, two "West India" telegrams flying about the world, or an equal number of "Pacifics" flashing over the surface of the earth would create endless confusion. Our old friends named above, have therefore adopted their present title, and this in itself will indicate one of the causes of change of name in firms when complications arise. "*The Royal Mail*" is certainly a first class designation—as it is quite in the Head of the Clan style, but for geographical expressiveness it cannot be compared with the former name of the Company who possessed the "Amazon," and many other fine steamships at that period.

How comfortable, how safe, how happy we all are while travelling on land and sea! We have good men in responsible positions, constantly watching over everything that might bring about disaster in any form, and carefully investigating and analysing all arrangements which can possibly benefit the public. But let me sketch another, though certainly imaginary, picture, in the hope of illustrating how the beneficial science of engineering might, with great ease, be turned into a blighting and universal evil.

Let us therefore suppose that instead of able and experienced men at the head of affairs in all departments, we had a set of people who had been promoted through influence instead of merit. Let us also suppose that Charles Y. Z. Hardinge, to whom we have previously referred, is one of them.

Since we last saw him, this young gentleman has been a draughtsman in the establishment he then entered. For a time he got along pretty fairly, having plenty of well matured drawings to aid him, and comparatively simple work to execute, but, owing to a few mistakes of his passing undetected through the shops, the chief draughtsman put him on to something he could not well spoil, and let him run in a groove for an indefinite period.

His parents are naturally anxious to see him advanced, and his rich uncle in London is again appealed to, as he possesses a large number of influential friends, some of whom are railway directors, Now it so happens that, just at this very time, a vacancy occurs on one of the main lines for a locomotive superintendent, and this is how it came about.

The late superintendent of the works was a highly accomplished man, socially as well as professionally; one of those sharp, intelligent, bright-witted people we sometimes meet with. He had, in early days, served a five years' apprenticeship with a celebrated firm, but had no greater opportunities than many of his contemporaries. The difference, however, lay in the use he made of them. He was one of those individuals who are ever on the outlook for something to learn, something to increase their practical experience with the view of future promotion, and in course of time he gradually rose until he reached the top of the tree.

As engineer-in-chief at the works, he was a strict disciplinarian, but nevertheless possessed so much kind feeling and consideration for others that he was not only highly esteemed by men immediately around him, but by all who had the pleasure of his acquaintance. In addition to the above qualifications, he possessed such a modest and unassuming character that no one would have imagined him to be a perfect master of the science and practice of railway engineering, and the responsible head of a great line.

It may here be said that men and women who run in grooves have their views of scientific or other matters much narrowed. To remedy this, they should read good general literature and avoid making themselves the slaves of a profession. Much study is never more wearisome than when unduly prolonged in *one* direction, and, as previously remarked, it is variety in thought that makes the acquisition of knowledge pleasantly profitable, and keeps people bright and springy. Besides this, readers of general literature frequently learn much that indirectly helps them to comprehend their own dry, technical treatises more fully, and also to obtain many valuable ideas which may often be utilised in various ways. Our locomotive superintendent—Mr. Fordyce—had long since found this out for himself, and thus became in time, not only a first rate engineer, but also an essentially "happy man," with—to all appearance—a bright future before him. Ah! poor Mr. Fordyce, he little knew. . . . .

One day he was outside, giving directions to the foreman of the "running shed," when the following announcement was handed to him:—

"Serious collision near Blanque station; six killed, many injured; send help at once."

Not a moment was to be lost; the foreman got his orders straight off, and, as an engine happened to be passing slowly at the time, the superintendent was after it in a twinkling. While trying, however, to get on the steps of the tender, his foot slipped, the wheels ran over him, and in a second nothing was left but a few mangled remains.

There was great sadness throughout the establishment when this became known. Everyone felt he had lost a highly valued friend, whose like he would never see again, and the Company a most able and efficient officer, who might be rather difficult to replace.

Well, now, this was the man young Hardinge hoped to succeed, and his uncle accordingly brought all his influence to bear upon the proper authorities for that object. They said "he was young and inexperienced," but the London merchant courteously explained to them that "his nephew had a good character, was steady, and would do everything he could to make himself worthy of the post." This required consideration by the Board of Directors, so also did the fact that the gentleman who was pleading for his relative influenced, in some way or other, a goods traffic of many thousand tons a year over their railway. At last they consented, and Mr. Hardinge was duly installed as Locomotive Superintendent, to the surprise of those who knew him best, but to the delight of himself and his near relations.

For a time things went on smoothly, because he ran upon the lines of his predecessor, and had the late chief's staff of able draughtsmen and foremen to keep him right. In letters to his friends, he said "he was getting on much better than he expected," in short, for the reasons given, everything seemed to go swimmingly. Manufacturing engineers of all kinds now inundated him with circulars and catalogues, which shewed in glowing colours how this "patent piston almost annihilates friction, and will save twenty per cent. in fuel;" and that "patent non-conducting composition for boilers will give an obvious economy of twenty-five per cent." Then came a flood of "injectors," "slide valves," "fire bars," so on and so forth, until the poor man could only arrive at the logical conclusion that if he used a sufficient number of these "improvements" in his engines he could run them for nothing, and thus prove to the directors the wisdom of their choice.

After carefully considering the various merits of these inventions, he finally decided upon scheming out for himself a tyre fastening, which he hoped would supersede all others, and accordingly introduced to the engineering world what he was pleased to style "Hardinge's patent improved tyre fastening for railway wheels."

If there is one thing more than another that causes those knights of the workshops—the foremen—to snigger and smile, it is when they discover unpractical ideas in their employers, and if a master wants to stand well in the opinion of these gentlemen, the best thing he can do is to show them that he is quite as good as they are in practical knowledge, and perhaps a great deal better. It is therefore needless to observe that Mr. Hardinge did not come up to this standard of excellence among the men he was placed over, because, as they remarked, "he was very conceited, and knew so little." All the staff, however, had to do as they were told, no matter what the consequences might be, and although some of them might have proposed beneficial alterations, he would hardly listen to them, chiefly because he did not understand what was said or what was aimed at.

For instance, the foreman of the pattern makers would say to him, "Don't you think, sir, we might put in a little more metal here?" or "make this a wee bit stronger?" He of the erectors might propose a simpler and better arrangement than was shewn on a plan, but these gentle remonstrances received no encouragement from the Superintendent, because, as he said,

"You have the drawings to work to, and they explain everything," and occasionally he would observe, "That is the way we used to do it in Sharp and Stewart's."

This last remark was a crusher, but not quite applic-

CHAPTER XXII.

STORY OF A DISASTROUS TRIAL TRIP.

Visit from a Shipowner—"Ship for Sale"—Engaged for Trial Trip—Handsome fee—Off to Gravesend—Locomotives and Railway Travelling past and present—Mr. Coventry, the Agent—First view of S.S. "Orinoco"—Description of an Engineer's "Report"—Beauty of Ship—Disappointment—The Captain—A Coffin Ship—Mystery about the Machinery—Vile Workmanship—Chief Engineer—Preparations for Starting—Something wrong in the Tunnel.

About eight o'clock one evening in November, 1885, I was comfortably seated before the fire and occupied with the perusal of an amusingly interesting narrative of an event that happened among the passengers of a P. and O. steamer in the olden time. I had gone about half way into the story—so charmingly written in the pages of my life-long friend, *Chambers's Journal*—when a feeling of drowsiness came over me, and I put down the book for a little. It may be mentioned that during the day I had been extremely busy at the office, and my head had been filled with ideas relating to "columns," "lattice girders," "bowstring bridges," "diagonal bracing," and so on, for an iron pile pier into which I was trying to introduce the greatest strength with the least quantity of material. The necessary calculations and scheming out of details had kept me so constantly occupied that I felt somewhat tired, and had just closed the book so that I might have about forty winks when a visitor was announced.

"There's a gentleman down stairs wishing to see you partiklerly, sir," said a domestic, handing me his card, on which I gazed inquisitively.

"What! Randolph Bellingham, Prince's Park Terrace?" I mentally exclaimed. "I have met that man hundreds of times on the street and elsewhere, but have never spoken to him in my life. Dear me, how strange! and yet he has such a kind, amiable, benevolent expression. Now, what can he be wanting with me at this time of the day?"

"Ask him to come in," I said to my attendant, and immediately afterwards the stranger was beside me.

"Oh!" said that gentleman, on entering the room, "Your face is quite familiar to me, I have seen you very often down in town for years past, but have never had the pleasure of speaking to you till now."

"That is exactly what I was thinking of you, sir, when I saw your card; let me give you a chair; I am very glad to see you."

"Before saying anything about the object of my visit," he continued, "would you kindly read this advertisement, which only came to my notice to-day, and which I intended to see you about this afternoon, had I not been detained at Birkenhead until too late to call at your office."

With me *first* impressions are very strong. In this case, however, not only were my original opinions of Mr. Bellingham fully confirmed, but I found that he also possessed a very quiet, easy, and attractive manner. Judging by his appearance, you would have fancied he was about fifty years of age, but he might have been a little older, because happy dispositioned people wear well, and amidst all their troubles and worries, preserve for a long time their youthful appearance. Let

CHAPTER XXII.

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"FOR SALE,

"Now lying at Gravesend, the very superior passenger and cargo steamer 'Orinoco,' built and engined in 1884 by a very celebrated firm. Gross register, about 3,300 tons. Length extreme, 375 ft.; beam, 40 ft.; and depth of hold, 31 ft. Built under Lloyd's special supervision and classed 100 A1.

"Engines: Inverted direct acting compound surface condensing, of 400 nominal horse power. Diameter of cylinders, 48 and 84 in.; length of stroke, 4 ft. 6 in.

"Three double-ended multitubular boilers; steam pressure, 75 lbs. Five steam winches, and steam steering gear. Speed, 14 knots per hour on a very low consumption of coal. Can be used either as a first class mail steamer or as a fast cargo ship.

"For price and other information, apply to Quirk, Gammon & Co., 666, Leadenhall Street, London, E.C."

"And now," observed Mr. Bellingham, after I had perused the document, "I may as well inform you that I am at present greatly in want of a ship similar to this, and had decided to give Denny Brothers an order for one, but as time is of the utmost consequence to us, I thought when I saw the advertisement that, if the vessel suited, I would buy her at once, and get a set of quadruple engines made for her while she was away on her voyage. She is, as you see, lying at Gravesend, and what I wish you to do,—if you will kindly take the matter in hand,—is to go out in her on a trial trip, minutely inspect everything about the ship, engines, and boilers, and send me a full report of your expedition, so that I may be able to judge what is best to be done in this business. Let me also request you to accept one hundred guineas, which I think is a fair remuneration for your services."

"I am extremely obliged to you," I replied, "but really I could not think of taking so much. In cases of this kind my usual fee is—"

"Oh! never mind what your *usual* fee is," said Mr. Bellingham, smilingly; "this is a special undertaking, which involves a good deal of care and trouble on your part, and I therefore cannot allow you to take anything less."

"In that case I shall be very happy to undertake the work, and give it my best attention. When do you wish me to go?"

"To-night; there must be no time lost; the mail leaves at 10-45, and I think you will have plenty of time to catch it. I have already been in communication with the brokers in London, and they have agreed to send their Mr. Coventry to meet you at the Royal Hotel, Gravesend, to-morrow morning at nine, and this gentleman will do everything he can to assist you. We intend giving the ship a run of twenty miles to sea, which will afford a good opportunity for noting the action of the machinery, the speed of the vessel, and also her general construction and arrangement."

"Very well, sir, I shall keep a sharp look-out. Is there anything else you can think of that might facilitate matters?"

"Nothing that I am aware of. I believe I have mentioned everything. Mr. Coventry is a very pleasant man, and you and he will get on nicely. By-the-bye, while it is in my mind, let me give you ten pounds for your expenses, and, as soon as the trial is over, please telegraph to my office in India Buildings, 'Satisfactory,' or 'Unsatisfactory,' as you may think proper."

"How strange!" I observed, "I am in Canton Buildings, next door to you; we therefore represent the two largest empires in the world."

Mr. Bellingham smiled, and his last words, as we parted at the outer door, were, "Now, you will be sure to go off by the 10.45 train?"

"Certainly," I said, "unless there is some delay at the station. Good night, sir."

"Good night, and a pleasant journey to you."

"Upon my word!" I thought, as the door closed on my kind and amiable visitor, "these shipowners are the finest set of people I have ever seen. I have always received the greatest courtesy from them, but really Mr. Bellingham outshines them all. What a charming man, to be sure! So frank—so genial—so bright-witted—so generous! If all my clients were like him, I would indeed be happy."

After putting a few things together, I thought of the office, and immediately wrote on a postcard, "Off to Gravesend, on urgent and important business; will return to-morrow night."

Giving myself twenty-five minutes to catch the train, I started on the journey, and arrived in good time at Lime Street station. One of my favourite occupations when about to travel any considerable distance is to have a good look at the iron horse which is to drag us along. It gives one more confidence in the speed of the train, and also in its safety, because it is only natural that the "express" people should be treated with greater respect down the line, and have their interests more carefully looked after, than if they were a lot of slow-going excursionists. What a difference it makes, too, when you feel yourself in tow, not of a dirty, old-fashioned, ramshackle, crawling, six-coupled goods engine, but a magnificent racehorse of the newest type!

In obedience to the command, "All take your seats for London," I entered a carriage where I thought I would be in good company, and in a few moments we were off.

To the general public, as well as to the engineer, everything connected with railways must be most interesting. Their history contains a great deal of romance, many amusing anecdotes, and very much that is practically and scientifically instructive.

Those who remember what railway travelling was thirty years ago will at once recognise the immense advantages we now possess in this respect. At that time, third-class carriages were merely cold, cheerless, uncomfortable boxes on wheels, with flat tops, which were sometimes crowded with passengers. The fares were also very high, and the speed of ordinary trains much less than it is now. The locomotives of the period, as well as the carriages, were very different indeed from those we now employ, as the steady march of improvement has gradually worked up the whole railway system to its present high pitch of excellence and cheapness in transit, while the early £550 four-wheeled engine—of rude construction, and four or five tons weight—has been superseded by six or eight-wheelers of the highest finish, costing about £2,500, and weighing from fifty to sixty tons, or even more.

The English style of locomotive is, with slight modifications, almost universal, but in America there is a marked change in its appearance and construction—the former consisting of elaborate adornments, and the latter of a certain amount of elasticity in the framing to enable the machine to adapt itself in a sinuous manner to the inequalities of the line. To these we must add the "cowcatcher" in front of the engine, and the "spark-catcher" outside the chimney, which form such distinctive features.

It would be rather difficult to say when a locomotive dies, or departs this life, on account of long-continued renewals. Our own noble selves are completely changed every seven years by means of a constant process of disintegration and creation, so is it with railway engines. They may be blown up, smashed up, and worn out in parts, but a new boiler here, a new cylinder or crank axle there, and other details more or less repaired, will make them all right again. Indeed, when parts are interchangeable, a splendid express or goods engine may be formed out of the remains of several others that have been almost annihilated when on duty.

On many lines in America, railway travelling is somewhat slow and tedious, owing to the irregular nature of the permanent way. It has also peculiarities common to the New World, where at one place you may travel for hundreds of miles at a stretch across a level prairie, and at another be away up in the Rockies, 11,000 feet or so above the sea, climbing steep inclines, or running along the edge of precipices, 1,000 feet deep. Artemus Ward says that on one occasion he suggested to the conductor of a train that the "cowketcher" was at the wrong end, for, as he observed,

"You will never overtake a cow you know, but if you put it at the other end it may be useful, and prevent those animals from walking in and bitin' folks."

Hardy Gillard, of panorama celebrity, tells another story of the Grand Pacific Line:—A lady and her son were once travelling from New York to San Francisco, and when they arrived at Chicago the collector came round to examine the tickets as usual.

"You'll have to pay for that boy, ma'am," he said, pointing to the youth.

"What for?"

"He's over ten."

"Wa'al," replied the lady, "I guess he wern't ten when we started!"

At three minutes to nine the next morning I entered the Royal Hotel, Gravesend, and after inquiring for Mr. Coventry, was at once shewn into the coffee-room, where I found that gentleman occupied with the newspapers.

"Good morning, sir," he blandly said on recognising me, "I am very glad to see you, and hope you had a pleasant journey."

"Very much so indeed, thank you," I replied.

"How fortunate we have been in our arrangements," he continued, "I see they had quite a gale here yesterday, but the wind subsided during the night, and now it is quite calm. We shall have a splendid trip; everything is in readiness, and I have given the chief engineer orders to have steam well up by ten o'clock. After breakfast,—which will be here immediately,—we shall go out to the ship in a boat, and start at once."

This, I need hardly say, was very cheering news, physically as well as professionally, because the morning air had given me an excellent appetite, and I was therefore in splendid condition for making a hearty breakfast, to which in a moment or two afterwards we sat down. My first impressions of Mr. Coventry were most favourable; he evidently was a man of education, and had also a charming way of "putting things" that quite interested me. "Ah," thought I, "these ship people are gentlemen, every inch of them, and set an excellent example to some professionals I have met in life."

I *had* been hungry, but now I was not, having done ample justice to the good things provided for us, and upon offering to pay our united costs, kind Mr. C. exclaimed, "My good sir, I could not allow you to do such a thing; you are my guest, you know," which of course settled the matter.

Down we went to the jetty, jumped into the boat which was waiting for us, and off we started. As we neared the "Orinoco," I could not help admiring her as she lay in such beautiful trim in the water. Her model was exquisite, and a very pretty bow for a ship of her class, and also a handsome elliptical stern made me take to her at once. In addition to this, her barque-rigged masts, well proportioned funnel, clean sides, indeed everything that could be thought of to make the vessel look well seemed to have been carefully considered, and from what I could see, I thought Mr. Bellingham would be fortunate if he purchased her. Under the influence of these impressions, I was already conning over in my own mind a few choice opening sentences in the preamble of my "Report."

A document of this nature, I need hardly inform my readers, is a very different thing from newspaper "reports," those at least which are given in the evening publications and contradicted next day. Whatever other people may do or say, an engineer's night and morning statements must agree, but to accomplish this great care is necessary. In the first place, he must be true and faithful in what he says, he must also describe fully and accurately what he sees and thinks, and in a very independent manner, too. In other words, as free of bias as possible, or the inclination to say a thing is good when it is not, simply to please a client. All honourable men act in this manner, but human nature is frail, and I am afraid that in spite of all our good intentions we are sometimes tempted to use a little rose colour injudiciously.

Not only must an engineer describe accurately what he sees, but be able at the same time to judge correctly, so that his client will have a fair idea of what he proposes to purchase, and also whether he ought to do so or not. It will therefore be seen that there is considerable responsibility incurred by the engineer who undertakes such work, which in some cases may involve very heavy outlay, necessarily or unnecessarily, on the part of the individuals or Company who employ him. Take, for example, the Manchester Canal scheme, and many others of lesser magnitude.

Besides all this, after the facts of the case have been carefully collected, they have to be arranged in a simple, intelligible, and literary style; indeed, an accomplished engineer's report ought to be quite a masterpiece of elegant language, and his opinions must be mildly stated, just in the same way as one Government treats another when the ultimatum is being concocted.

No one, for instance, would ever think of writing in his despatch that "The roof fell in on account of the stupid blundering of its ignorant designer," when the proper style should be, "The cause of failure in the roof I have just described was, in my opinion, the inherent weakness of the fractured tie-rod," or "Want of uniformity in the strength of the ruptured plate evidently brought about the explosion of the boiler." Even at the worst, our language is studiously mild, but, underlying an engineer's euphemisms, there is a great deal that people should beware of, if they wish to profit by those expressions which refer to unpleasant facts.

The anticipated length of a report is somewhat delusive, and depends entirely upon the nature of the case, and the completeness with which its details are gone into, but whether a large number of foolscap pages are required, or only one sheet of letter paper, the object of the writer is to convey as much information as possible in few words, and to avoid to the utmost those apparently vain repetitions the lawyers so liberally treat us to, such as "and the said Dashe Blanque doth hereby for himself, his executors, administrators and assigns, agree," &c., every tenth line. After the document is fully written out—on one side only—it is paged at the bottom, and securely fastened with two brass clips at the upper left hand corner. After this is done, the report is carefully folded, endorsed on the outside, and sent off.

To return to my own proceedings: During the time I was mentally noting the external appearance of the "Orinoco," as we approached the ship, I could not help expressing my opinions somewhat favourably to Mr. Coventry, which greatly pleased him.

"Yes," he added, "I am sure she will suit your people exactly. She is truly a splendid vessel."

When we got on board, however, I was considerably disappointed with what I saw. The deck houses and other fittings, which looked so well at a distance, now appeared coarse in quality and sloppily put together. The rigging was in a very bad condition in many places, and the decks looked as if they had been made of ill-seasoned wood, which had shrunk very much under a hot sun, and then been clumsily caulked. As we walked slowly along, examining everything closely, I observed a blunt, burly looking fellow swearing away in awful style at one of the sailors.

"Let me introduce you," my companion remarked, "Let me introduce you to Captain Vanderdecken, he is a Dutchman by birth, but has been a long time in England, and knows this ship well, having been three voyages in her to the Cape of Good Hope."

We bowed.

"Ver glad to see you, sare," said the commander, trying to look amiable, "you come to see my sheep?"

"Oh yes."

"Vell den, you vill find her von shplendid sheep—gr-r-and sea botte, ver fine engines, ver high speed, vat vill you vish for more?"

I did not answer the question, but under Mr. Coventry's guidance extended my survey to the lower regions. Here, too, as on the upper deck, I was again disappointed, as all the doors, floors, bulkheads, and general fittings were thrown together in such a sloppy, scamped, and disreputable manner that I at once became suspicious of everything.

"Good gracious!" I thought, "Laird Brothers would have eaten their very heads off sooner than have sent out such a floating coffin."

Mr. Coventry gazed at me inquisitively, and I wondered what his opinion was, but did not ask him. Perhaps he had an idea that I did not know much because I said so little, probably he fancied that I approved of everything upon the principle that "silence gives consent," but his ignorance was bliss. The fact was that I saw and relentlessly noted in my own mind everything before me, but refrained from saying anything that might hurt his feelings, in consideration of the kindness and courtesy I had already received from him. Another reason was that he only acted as the irresponsible agent for the brokers, and therefore it was no use saying unpleasant things without some definite object in view. The conclusion I had come to, however, so far as I had gone, was that I would give Mr. Bellingham a sweepingly condemnatory report of the vessel, and thus stop all further proceedings, but this my telegram "unsatisfactory" would partially forestall.

"I think we better go down to the engine-room now," said Mr. Coventry. I thought so too, so away we went.

On reaching the starting platform I could not help admiring the machinery, as everything looked so smart, so trim, so bright. The connecting rods, and all the other gear I was so familiar with, were highly finished, and were indeed splendid works of art, so far as I could see at least, but upon gazing inquisitively round the engine-room I was unable to discover any name plate with the maker's name and date of manufacture. Now, if I could only have found this "missing link," with the usual Egyptian block letters so arranged upon it as to indicate that "Caird & Co.," "Maudslay, Sons & Field," or any other well known firm, had been the builders, I should have felt complete confidence in the excellence of the work before me. I fancied, however, the plate had been taken down for repairs, or, perhaps, had been forgotten by the engineers.

"Who made these engines," I said to Mr. C.

"Oh!" replied that gentleman, "they are made by a very eminent Northern firm whom I know intimately, but—tut, tut—dear me! I can't for the life of me, remember their name at present."

"Don't trouble yourself," I said, "you will remember it by-and-by without any exertion."

I thought this strange, so at once began to investigate for myself, and very soon discovered that underneath this fair exterior there was a great deal of vile fitting. In other words, things were loose when they should have been tight, and stiff when they ought to have been easy. It happened, however, that the cover of the crank shaft after-bearing had been taken off, and was lying on the floor, so also were the nuts belonging to the main bolts. Down I went therefore to the lower regions to have a look at them. The cover was right enough to be sure, but upon trying the nuts on the holding-down bolts I was so shocked to find the screws loose and shaky, that I could not help mentally exclaiming—

"Can it be possible that any decent engineering firm could send out such atrocious work? If this ship ever runs close to a lee shore in a gale of wind I would not give a sixpence for her safety. Napier and Laird would have closed their establishments sooner than make such things." This discovery made me still more suspicious about everything I could not see, so I returned to the starting platform, where I met the chief engineer, who had all this time been looking after the boiler-room arrangements.

"Remarkably fine pair of engines, sir," he said, upon ascertaining who I was,—"never saw anything work smoother in my life."

"Who made them?" I asked.

"They are made by a first-rate firm in the North, but"—running his hand through his hair—"drat it all, I can't remember their name just now; it will come into my head in a little I have no doubt."

Upon observing some of the other "hands" going about, I shouted in a clear, ringing, and somewhat angry tone—"Do any of you know, can any of you tell, who made these engines?" but they were all speechless.

Taking one thing with another, I was fairly puzzled while trying to find out what all this jugglery meant. The steam was getting well up, so Mr. Coventry proposed that we should start at once.

"Just about time," I said. "It is now eleven o'clock, and we have much to do."

The "chief" now began to warm up his cylinders by letting steam into them gently, but upon seeing the main bearing cover still lying on the floor below, I was just on the point of shouting out—"Haven't you got that cover screwed up yet?" when I checked myself, as it was not etiquette for a visitor, however interested he might be, to give orders on board a ship. I now had a turn through the tunnel to see what I could see, and with the intention of treating the boiler-room in the same way later on. Here, however, I was agreeably surprised. Everything looked smart, clean, tidy—the cooling cocks and pipes were in good order, so also was the lifting gear overhead.

"Very nice indeed, so far as can be seen," I thought. "As for the bearings, they are the only specimen of Whitworth fitting I have discovered in the ship—perhaps just a little—quite a wee bit too ——." It was only an idea that flashed across my mind, hardly worth mentioning at the time, but nevertheless a source of unexpected trouble afterwards.

CHAPTER XXIII.

END OF THE FATAL TRIAL TRIP.

Ship off at Last—Slow speed of Engines—Mr. Coventry's promise—Increased Velocity—Bad working Engines—Suspicions aroused—Study of Characters in the play—High speed, and effect on hull—Heated bearings in Tunnel—The Remedy—Painful discoveries in Engine room—Terror-stricken "Chief"—Dreadful Smash, and Boiler Explosion—Loss of the "Orinoco"—Reflections upon the event—Practical Lessons.

THE engines had now started slowly, and we were fairly off from Gravesend, but, with the exception of thumping and bumping and jolting in various places, which I had already predicted, there was nothing special to comment upon; the chief engineer, too, seemed quite pleased with everything. After we had been going on at this rate for about an hour, I said to Mr. Coventry—

"Can't we go ahead full speed, now that we are well out?"

"Certainly," said he, "I will tell Mr. Davenport to put on full steam at once; I am glad you mentioned it."

Another half hour passed, but there was so little improvement that I again ventured to approach Mr. C. on the subject. "Dear me!" he remarked, "what a stupid man that engineer must be; I told him distinctly to go ahead full speed. He must have forgotten it, surely. I will go and look after things myself now," and away he went to give orders in the boiler-room, but, curiously enough, I never saw him again. I am naturally of a sensitive disposition, and, on the spur of the moment, somewhat prone to imagine evils that do not exist, and, as my companion thus expressed himself, there was something in his manner that rather surprised me. I tried, however, to dismiss the idea from my mind, but *was* it a fancy? We shall see.

The engines now went ahead in grand style. They had been running all the time at about 40 revolutions per minute, but that had been increased to 60, and if they had kept to this speed I would have been quite satisfied, but, somehow or other, it increased rapidly. In a short time the revolutions had gone up, first to 70, then to 80, and now they were 100 per minute, and manifested no intention of stopping there either.

The clattering and thumping of everything had become so great that for the last time I thought of my report, which I had decided should be very brief, but crushing in its arguments against Mr. Bellingham's purchase of the vessel. One ray of light, however, indicated to me that I would thus clearly shew him that my hundred guinea fee had been well earned, and that my professional assistance would save him from utterly throwing away a good many thousand pounds.

I next turned over in my own mind all that had occurred since I left Liverpool, and in the following manner.

"Mr. Bellingham is an honest, straightforward, and thoroughly reliable gentleman; no mistake about *that.* Mr. Coventry is—well, I *did* think he was the same, when I first saw him, as his kindness and amiability prepossessed me entirely in his favour; but now I think differently of him. At this very moment I have reason to believe that he is not only most plausible in his speech, but,—what is worse,—cunning and deceptive in his acts, and I am sure of this from what I have already seen. The chief engineer seems to be of the same breed, and evidently knows very little about his engines or their management. Captain Vanderdecken is entirely beneath my notice, and as for the other hands, they are 'duffers,' every one of them." The only conclusion I could come to after summing up these unpleasant facts was, that all on board were a pack of artful deceivers, and totally unworthy of the slightest consideration.

The speed of the engines,—now increased to 180 revolutions per minute,—was extremely disagreeable for the ship, if for no one else, as the unfortunate vessel was quivering violently from stem to stern, and seemed as if she were going to pieces. A man who looked down the skylight told me, on being questioned, that our speed was "31 knots an hour, sir," but strange as it may appear, I did not consider it very remarkable, because at this time my mind was fixed more upon the machinery than anything else, and, even when I came to reason out the matter, I concluded that such a high velocity was only the natural result of certainly a most extraordinary cause, which I investigated in this way:—

"If our steamer can run fourteen knots at sixty revolutions, she ought, theoretically speaking, to go forty-two knots an hour at one hundred and eighty per minute, but inasmuch as retarding forces, such as increased resistance of the water, augmented slip of the propeller, and 'skin resistance' of the hull have to be allowed for, we cannot take off less than about eleven knots, which will bring down the velocity to thirty-one, as the man has just said."

The suspicions that had been aroused on my visit to the tunnel were now awakened, so I immediately entered it just to see how things were working, but the moment I did so was received with a blast of steam which quite took my breath away.

"Good gracious!" I said to the hand nearest me, "where is all this steam coming from?"

"The bearin's is heatin', sir, and we're pourin' water on 'em to cool 'em."

Not caring one pin what the engineer said, I shouted "All hands stand by the bearings, open every cooling cock in the place full bore, and flood the ship rather than crack those plummer blocks or break the shaft."

They obeyed my orders—the ship *was* flooded—dense volumes of steam prevented us from seeing anything, nevertheless we felt our way cautiously, and all danger was over, so far as we were concerned. On returning to the engine room, however, what a spectacle met my astonished gaze! never in my life will I forget it. The whole place appeared in semi-darkness, which was only illumined by a lurid glare which enabled me to reach in safety the foot of the engine room entrance ladder. From this commanding spot I could see everything. The crank shaft bearings were luminously hot, the piston rod guides frightfully grooved and giving off showers of sparks, the cylinder lagging was in a blaze, and red hot steam blowing off at the stuffing boxes, owing to the packing having been burnt.

The engines seemed to have reached their very highest speed, and were tearing away as if "Clootie" himself had got hold of them and was driving us all to Inferno, amidst the most unearthly noises and smells I had ever experienced. It seemed as if marvels would never cease on board the "Orinoco," and I wondered if we were going to have the "Amazon" story over again?

Just as I was thinking of going on deck, the "chief" came to me with a terror-stricken countenance, and said, "I think, sir, we better slow the engines, or we may have a breakdown. I would have done so long ago, but had to obey Mr. Coventry's orders."

"Certainly," I replied, "stop them at once, they have done enough of mischief already, and may do more."

No sooner did he touch the stop valve gear than the high pressure connecting rod snapped through the middle, and at the same time the piston and cylinder cover were smashed to atoms, while the lower half of the rod broke into the condenser, cracked the bed plate, and finished up by punching a hole in the bottom of the vessel, through which the water came in like a flood, and all in a twinkling, too!

In spite of the dense volumes of steam by which I was surrounded, I succeeded in reaching the deck, only, however, to have another startling experience. The whole of the waist of the ship was in a blaze, and the vessel, even at reduced speed, was positively flying through the water, far out of sight of land. I had just gazed for a moment in a horror stricken manner at the awful scene, when one of the boilers exploded and blew out the side of the steamer, which in a few moments foundered.

Down she went, sucking me after her—down—down—down; it seemed like a hundred thousand fathoms, and yet I could not reach the bottom. With fortunate presence of mind, I struggled for life, and striking out to the right and to the left, at last came to the surface; but as I did so, received a tremendous blow on the forehead from a piece of timber which had come up with me. While feeling about in a stunned manner for something to keep me afloat, I found what I thought might help me in the darkness by which I was enveloped; indeed, it was the only thing within reach, and, although soft and flabby, it was still better than nothing. Returning consciousness enabled me to make a closer examination of my position, and I could hardly express my emotion when I found that what I had in my hand was nothing less than my dear old friend *Chambers's Journal!* who had come to my rescue in the ocean, as it had done so often on board ship in youthful days.

"But stop a moment," I said, upon further consideration, "Am I at sea at all? Dear me! is it possible? Can I believe my eyes? for surely I can discern things not usually to be found on the bosom of the Atlantic. I see a gasalier, and the walls of a room covered with pictures, and a fire place right in front of me!!"

"Where am I then?" I thought, and immediately the whole truth flashed upon me. The vividly realistic and active scenes I had been engaged in were, after all, merely a wild creation of the brain—in short, what is commonly called a dream! This discovery gave me intense relief, and thankfulness that I was still in the land of living.

The hundred guinea fee was, of course, lost, and as for the remains of the £10 Mr. Bellingham had so kindly given me for expenses—well, they could not be found, but under the circumstances I felt no regret. It was also consoling to find that I would have more time next day for pushing on with the iron pier and bowstring bridge in which I was so interested.

Ten o'clock had just struck, and upon thoroughly rousing myself up, the whole truth flashed upon me.

When I sat down about 7.30 in a chair before the fire to read the P. and O. story, I felt somewhat drowsy, and my excellent mother—who, through a long lifetime, has studied my welfare—said to me, "Don't tax your brain too much by reading that book, you have had a very busy day, take rest when you can get it."

I said, "The story I was reading was quite a pleasant relief after the office cares, and that rest with me lay in *change* of employment." However, in a few minutes, I reluctantly laid down the book on my knee in deference to her wishes, and was left to sleep undisturbed for two whole hours. At the end of that time I must have moved in some way or other, as it now appeared that I had fallen off the chair and knocked my head against the mantel-piece, which of course aroused me. I then picked up *Chambers's Journal*, which was lying on the rug, and this explained what seemed to have been my last struggles in the sea. Here, then, was the solution of the mystery, and this is how I spent my hours of sleep, and—"rest!"

Let me only add, that with the exception of the remarks upon an engineer's report, which are quite correct, and also those upon railway travelling, which are equally so, this "*Story of a Disastrous Trial Trip*" is merely an imaginary scene, that is to say if collectively taken, but if looked at from an analytical point of view, it is not. Though somewhat fanciful in construction, it has nevertheless a great many veins of truth and threads from my own experience interwoven with it, and may therefore be considered a fair illustration of the manner in which the inexplicable machinery of the mind is sometimes actuated during the hours of sleep.

When office work is not harassing through outside pressure, an engineer can sleep as well and as soundly as those gentlemen the great Cæsar liked to have about him. There are occasions, however, when he is called upon by a client to design something of a perplexing nature as rapidly as possible. No time must therefore be lost, and all the resources of past experience have to be suddenly utilized to tide him over the difficulty. For this reason he has sometimes to make the drawings himself to save time, instead of instructing assistants to do so, which thus entails very active mental employment. If, however, it is anxiously continued, not only during the day, but through the evening, and into the small sized hours of the morning, the mind becomes somewhat strained, and upon going to bed in the early dawn the engineer may take his plans and calculations with him, and during the watches of the night be busily running over them all. Such, indeed, has been my own experience when unduly pressed.

For example, after going to bed with the intention of sleeping, I have had what you might call a rough night, or morning of it, having been engaged all through the state of somnolence in making calculations, designing and drawing plans, and so on. The worst of it was, that the cantankerously unmanageable things never would come right, and no matter what I did, every effort failed. Calculations would persist in being wrong, colours would not go on a drawing properly, and nothing I could think of was either feasible or workable. There was always something missing that had to be found, something incorrect, something unattainable, and I was glad enough to find on awaking that it had all been a dream.

This unpleasant state of things appears to have been the lot of Napier's shipbuilding manager for weeks before the launch of H.M.S. "Black Prince," owing to heavy responsibility and the local difficulties by which he was beset. Indeed, undue professional anxiety concerning new and complicated schemes, may do much mischief to those engaged upon them, and of this we have only recently had a tragic example.

Although to superficial thinkers the subject of dreams may be unworthy of notice, it nevertheless possesses features which deserve consideration. An ancient writer has said that—"There is as much temerity in never giving credit to dreams, as there is superstition in always doing so. . . . Treat them as you would a known liar, who usually tells falsehoods, but *sometimes* speaks the truth." This has been frequently confirmed in modern times, by people who have been urged to act contrary to their own judgment in important movements by means of these premonitions, and the result has been variously beneficial.

One of the titled families of England owes its immense wealth to the dream of one of its ancestors who, when captain of a frigate, during the Peninsular War, was thus compelled to disobey Admiralty instructions.

The most extraordinary event, however, of this kind happened to a ship that sailed many years ago from Liverpool to Valparaiso. She had a fine passage as far as the Falkland Islands, when one night the commander was powerfully forewarned in his sleep that if he rounded Cape Horn they would all be lost. The idea clung to him in spite of every effort to throw it off, and he was obliged to return to the Mersey. The vessel was sent off again with another captain, but to this day no one knows what became of her.

My own experiences have been peculiar. During the hours of sleep I have sometimes taken part in the most vividly realistic scenes, a few of which have been dreadful. Locked up in the cabin of a steamer, I have stood alone with murderers, and the last moment had come. I have clung in despair to the narrow ledge of a lofty precipice with instant death awaiting me, and I have had the honour of going down with a foundering ship. Such events can never be forgotten, neither can the marvellously simple means used in each case for obtaining help in those moments of extreme peril. To my intense relief, the murderers were changed, as by the lightning's flash, into statues—the precipice gradually melted away to level ground—and when the ship had sunk I was safe at the mast head.

Although in one thousand instances dreams may have no significance, the ominous one thousand and first may bring prosperity or adversity, and may, indeed, kill or save, according to circumstances. Those mentioned above have, however, proved a lasting source of encouragement to myself, and have also occasionally foreshadowed what has actually happened in daily life.

There is nothing, perhaps, more surprising than the unexpected and unaccountable manner in which people in difficulties sometimes have their way opened out, and things in darkness made plain—after many fruitless efforts—by means of ideas caught, they cannot tell how; by people met they did not even think of; and not unfrequently, through the action of the mind during the period of *rest*, when the engineer is sometimes most intensely occupied—as we have tried to show in this chapter.

CHAPTER XXIV.

HOW I COMMENCED PRIVATE PRACTICE.

Birkenhead Iron Works in 1867—Dull times—Idle Engineers in London—Crisis in 1872—Retirement from the Works—First movements in a new direction—Advice of friends—Serious obstacles—The Generous C.E.—Success at Last—Cause of difficulties in Private Practice—Hints to those intending to enter upon it—Index Books and Engineering Literature.

DURING my long stay in the Birkenhead Iron Works, we had two periods of great depression, the first of which was in the year 1867, and the second in 1872. In the former case, we had been gradually working every order out of the place, until there was very little indeed to be done, and, what was worse, nothing coming in.

The report came that, in London alone, a great number of draughtsmen were unemployed, and, soon afterwards, one of them was taken into our office after eighteen months of compulsory idleness. This intelligence made us feel uncomfortable, because everyone would have felt very sorry to leave such an excellent and hitherto most steady establishment. Quite apart from the dulness which pervades active minds when employment fails, there is always the dread on such occasions of being idle for a very indefinite period, and with one's income stopped, and no private means, this is doubly severe.

Just when things had come to the worst, as we thought, an order was received for a great ironclad for the English Government, which set us on our feet again, and soon afterwards other contracts came in, and we were kept busy for years.

In 1872, we had another very dull period. Vessels were launched, completed, and sent away, one after the other, but hardly any new orders sprung up, although we tried for several. Unfortunately, there were too many people who either could not or would not pay a reasonable price for high-class ships or machinery, and thus our estimates so often failed. Well, in consequence of this, and also on account of previous overbuilding throughout the country, our work died away to such an extent that a climax came from which there was no relief. The expected reduction of the staff at last took place, about the end of the year, and I happened to be one of those selected for retirement from the service of the Firm.

One day the manager sent for me. "Now then," thought I, "it's come at last." And so it had. On entering his room, he said, "You must have observed for some time past how little there has been to do in the office."

"Oh, yes," I replied.

"Well, then," he continued, "as we have no orders coming in, nor even a prospect of any, we shall be obliged to reduce our staff, I regret to say, and dispense with your services"; but adding, "There's an advertisement of Humphrey and Tennant's"—pointing to it in *The Engineer*—"you might look after."

"Very sorry, indeed," I answered. "When do you wish me to leave?"

"Oh! I am in no hurry about it; say three weeks or so."

I went upstairs, depressed at the prospect of my compulsory departure; but when I began to consider things, I soon regained my usual brightness. "Now then," I thought, "here have I been these many years, gaining valuable experience, certainly, but without a chance or hope of promotion, and if I remained in this establishment for some time to come, it would make little difference to me. I should not be at all surprised if my prospects are not so dark as they look, and this unwelcome change may work out something better, though I cannot see how." This idea gave me a spring at once, and I became as merry as a lark, because the back door was closed, and I was obliged to make some unknown but forward movement.

When the time arrived, I went to the manager for my certificate. "Oh," said he, in such a kind manner, "you had better stop another fortnight, and see if something does not come in."

I did so, but, as no fresh work made its appearance, I soon found myself "at sea," so far as the future was concerned. My next move was to call upon a number of shipowners and engineers in Liverpool, with the object of sounding them as to the possibility of starting on my own account as a consulting engineer. The former received me most courteously. Some said one thing and some another, but all agreed that it would be most difficult to commence at all unless I had something to "keep the wolf from the door for the first two or three years." The engineers held the same opinion, but in a more marked degree; indeed, one or two of them said it was impossible without help of some kind.

Here, then, was a damper at the outset, because, in the first place, I had no one to look to for employment, and, in the next place, I had only the remains of a small legacy to tide me over my difficulties for a time. Amongst those I visited was the proprietor of one of the brass foundries, whom I knew well, as he had made some thousands of pounds worth of work from my plans in former days. This gentleman often came over to see if we had anything for him to do, and sometimes went away hopeful, at least, if not joyous, because our drawings had not been sufficiently matured.

Upon visiting my old friend, he asked me whom I had seen, and what they had said. I told him.

"Have you seen Mr. A—— ?"

"Oh, yes."

"What encouragement did he hold out to you?"

The information was given.

"Well, now," said Mr. Marsden, "why don't you start for yourself? There's Mr. So and-so; *he* began on his own account some years ago, and has succeeded. Then there's Mr. Somebody-else, who did the same thing, and he has never gone back. Go and speak to Mr. A—— again, and say I sent you."

On my way to this gentleman's chambers, I met him on the street, and was told that whenever I could get something to do I might have the use of a desk in his establishment. This was very cheering, because the main obstacle at the outset was to obtain a decent office, and, at the same time, work to begin upon which would help to pay expenses. Up to this period, I thought I had seen nearly all the engineers who were likely to encourage me, but, a few minutes after the office difficulty had been settled, while quietly walking along Dale Street, I saw the name of a civil engineer I had not known of before, and immediately called upon him as a sort of forlorn hope. He received me very kindly, and asked if I would help him with some plans he had to prepare, and, upon telling him I would be very glad to do so, they were at once handed over to me.

I went home happy that night, because one of the most fortuitous coincidences imaginable had, in a single hour, removed from my path two apparently insurmountable difficulties, and also opened out my prospects for the future. That is to say, I had found an office and remunerative employment, when to all appearance there was not the slightest chance of either.

That generous C.E., who had also an establishment in London, has never, I believe, had occasion to regret having extended a helping hand, and given the first five guinea fee to one by whom he will always be gratefully remembered. The temporary desk gave place in a few weeks to a permanent office, and, in course of time, I came in for a civil and mechanical engineering practice of a most varied and interesting character. One part of my experience, however, consisted in sailing tremendously close to the wind, and trying to make headway against the usually small amount of financial success. So hard, indeed, was this species of navigation, that, had I not been possessed of private means, there were critical periods in which all my professional experience would have proved unavailing, and I would have been unable to keep to the course I had endeavoured to steer.

This will be easily understood when it is stated that one of our ultimately most successful engineers could only make sufficient to pay his office rent for the first five years. This gentleman I knew well; he, however, had the advantage of a private fortune, which many of our tribe have to do without.

Another friend of mine, who for a considerable period was superintending engineer to a great ocean line of steamers, had £1,000 a year for looking after them, but was obliged to retire on a pension, as his health would not stand such a severe strain. He, however, began on his own account, and notwithstanding the prestige derived from having been associated with so eminent a firm, absolutely failed to obtain any employment connected with ships for more than two years afterwards. In this case, his great ability seems to have been unrecognised on account of his too retiring disposition.

It will thus be seen that even when accomplished engineers commence to practise their worst difficulty consists in getting work to execute, unless they have been fortunate enough to secure a few good clients beforehand, and this, in many cases, is almost impossible.

The reason of this is that so many people are retained in important positions, such as engineers in chief to railways, docks, and harbours, city and borough engineers to towns of all sizes, and so on. These men, at the head of experienced staffs, do an immense quantity of the work that in early days fell into the hands of private practitioners, who by this system are deprived of an enormous amount of employment. So much is this the case that, although there are a few who have made large fortunes, a great proportion of the remainder make, considering their capabilities, incomes of—well, I should be ashamed to say how much, or, more correctly speaking, how little. This is a sore point, but as I am giving a faithful description of the profession, I shall, while explaining its beneficial qualities, take care to throw some light upon its dark features, which, it is needless to say, are almost entirely of a financial character.

To give a little variety, I also hope to sketch in their proper places a few of the humorous and peculiar aspects of engineering life from a private point of view, and endeavour to show how and where improvements might possibly be introduced.

Some may ask why I did not commence private practice sooner. Well, that is easily explained. In the first place, it is very risky to leave permanent and good employment for what may be very uncertain, unless you have reasonable inducement to do so, or have sufficient means. And secondly, so great has this risk now become that people are more or less content to run in a groove until pushed out of it. In other words, we think it safer to bear the ills we know than fly to those we know not of. If the history of some of our most successful men could be analysed, we should find that in many cases they owed their prosperity to some unforeseen movement which threw them involuntarily on their own resources and caused them to look about elsewhere. Indeed, purely accidental circumstances have often done more to advance people's interests than the most skilful, and long sustained planning could possibly have accomplished.

To enable engineers to succeed in private practice, or, indeed, in any other way at home or abroad, it is often necessary to have a good general knowledge of the profession outside of the particular branch—say locomotive or marine—that they have been educated to. This will be apparent when the difficulty of obtaining employment is considered, and therefore it is to one's advantage to be able to direct the mind to other lines of thought and study.

For reasons already stated, the locomotive branch can only give experience of a limited nature, and does not allow of much expansion. On the other hand, *railway* engineering has a very extended sweep, and embraces a great variety of most interesting subjects, such as bridge building in iron and brick or stone—roofs of all sizes from that of St. Pancras to those of little roadside stations—steam and hydraulic machinery of every description—constructional ironwork, such as girders, columns, etc., and a thousand and one other things most necessary for the safe and economical working of our iron roads. Marine engineering is also of a similarly varied description, so varied, indeed, that people with fair ability and a certain amount of adaptability to different pursuits, may easily take in hand work of a general character.

To those who have time and opportunities, no difficulty need exist on such points, because there are now so many avenues of information open to all who wish it. People who venture upon private practice will soon find out, unless possessed of powerful influence, that, for the first few years, they will have a great deal more spare time than is desirable, and may frequently be at a loss to know how to occupy themselves advantageously. In small towns this will no doubt be severely felt, but in large cities it need not be the case, when a valuable reference library may be within easy reach, from which an immense amount of professional knowledge may be obtained, and thus provide much that is interesting, and perhaps profitable in the future.

The engineering literature of the present day is most extensive and practical, so extensive, indeed, that a student may often be unable to know what to do with it. It may therefore be broadly stated that, if only a small part of the really useful books and periodicals were carefully studied, no time would be left for anything else. Of this I soon became aware, and therefore employed a simple system of notation, which in various forms is well known, I should think, in many of the professions.

We all require as much information as possible, but without slavish and unnecessary labour, and this can easily be accomplished in the following manner :—

Read most carefully everything that bears directly upon what may be your own practice in the near future ; pick out simple formulæ which are *not* given by Molesworth, or Hurst, or D. K. Clark. Analyse minutely the results of experiments on various metals, timber, and other substances, also any other useful information which may be gleaned from the great mass of books and periodicals, and enter your conclusions in private note-books, morocco bound or otherwise,—generally the latter.

In the next place, glance at, more or less intently, any number of volumes you please of a kindred nature, and transfer the titles of their contents very briefly as aforesaid. If this is done as the years roll by, an enormous amount of valuable information will be at hand for immediate reference, which may tide the engineer over many critical points, and enable him to work rapidly and confidently. These note-books should be well bound in soft leather, stepped down at the edges, and red lettered, with so many pages to each letter, according to expected requirements, and every entry should be as brief as possible. Notes from professional and general literature, however, should — for easy reference—be kept separate from the invaluable sketches, tables of detail proportions, and simple formulæ obtained from actual practice.

Since calculations and statements referring to work in progress are so important as to involve the possibility of serious accidents unless clearly understood, the engineer would do well if he compared one authority with another, and endeavoured in every possible way to obtain a rational interpretation of formulæ which so often appear to be empirical, but are nevertheless based upon scientific reasoning, as we have endeavoured to show in a previous chapter. Our opinions—like those of medical gentlemen and also lawyers—often differ in detail, but vital principles in design and construction are the same everywhere, and cannot be too closely followed out.

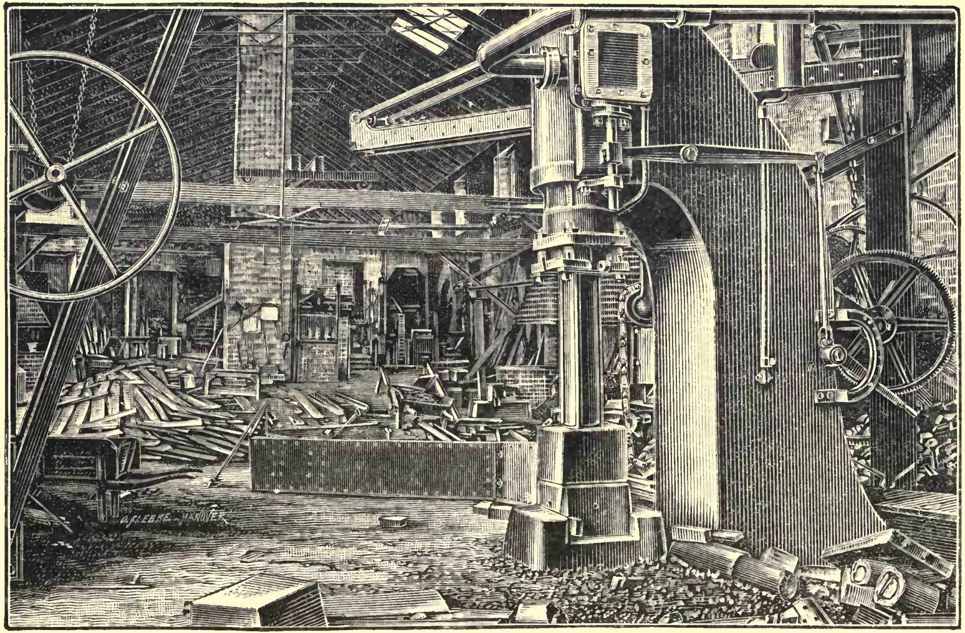
If from the deck of a ship in mid ocean you were to throw into the sea a bag of sovereigns, it would be lost; but if a cord had been attached to it the money could easily be recovered. And thus it is that the science of memory can be similarly made to call up from the depths of oblivion something that had been forgotten. This science is based upon three great laws:—the Association of ideas—the Assimilation of words or phrases—and the Location of persons or things.

Firstly, you associate the missing link with some amusing, etc., circumstance, and the link is found.

Secondly, you remember it was the S.S. "Golconda" that brought your daughter from Calcutta, because the ship carried a large amount of *gold*; and

Thirdly, when upon passing someone on the street, you become perplexed because you cannot remember a previous meeting, the whole surroundings of the individual are at once revealed as it flashes upon the mind that you saw her in Sydney or Bombay, or indeed in any other part of the world.

Now this is *rational* science, because the scenes are effectively pictured in the mind, and every connecting circumstance can therefore be easily and pleasantly



PORTION OF THE FORGING DEPARTMENT, "NEPTUNE" WORKS, NEWCASTLE.

recalled. So also is it with figures when you know how the thing is done, and hence the science of memory is very useful to the engineer who frequently requires its aid in many ways. It is not necessary to apply the art in a general sense, because it would be too cumbersome, but enough may easily be learnt to enable the practitioner to remember useful facts and figures at any time, and also to improve the natural memory in a charming manner by the pictorial concentration of thought thus created.

Besides the professional information just referred to, an engineer should have an extensive knowledge of the various firms who make machinery of all descriptions. He will thus be enabled to advise his clients in the best manner regarding the purchase of what they require, and its suitability for the purpose intended. The plate opposite has been described on page 286, and contains a good illustration of a steam hammer much used in marine works.

The disappointments of private practice are many, and the vicissitudes one experiences amidst the best sustained efforts too numerous to mention. However, as the poet says :—

> " 'Tis not in mortals to command success,
> But we'll do more, Sempronius, we'll deserve it."

And as an encouragement to the members of all professions whose hopes may be somewhat blighted, we may appropriately close this chapter with the well-known words of another writer :—

> " Honour and fame from no condition rise,
> Act well your part, there all the honour lies."

CHAPTER XXV.

HOW "COMPETITIONS" ARE CONDUCTED.

Architectural and Engineering Schemes—Eatanswill Bridge Competition—Town Councillors' Invitation to Engineers—The Opening Day—Arrival of Plans—Character of the Town Councillors—S. J. Drayne, the Borough Surveyor—Alfred Sketchly, the Draughtsman—How he spent his Apprenticeship—Private Note Books—Discussing the Plans—Mr. Drayne's Advice—The Draughtsman's Logic—Results—Present System of Competitions — Skill and Labour required in preparing Designs and Estimates—Improved System—"Iron Pier Competition."

THERE is no class of work in which engineers, as well as architects, have been so scandalously abused, as that known by the term "Competitions," and so important is this subject that I propose to devote a whole chapter to its consideration.

With many architects, the preparation of competitive sets of drawings necessarily occupies a large amount of their early and unremunerative practice. So also is it sometimes the case with engineers who are ignorant enough to enter upon such work, unless the information or employment it yields is a sufficient inducement. The true object of a competition is to obtain from as many able professionals as possible a set of plans, estimates, etc., expressing their matured ideas in reference to a bridge, railway station, promenade pier, or, indeed, anything else that has to be built on the most approved principles, and in the most desirable manner. When these plans have all been prepared, they are sent on a certain day to the secretary, or other official, of a Company or Corporation.

At the next meeting of the Board of Directors, these plans, specifications, and estimates are carefully looked into, and their merits balanced. "Alpha's" design is compared with those of "Beta," "Gamma," and "Delta," and all the others come in for a fair share of skilled and judicious criticism. Plenty of time is taken to consider the matter, and at last the prizes are awarded to the successful competitors, and the gentleman first on the list is requested to carry out the work, but his prize money is included in the commission he will receive, generally five per cent. on the total cost of the undertaking, exclusive of land or other expenses he has nothing to do with. If, however, he takes out his own "quantities," two-and-a-half per cent. in addition will be allowed on the total amount of the accepted tender.

Now this is as it should be; but is it always, or even frequently, so? I am sorry to say it is not. In too many instances, "this is how it is done," as Dr. Lynn used to tell his audiences.

Suppose, for example, that a handsome road bridge has to be erected across the river Muddle, which cuts the town of Eatanswill in two, and is required to supersede the old ricketty wooden structure which has been used for no one knows how many years. The first thing to be done is to obtain the consent of Lord Portansherry, who owns the whole of the property, and who will be very glad to sanction the scheme because he thinks it will do him good indirectly, as well as the townspeople, who feel that it is a necessity.

A meeting of the Town Councillors is now held to decide upon what is the best thing to do in the matter. One gentleman proposes a stone bridge, as there is an excellent quarry close at hand, which belongs to him.

Another, who is a timber merchant, and has been in America, thinks they ought to have a trestle bridge, because it will cost so little; and, lastly, one of the "committee," who had six months' jobbing in a small foundry, and fancies himself an "engineer," advises them to make it of iron, and "he will see that it is well done."

As the latter is considered quite an authority in the manufacture of iron, his proposal is adopted, and it is definitely settled that the new structure shall be of that material, and in every respect suited to the requirements of the town. And, since their own low salaried borough engineer is too inexperienced either to design or to carry out the details of the proposed bridge on his own responsibility, it is also decided to "invite" engineers, through the columns of the professional journals, to send in competitive sets of drawings, with specifications and estimates, by a certain date. The invitation reads as follows:—

"BOROUGH OF EATANSWILL.—PROPOSED NEW BRIDGE.

"The Town Council of the Borough of Eatanswill, acting as Urban Sanitary Authority, INVITE COMPETITIVE DESIGNS and ESTIMATES for the CONSTRUCTION and ERECTION of a WROUGHT IRON BRIDGE over the River Muddle, with the necessary foundations, piers, abutments, and approaches.

"The Bridge is to be 200 feet long, by 35 feet wide, and adapted to carry a moving load of 20 tons.

"A plan and sections of the proposed site and approaches, with other particulars, can be obtained on application to Mr. Streeter J. Drayne, Surveyor to the Council, Town Hall, Eatanswill, to whom all estimates and designs, under seal, must be sent on or before the first day of June.

"The Author whose Designs and Estimates, in the opinion of the Council, shall be considered best suited to their requirements, will be awarded a premium of £25, unless he be appointed at the usual commission to carry out the Works.

"By order,
"E. VERNON QUILLE,
"Clerk to the said Council.

"Eatanswill, 11th May, 1889."

Let us suppose that the opening day has arrived. Fifty or sixty sets of plans having come in, a second meeting of the committee is held for the purpose of examining the drawings and considering their merits. The members now assembled are all good and true, and also accomplished men; that is to say, good at selling spirits, groceries, meat, etc.,—true to their own interests,—and accomplished in the art of painting, or at least colouring their statements to suit their own ideas. Not one of them knows anything about bridges but the ironfounder, and his information is so superficial as to be practically of little value. With this exception, however, you might just as well talk to the Horse Marines about "ties" or "struts," "top and bottom flanges." "buckled plates," or "cross girders," as to his colleagues. Another feature they possess is, that actions which each would consider dishonourable are thought quite excusable when taken collectively by the Town Councillors.

We shall now imagine them all sitting round a table in the committee-room, with the plans exposed to view on the walls, and, with Mr. Drayne, the borough surveyor, on one side, and Mr. Sketchly, his draughtsman, on the other side of the chairman, they are ready to begin operations. Before describing the next scenes in the play, however, let us say a few words concerning the two professionals, whose services will be of a very important character.

Mr. Drayne served his apprenticeship in a builder's office, in London, and acted as draughtsman for some years to the borough surveyor of a small town. He was one of those inquisitive people who are profoundly impressed with the idea that the surest road to success is by picking up all the professional knowledge they can, and grabbing at every kind of information that comes within their reach, and may possibly be useful to them at some time or other. The result of this line of action in days gone by is, that Streeter J. Drayne, Esquire, is now installed in his present position, and, although the salary is not much, the experience gained while thus employed will prepare him for a more lucrative appointment in course of time, which, indeed, he is now aiming at.

If you had a peep into his private note-books, you would find all sorts of memoranda and tables, compiled from a great variety of sources, and having special reference to hydraulic calculations of various kinds; useful particulars concerning gas and water works, and also sanitary engineering in general; notes of experiments upon the strength of brickwork, cement, mortar, timber, and an immense quantity of general information which he now finds most useful.

Mr. Sketchly, on the other hand, was a pupil of Fairbairn's for five years in the works and drawing office. He was a lively, happy youth, and liked a joke at times as much as anyone, but was, nevertheless, one of the most acquisitive characters that ever entered the famous Canal Street Establishment. The great engineer no doubt knew pretty well what to expect from the dashing sons of Continental counts and barons, and also English gentlemen, whom he received from time to time. In other words, he had a good idea that many of them would make engineering a sort of fashionable amusement, and leave him with little more practical knowledge of his splendid water wheels, beam engines, and other machinery, than when they began their apprenticeship.

With Mr. Sketchly, however, the case was very different. He, too, was connected with the "upper ten," and had been brought up among London west end society, but owing to the death of his father, who had been a colonel of the Bengal Fencibles, it was necessary that he and his brothers should bend their whole energies to whatever pursuit in life they entered upon. Reduced means, therefore, to provide for the wants of a large family was the mainspring that set them all a-going, and stimulated Alfred Sketchly to active exertion in the profession he delighted in.

Nothing escaped his notice, either of an inside or an outside character, relating to the daily practice in the works, and, however idle and vapid the other apprentices might have been, there was one, at least, amongst them who went in and came out with the intention of using every effort, and watching every chance of obtaining information which would enable him, when future opportunities arose, to climb hand over hand, in sailor fashion, until he reached the very top of the tree. And thus Mr. Fairbairn's choicest practice was in a fair way of being utilized to the utmost—so also was that of other people in other places.

If Mr. Sketchly had allowed you to look into *his* private note books, you would have seen a large number of very neat sketches of engine, boiler, bridge, and general engineering details, carefully lettered in reference to accompanying tables of proportions, taken from the work as executed. You would also observe a great quantity of simple formulæ and memoranda of all kinds, derived from the very best sources, and forming an accumulation of several years' study. Such books, he would tell you, were absolutely invaluable to him, on account of the saving of time and the confidence they inspired when designing similar work, and forming, as they always do, a most efficient check upon the not generally trustworthy deductions of mere theory.

Now it so happened that Mr. Sketchly was quite a "dab hand" in every kind of bridge work, and Mr. Drayne was equally eminent in his own particular sphere. They also acted in concert most harmoniously, and tried to learn as much as possible from each other in view of future changes arising. We may therefore congratulate the Town Council of Eatanswill upon having obtained the services of these gentlemen.

Having thus introduced to the reader the company now assembled in the committee room we shall proceed to open the ball, or rather let the chairman do so in his own way.

After gazing quietly for a time at the array of "trellis," "lattice," "arched," and other bridge designs, with which the walls are adorned, that individual begins with a few preliminary remarks, and then, turning to Mr. Drayne, observes :—

"Now, what do *you* think of them 'ere drawin's?" pointing at them with his thumb.

"Well, sir," replies the surveyor,—who has been carefully instructed by Mr. Sketchly,—"I have just been looking over them all, and I think that, on the whole, they are a very nice collection of designs, but, in my own opinion, I consider 'Gamma's' piers and abutments have a very tasteful appearance, but his plan is too expensive. That lattice bridge by 'Alpha' looks remarkably well, but the struts seem to be rather weak"—"*Ties*," whispers the draughtsman. "As I was observing when Mr. Sketchly interrupted me, the ties seem rather defective in strength, although no doubt they may possibly do well enough. The most suitable of all the designs, however, so far as I can see, is 'Delta's,' and if we could only get it executed a little more cheaply, I think we ought to adopt his arrangement."

A lively discussion now takes place amongst the members of the committee upon the merits of every design, and the four Greeks, with their companions in misfortune, are fairly on their trial. One leading feature after another is pointed out and commented upon. The spirit dealer greatly admires the colouring and printing of some of the drawings. The greengrocer is charmed with a few of the piers and abutments, while the construction of others, and the cost of all, are fully considered. Some are in favour of one thing and some of another, but on those points which are really of the highest importance, none will agree.

Mr. Sketchly is the only person who knows anything at all on the subject, and able to give a good opinion, but as he is "only a draughtsman," his advice is not asked for. This gentleman takes good care, however, to show his talent by talking so freely about the technicalities of bridge construction that not a single member can follow him, although they are at the same time, astonished at his "cleverness." And if any of them objected to his style of reasoning, the "draughtsman" crushed them at once by observing, "*That is the way we used to do it in Fairbairn's.*"

Owing to the extremely varied and conflicting opinions of the committee, the ironfounder proposes that a new set of plans should be made, embodying all their matured ideas, and, as this proposition is unanimously carried, the chairman orders Mr. Drayne to "pick out all the best p'ints of them 'ere drawin's; arrange our improvements as you think best, and make the bridge cheap enough. Do you 'ear?"

"Yes, sir."

The plans are now handed over to Mr. Sketchly, who delightedly does the rest. Estimates are again requested for work to be done in accordance with his specification and drawings, and eventually a handsome bridge is erected, which Lord Portansherry has the pleasure of opening. The rejected designs, &c., are returned to their owners, after a few of them, at least, have been traced, copied, or noted in some way or other, with the object of facilitating the compilation of the "new and improved arrangement," and the successful competitor receives his £25, which, at the best, is miserable compensation for all his time and trouble.

The gentleman first on the list, who should have had the work to carry out, which was, indeed, the real prize he aimed at, is grievously disappointed, and all the others, who expected, at least, fair treatment, discover that their labour has been in vain, because there was no one on the Board who knew how to appreciate a good design when he saw it, or treat its owner with proper consideration. For the paltry sum of £25 the councillors obtained a large amount of valuable information from a great variety of sources, and perhaps the only legitimate advantage derived from the whole transaction was the knowledge thus conveyed to the numerous competitors regarding the treatment they might expect in future if rash enough to engage in similar work.

This subject was fully discussed at a conference of architects held not long ago in Manchester, on "Professional Practice," et cetera.

The Chairman remarked that—

"Competitions, as at present conducted, are becoming the very curse of the profession. The gross acts of injustice which are being constantly brought before us show clearly that some action must ere long be taken to remedy such a crying evil. Properly managed, they may be of use to many, and afford numerous opportunities for the display of ability, but such is seldom the case now. It is not the best design, as a rule, that is chosen, but one whose author has most friends. Very often he is practically selected before the competition is invited, and, after his selection he is allowed to adopt ideas taken from the real competitors' plans. . . . Fifteen hundred architects have pledged themselves not to enter into open competition, unless a professional arbitrator is appointed, but this alone is not a sufficient remedy."

Referring to estimates and contracts, this gentleman also stated that—

"It is well known to architects that the lowest estimate often means something less than cost price, and also faith in the chapter of accidents, such as alterations and additions, or scamping the work so as to obtain a fair profit."

We may only add that the above statements are applicable nearly as much to the engineering as they are to the architectural profession.

I hope, however, that none of my readers will imagine that the sketch of the "Eatanswill Bridge Competition" refers to similar undertakings in general. Nothing could be further from my intention. What I have said applies only to that obscure, but nevertheless well known, little town, and others of a similar nature. Of course, in the great cities things are done much more genteelly, but, in too many instances, the results, from various causes, have been much about the same.

We may, however, in common justice, try to believe that the state of things described is sometimes caused by the ignorance of people regarding the amount of skill, and time, and labour required for engineering plans, and this, unhappily, the outer world seems to know nothing of. A good design for a bridge, great roof, waterworks, et cetera, requires most careful, elaborate, and patient investigation of all the features of the case before the engineer can fairly realize what has to be done, and how it is most cheaply to be accomplished. In the next place, all the proportions, strengths, and arrangements of the various parts have to be calculated and sketched out roughly, for transference to the drawings as they proceed. This portion of the work requires as much exactness as if it had to be executed, because the specification, quantities, estimate, and expected success of the scheme, are entirely dependent upon it.

For the same reason, also, the specification must be a complete document in every sense of the word. The quantities are not often written out officially for a competition, but the engineer must nevertheless know, for his own satisfaction, what they amount to, before any correct estimate of cost can be arrived at. If, however, a merely approximate tender is required, which is seldom the case, these conditions can be materially simplified.

We may add that the architects have caused an improved system to be introduced, which is as follows:—

When competitive designs are required for a building, and, in accordance with clearly defined conditions, anyone who pleases may compete, all, however, that is required to be done, is to send in sufficiently illustrative sketch plans to a small scale. These preliminary designs are now examined by competent persons, who select, say about six of the best, the authors of which are requested to re-arrange in a larger and more complete form, with full specifications and estimates, and deliver them, as in all other cases, on a certain day to the secretary of the Company for whom the work is intended.

The plans are now carefully scrutinised by leading professionals, and one feature is intelligently compared with another, until a fair and impartial opinion is formed concerning their respective merits.

When this is accomplished, the owner of the design most approved of is advised to proceed with the details, superintendence, and all other works connected with the undertaking, until it is completed. For these services he will receive five per cent. commission on the accepted estimate of total cost, and two-and-a-half per cent. additional on the quantities, while the five rejected competitors will each receive perhaps from £100 to £150, or, as in the case of the Liverpool Cathedral competition, at least £300 for their trouble. The original sketch plan people, on the other hand, however, have no remuneration of any kind given them, but this they fully understood from the beginning.

Although this system is far from being perfect, it is nevertheless the best that has yet been devised, and if engineers were similarly treated we should have no reasonable ground for complaint. As the matter stands, however, regarding ourselves, it has become unworthy of the slightest consideration, and I am of opinion that those who engage in such work have either nothing better to do, or, what is quite as probable, are totally ignorant of the true state of affairs, which often prevents the real "talent," which is so much desired, from engaging in similar undertakings. There are indications, however, that before long this wretched state of things will have passed away.

It is my usual practice, when obliged to speak or write on disagreeable subjects, to try and throw in, somehow or other, a scintilla of light — a ray of sunshine— and, if possible, a spark of humour. I have therefore much pleasure in closing my remarks upon such an unhappy theme as "Competitions" with a felicitous experience of my own.

Some time ago a firm of Architects invited me to perform my share of the work in connection with an iron pile pier they were trying for. This pier was in numerous fifty-feet lengths of lattice girders, supported on cast iron columns or "piles." The land approaches were in masonry and concrete, and at the extreme outer end was a fine bowstring bridge of 140 feet span, leading down to a landing stage. Well, we sent in very clear and nicely finished drawings, which the "Commissioners" were pleased to consider better than any of the others, and at last they favoured us with the whole of the work to carry out in accordance with our own ideas. The pier was therefore erected in course of time, and has been doing excellent duty ever since.

We had a little pardonable triumph over this business, because another plan might really have been superior to ours, but the drawings we prepared were so explicit that the judges no doubt understood them easily, and considered themselves good engineers, without ever having used a file, or drawn a line.

After two years of successful working, the Eatanswill bridge collapsed while an ordinarily heavy load was passing over it, and both fell into the river, to the astonishment of the natives, and the confusion of the Town Council. The cause of this disaster was a weak point in the structure which no one had been able to discover, and which had escaped the notice of Mr. Drayne.

Mr. Sketchley was certainly an admirable general draughtsman and engineer, but his experience in bridge building was, in this case, neutralised by the unwise interference of the responsible chief. The borough surveyor was, as we have shown, quite ignorant on this subject, and his principals were utterly incapable of appreciating the value of professional talent when it was placed within their reach by some of the engineers who sent in the original plans.

They were also unable to comprehend the true economy which results from the employment of accomplished men in costly undertakings, and also the disastrous consequences which may arise when a brick-and-mortar surveyor, or an irresponsible draughtsman, occupies the post of engineer-in-chief in such cases.

In course of time another bridge was built, upon improved lines, under different management, and with at last permanently successful results.

CHAPTER XXVI.

CLIENTS: AN IRON WORK SPECULATION.

Varieties of Clients in Private Practice—Mr. O'Brien's character—His Law Case—Wrongful Dismissal from the Works—An enthusiastic "Invintor"—Duties of a Scientific Witness—Inspection of the Works—"New and Improved" Patent Machinery—Collecting information—The Bones of one of O'Brien's Pets—Three Lines of Argument in a Report—High Court of Justice, London—Opening the Case—O'Brien in the Witness-box—An Opposing Q.C.—Scientific Witnesses, past and present—Professional and non-Professional Clients—Two more Designers and their Works—Hints to Inventors.

In the course of many years' practice, an engineer experiences an immensely varied amount of work, and, perhaps, an equally variegated set of clients, which certainly increases his knowledge of the world, but not always in the most pleasant manner.

One of my most notable clients was a lively, quick-witted, impulsive Irishman, from Dublin city; one of those people with fertile brains who are always inventing something or other, out of which they cannot make any money. Amongst his numerous innovations was a machine for—well, I suppose there is no harm in letting out the secret—a machine for producing perpetual motion. The whole scheme was joyously described to me, and, to all appearance, its inventor was theoretically correct in his ideas. Unfortunately, however, Force of Gravity, Laws of Friction, and Atmospheric Resistance so relentlessly opposed him, that he was at last compelled to give his attention to something more practicable, such, for instance, as the economical manufacture of iron, to which we intend to devote a few remarks.

One of my visitor's peculiarities was a great love of lawsuits, which, curiously enough, somewhat impoverished him, and his last "case," previous to the event I am now going to write about, was an action he brought against the Duke of ——, which he lost, in the usual way.

Now this Mr. O'Brien—let us call him—was "a fellow of infinite jest," a rollicky, smiling, brimful-of-merriment sort of individual, and was vain enough to say that I never laughed except when *he* came to see me. Indeed, his description of the way in which he got his wife would have given intense enjoyment even to the most cynical and melancholy people, aye, even to those with hearts of stone, and the references he made to his "Invintions" were not far in the rear. In addition to this, he was kind hearted and liberal, that is to say, when he had money to be lavish with, which, I may only add, was very seldom.

Having thus introduced my client, let me now proceed to narrate the story.

One day he came into my office, and handed me a paper in which I found that I was subpœnaed to attend the High Court of Justice, in London, and appear as a scientific witness on his behalf, before Vice-Chancellor Bacon. He also threw down, in a free, off-hand manner, the preliminary fee of three guineas, which, small as it was, necessarily accompanied the document. The cause of this trial was the ejectment, or, I should rather say, the dismissal, of Mr. O'Brien from an Iron Work containing a quantity of his special patent machinery, which was expected to do wonders, and enrich its proprietors, but, although a wealthy Greek in London had actually advanced £20,000 to work the establishment, and placed my friend in it as manager, there was, after at least two years' labour, no profit of any kind. Mr. O'Brien felt hurt at the treatment he had received, and at once brought an action against his employer for wrongful dismissal, upon the ground of his interference with the management, and not giving him sufficient time for the development of a system of ironworking which was sure to bring, in the end, "an imminse fortune."

I should be very sorry indeed to give it as my opinion that Mr. O'Brien was a hare-brained schemer, but I must say that no one could have been a more enthusiastic admirer of his own practical discoveries than he himself was, and this fact alone must have given very great pleasure and confidence to those who trusted him, up to a certain point. Before going any farther, however, let me briefly describe the duties of a Scientific witness.

As it was in days of yore, so is it now. This gentleman occupies an important position, and one which involves trust, responsibility, and delicacy. *Trust*, because the client looks to him as one who is faithful and true, and quite above being led astray by the apparently superior arguments and facts the opposing counsel may bring to bear on the case. He is also expected to favour and protect, in every possible and legitimate way, the interests of his client.

It is a position of *responsibility*, because he is often the main point of attack and defence, and whatever evidence he gives may either make or mar the interests he represents, involving, it may be, issues of tremendous magnitude, as all those who have read the Manchester Canal investigations will know.

Still more is it a position of *delicacy*, because, however great the witness's knowledge of the case may be, he must be very careful how he uses it, and not put his foot in the business, as the over-zealous Mr. Phunky did in the Bardell trial. He will be exposed to a great many hard questions, which he can answer most confidently, so long as they are in his client's favour, but, at the same time, be reserved on points which are not to his advantage; indeed, when it comes to this, he had better, as a rule, say as little as possible.

Before this can be done, however, the case, in all its bearings, has to be carefully studied—minutely investigated—and plans and calculations made when necessary, to render everything clear to the jury, as well as to the engineer himself. Above all, nothing must be said or written that cannot be sustained in court. If you do anything else, the opposing counsel will be down upon you like a thunderbolt, and your client's case may be grievously weakened, if not lost. On the other hand, with care and skill, you may be able to crush them with your incontrovertible statements, and defeat them all in detail by the irresistible logic of facts.

My first movement in the matter was to go to the Works with the late manager, and make a careful survey of the premises, upon which to base my report, which was to be given to our barrister. The machinery was all stopped; indeed, the whole place was closed, and I had therefore to do the best I could under the circumstances. My position was simply this:—

I had been invited to look at a collection of patent machines of the newest and "most improved" type, which I had never seen before, neither, indeed, had anyone else, and the action of which I was expected to form a favourable opinion of, from the appearance of the inanimate masses before me, instead of having an opportunity of estimating their merits from the amount and excellence of the work I saw carried out by them. It will therefore be easily seen that I had no satisfactory ground of any kind to stand on.

Mr. O'Brien thought differently, and, as he walked beside me, explaining the action of one machine, and telling me what another piece of mechanism ought to have done, had *he* not been interfered with, naturally enough concluded that I would be quite able to understand them at a glance. I had therefore to use my wits, that is, I had to gaze at everything inquisitively, peer into every nook and corner about the place, ask any number of questions, ponder carefully and anxiously over all I saw or didn't see, and at last endeavour to write so favourable a statement of what I had observed, and also what I thought the machinery was capable of doing, that our law suit would be successfully carried.

My mind had been on the stretch for some time, and by degrees I had sketched out in imagination the leading ideas of my report, which I intended to clothe in the usual finished style when I returned to the office. So far, all was well, but I little knew what was in store for me. In the yard outside lay a few disjointed pieces of what had once been a "valuable invintion," but were now in a very rusty and disreputable condition; nevertheless, their construction and application were very fully explained to me. Here, however, my mental powers failed, and I was totally unable to conceive what the appearance of this machine had been in life, or even realise satisfactorily what it could have done when in the flesh.

If kind readers wish to understand my feelings at this stage, may I request the ladies or gentlemen to fancy themselves in the British Museum, with a leg, an arm, and a few ribs of the Megatherium or Mastodon placed in front of them on the floor. Let them still further suppose that they were asked, not only to imagine they saw the living animal before them, but to be able to describe his physical and other peculiarities. If the aforesaid ladies or gentlemen can execute this flight of fancy, then I think they will comprehend my state of mind whilst meditating among a few of the bones of one of Mr. O'Brien's pets.

I did everything I could to collect as much of the best and most trustworthy information previous to delivering judgment in my report. Before doing this, however, I had three courses open to me. One was to say confidently that the machines were quite capable of doing all that their inventor claimed for them, which he fully expected I would say. Another was to declare positively that they were not able to do this; while the third, and last, consisted in taking the mean,—in striking the average,—in fact, steering dead between Scylla and Charybdis. The first and last were utterly impracticable, so I took the intermediate course, which was the only one I could reasonably adopt. My legal document was very brief, for I took good care not to say too much lest I should do mischief, and I was specially constrained to do this because going through these works was like walking on rotten ice, which gave no safe foothold of any kind.

The wording of the report was somewhat in this style:—"I believed"; "I considered"; "So far as I could see"; "In the absence of direct proof"; "The machinery was, in my opinion"; so on, and such like, to the end.

The day of the trial came on, as every day does, for good or evil, and I was at my post in the High Court of Justice. An old friend of mine was also engaged as a scientific witness on our side, while on the other side were two more "eminents." The defendant, whom we shall call Mr. Epaminondas, had also engaged two of the most celebrated Q.C.s in London to look after his interests, and thus all the actors in the play being on the stage, the case of the "Darkfield Iron Works Company Limited" was opened in the presence of Vice-Chancellor Bacon by placing Mr. O'Brien in the witness-box.

Never in my life—no, *never*,—have I seen a man in any position who could look so much the picture of injured innocence and humility as this son of the Emerald Isle did on that eventful morning. It seemed as if he had neither the heart to kill a fly nor crush a beetle, and yet, when the time came, he could turn upon his persecutors, and with the most unbounded confidence in the justness of his cause and his "armour of triple steel," defy every one of them. In opening his case, he compared the Greek—who sat close to him—to the "wicked king in the Bible," meaning I suppose, Ahab, who murdered Naboth, and then appropriated his vineyard; and during the whole of Mr. O'Brien's lengthy examination those in court had a most amusing entertainment freely provided for them. Question after question was asked in the usual "be careful" style, first by one barrister, and then by another—the Vice-Chancellor assisting—but the replies were sometimes of a surprising, if not of a damaging character. One of the interrogations was:—

"How much profit do you think might have been made out of the works if you had not been interfered with in the management?"

"Millions," was the prompt reply.

"As matters stood when you were there, and with the machinery in good working order, what were the actual returns?"

"None, but that wasn't my fault, I did what I could to make the place a success, and if I had only had a little more time I would have done so."

In the course of the trial the Greek's perfidy was fully exposed, and irrelevant things connected with his private character were introduced from time to time in support of the plaintiff's arguments.

"Read that letter," said the indignant gentleman in the box to the very eminent opposing Q.C. and M.P., who was busily occupied in conning over a large quantity of correspondence relating to the defendant. "Read that letter you have just skipped over, and see what his brother says about him—read it like a man, and you will see the character he gets."

Now, I suppose that part of a barrister's education consists in practising the art of reticence—that is to say, keeping silent on points inimical to a client's interests. I also fancy that in time he becomes quite accomplished in the art of hearing what he ought to hear, and in suddenly becoming deaf to statements it would be unwise to listen to, and such, I think, was the case in this instance. The Q.C. went on reading for the benefit of the judge and jury only what *he* thought proper, and rejected the rest as irrelevant—at least in his own opinion—he also took not the slightest notice of Mr. O'Brien's proposal.

After attending the court for the whole of two and a half days my turn came at last. I told them plump and plain what I thought of the machinery, "so far as I could see," "so far as I could judge," etc., etc., and the result was quite satisfactory, to myself at least. Our barrister, a most accomplished and intelligent man, whom it was quite a pleasure to meet, did not ask very many questions—for wise reasons, probably—and I went through the ordeal more easily than I anticipated. Other witnesses followed, and amongst them was a drawly, slow-speaking Yorkshireman, who had been a gateman at the works. Upon being asked—

"What time did the works close at night?"

"E–eh," he said, "wa–at toi–ime?"

"Yes," replied our counsel, in a smart, gentlemanly style, "what time of the *day* did you leave off at night?"

"Wa–al it wor abee–out foi–ive o'claw–k."

This was the last scene for me, so after saying "good bye" to friends in court, I "hooked it," as the common saying is, and after visiting a few relatives in London, left by an evening train for Liverpool, happily, however, we just escaped a collision the previous "Royal mail" came in for at Rugby, which only detained us two hours on the road, and thus ended my "scientific witness" expedition to the great city. Mr. O'Brien lost his case, chiefly on commercial grounds, which no one perhaps, except himself, could possibly have been surprised at.

My client had quite impoverished himself, and I rather think that none of his witnesses received very much for their trouble. Had, our trial, however, been successful, we should have been handsomely treated all round, for the fertile inventor and lover of legal disputation was an honourable and liberal-minded man, and would then have had more than enough to enable him to settle all claims in a generous manner, as I am sure he would have done.

But if we on the plaintiff's side were scrimpily treated in the finance part of the business, we certainly had plenty of amusement, which at times was as good as a play, and kept the court in a state of extreme hilarity. And even now, after the lapse of several years, the remembrance of the scenes enacted in that High Court of Justice cause the engineers who took part in them to smile—not always, however, in the most silent manner.

When we take into account the way in which the scientific witness is now treated by opposing counsel, when engaged in law cases, it appears to me that there has been a very great improvement in this respect since Stephenson's time. Instead of the bullying which then existed, there is a great deal of respect and a large amount of courtesy shewn to the witnesses, which is highly commendable. They seem to understand each other better, and the engineer has proved, I think, that although quite a modern creation, in some branches, at least, he is nevertheless able to appreciate and highly value gentlemanly treatment and kind consideration.

Another of my clients was a man who came from Australia with an invention to which he attached so much importance that he secured the services of the best people he could find to do the legal and patenting part of the business for him in connection with every civilised country. He also favoured me by asking me to prepare the working plans, and superintend the erection of Works wherein to test the value of the invention on a practical scale.

The gentleman referred to was a quiet pleasant man, who had studied and worked at his subject for several years, and possessed a most exalted idea of its value. He was frank, straightforward, and generous, and wished everything done in the very best manner, and yet, after the scientific importance of this invention became known throughout the world, it proved an utter failure from a financial point of view, *simply* because the new process—admirable as it certainly was—could not be worked economically enough to enable it to compete successfully with a long established and similar manufacture upon different lines.

An engineer's clients may be said to include two great classes—the professional and the non-professional. The former refers to those who are engaged on some undertaking which belongs partly to one branch of science, and partly to another, such, for example, as railway stations, public buildings, warehouses, &c., in which the architect may require the services of an engineer, or *vice versa*.

In cases of this kind each individual bears his own responsibility, that is, the architect has sole charge of the brick, stone, concrete, and timber portions of the building, while the engineer designs and superintends the erection of all the ironwork contained in it, such as girders, columns, and all other similarly constructive parts. When this occurs, the chiefs in each department are termed "joint engineer," or "joint architect," according to arrangement, and have undisputed authority in their separate spheres of usefulness. Under these circumstances a large contract may be executed in the most felicitous manner, because the two principals thoroughly understand their duties, and act independently of, but at the same time in concert with, each other.

This state of affairs is entirely changed when a capricious non-professional engages the services of a C.E. to assist him with a new and perplexing scheme. In private practice instances of this kind are by no means uncommon, as an engineer is sometimes called upon to work out the hazily conceived and imperfectly described ideas of a client whose perceptions are visionary, if not unpractical, and who, therefore, causes a great deal of trouble and considerable loss of time while endeavouring to obtain what he desires. One of these clients I well remember; let me call him Mr. Smith.

For some time previous to our acquaintance this gentleman had gradually matured an idea in reference to the economical management of tramways, a miniature model of which had been made with the object of illustrating the beautiful simplicity and admirable working qualities of his invention. Unfortunately, however, when we came to examine its peculiarities critically by the aid of working drawings, it was found impracticable on account of the great difference which existed between a real tramway and a model tramway. We, therefore, condemned the scheme and tried another system, and in this we eventually succeeded.

Mr. Smith was a most impetuous and enthusiastic inventor, and fancied he had discovered something that would pay much better than the mercantile transactions he had been accustomed to. Almost every day he came to my office with his mind filled with "grand ideas" he had conceived the night before, which completely neutralised all our previous labour. I gave him the best advice in my power under the circumstances, but he preferred having his own way, as he had thought of his invention by night and by day, had cogitated and ruminated on it, and slept over it and dreamed over it, and I had not.

The continuous alterations of the drawings was of no consequence to him, and what he did in this respect was accomplished in such a slap dash, bang! sort of style as to give one the impression that he was going to make a fortune by his discovery, and that it would be a good thing for everyone connected with it. At last we succeeded in designing a very simple and perfect arrangement, and a tramway Company gave him permission to lay down his improved apparatus at two or three points on their line. He did so, to their entire satisfaction, but beyond this initiatory movement nothing else was ever accomplished, although a somewhat favourable offer was made for the purchase of the invention, which, however, was declined.

Here then, was a failure, which was no doubt created by prejudice on the one hand, and a want of sufficient influence on the other, to enable Mr. Smith to push his scheme successfully in important districts. Perhaps, also, he was too exacting in his terms, but whatever the cause of disappointment may have been, a large amount of money was freely expended while endeavouring to introduce an engineering improvement which certainly deserved a better fate.

I have thus given a few of my own experiences of inventors and inventions, for the benefit of those who have not been behind the scenes, and to whom such information may be useful. The rock upon which so many worthy people of the above class lose themselves, is the limited sweep of their views regarding the adaptability of their invention to some particular purpose for which there is, or is likely to be, a demand. And also the system of manufacture employed, which alone can enable it to become a commercial success.

To make this clear, let us imagine that a clever inventor had constructed a most admirably designed machine for washing, dressing, and finishing, with the aid of Sunlight Soap—the cuffs, collars, and pockethandkerchiefs of our coloured brethren and sisters in Central Africa. When at the same time these ladies and gentlemen had *too much* "sunlight" of their own, and never, or at least hardly ever, wished to have their linen gear cleaned in any way. Now this is exactly the principle that misinformed or ignorant designers occasionally adopt in some form or other, only to discover, when too late, that they have wasted their money and their time while pursuing an unprofitable scheme.

Very many inventors are not engineers, or at least are unable to comprehend the difficulties that may arise. Their best plan, therefore, is to consult a good patent agent, who will gladly give the information required, and thus save them, perhaps, from grievous loss and numerous disappointments.

CHAPTER XXVII.

VOYAGE FROM SYDNEY TO LONDON IN 1845.

Early Days in Australia—Engineering of the period—Arrival of H.M.S. "Vestal," 1844—Departure from Sydney—At Sea—Moon Poisoning Story from S.S. "Magellan"—Marvellous Transmission of Sound—Ocean Depths—Soundings, past and present—Two vast Depressions—Motive Power in Volcanoes—Arrival in London—"Life" in the "Orient" and "P. and O." liners, 1889.

In the year 1833, my father left Edinburgh with the object of practising law at Hobart Town, Tasmania. The state of his health, however, ultimately compelled him to try the more suitable climate of Australia, and also another occupation. After all the necessary arrangements had been completed, he began as an agriculturist in a district about one hundred miles inland from Sydney. Our early experiences of the country were somewhat peculiar. At the very outset we were robbed of our valuables, while journeying to the interior. After that, we were plundered by a band of bushrangers, and, in course of time, came in for long droughts, bush fires, floods, and other evils incidental to the colony.

At that period, there were very few mechanical contrivances for performing the most ordinary operations of any description. Everything was done by manual labour, assisted by bullock power, and in the transport of goods the dray drawn by oxen was generally employed, the speed of which did not exceed three miles an hour. When people wished to travel, they either rode on horse-back, or drove in carts, which were covered or open, according to circumstances.

House building was in an extremely primitive condition, everything being of timber, and rudely put together. The climate, however, was magnificent, and this in no small degree compensated for faults in the construction of the dwellings.

We had a great many visitors, who were much pleased to make our acquaintance, and who certainly made up in quantity for what they lacked in "quality." Their complexion was of a very dark shade of brown,—we called them "blacks," but the few now living will no doubt be designated "coloured people," in accordance with the usages of advanced civilisation. These visitors, who came in tribes, had an undesirable partiality for our splendid potatoes, but we could not well interfere with them lest they should do something worse; indeed, we were told that "up the country they had killed some white people, but down here they were quiet," which was reassuring. In other respects they were well behaved, and willing to assist in any way for little gifts of old sugar bags, and potatoes and beef.

The costume of those "natives"—well, the less we say on *that* point the better, I should think. It may only be stated, however, that when the handsome and generally useful opossum skin cloak was worn, they were dressed; but when, for climatic reasons, it was thrown off, there was nothing left to describe. The manners and customs of our dark complexioned friends were so peculiar that their description might be rather irrelevant in a book on engineering, although it would certainly be interesting in some other volume of a less scientific character.

For such a roving class of people temporary "camps" were alone suitable, and these consisted of long, slender saplings, cut and bent in the form of a triangle, steadied with a back stay, and covered with the thick bark of the gum trees. These structures were remarkably simple and worthy of imitation even by white settlers, as they had all the materials at hand when in the bush, and certainly nothing could have been so easily or so economically put together. It is only right to add that our few years' acquaintance with those dark complexioned "savages," proved beyond doubt that they were infinitely superior to men and women, and even boys, bearing the same title and living in the slums of England, whose occupations now include killing and maiming for pleasure, and murdering for amusement.

One of the curious incidents connected with this class of people was the famous "Black war" of 1836, in Tasmania. At that time Sir George Arthur,—from whom we received much kind hospitality,—was the Governor of the island, and as the natives had all along given much trouble, he conceived the happy idea of exterminating the whole race, not by killing, but by exiling. To accomplish this, he attempted to capture them all by drawing a cordon of 3,500 troops and others across the country. The blacks, however, evaded their pursuers in every possible way, and thus the efforts which had been made on their behalf at an outlay of fully £30,000, proved unsuccessful. Diplomacy succeeded where force had failed, and our coloured brethren were finally induced to surrender, when the whole of the tribes were shipped to Flinders Island to spend the rest of their days.

For various reasons farming did not prove a good speculation, so we gave it up and went back to civilisation again, at the beautifully situated and pretty little seaside town of Wollongong, 60 miles south of Sydney, where my father practised law once more.

Let me describe our journey of one hundred miles through the Australian wilderness :—

By means of a covered cart drawn by a horse we traversed a distance of twenty-five miles the first day, and spent the night at the "Blackheath Inn." On the following day about twenty miles to the "Weatherboard Inn" was all we could accomplish. On the third day we continued our journey through a very wild territory, and passing over in our course a dangerous precipice and also part of the Emu Plains, reached the river Nepean, which we crossed in a punt, and arrived soon afterwards at the village of Penrith in time to catch the mail coach.

At 2 o'clock next morning we were off again, over hill and dale, and rut, and bog, and ditch. On we went through Parramatta with its orange trees, letting everyone know that we of the *Royal Mail* were approaching. The horses pranced along in fine style, and in the afternoon—under the rays of a tropical sun—we entered the city of Sydney, the capital of New South Wales!

I shall never forget that eventful day in the year 1842, as it was my first introduction to civilised life—to ships and steamers, to the beautiful shops and the crowded streets—indeed, to me, it was quite equal to a scene from the *Arabian Nights*. After a short stay, we left by the steamer "Sophia Jane" for Wollongong, but, as my father died not long afterwards, we returned to Sydney for a time, previous to our departure for London.

The vast island of New Holland was, at this period, utterly destitute of railways and docks, and everything relating to engineering was of a most primitive character. The "Tamar," "James Watt," "William the Fourth," and a few other vessels fairly represented steam navigation, but, as there were no tugs, ships sailed in or sailed out of the harbour, or were helped by the tide. Waterworks were unknown, and the only supply in the towns was obtained from street pumps, or from water carts. Gas had not long been introduced, and other manufactures did not exist. The shipping lay alongside of timber wharves, and when vessels needed repairs they were hauled up on Morton's patent slip, by manual labour, assisted by winch gearing. The steam engine, no doubt, was fully appreciated in a small way, but the windmill, in many instances, proved very useful, as well as picturesquely ornamental.

Everything, in this respect, is now wondrously changed, and I believe that there is no part of the world where engineering, in all its branches, is making more rapid advances than in New South Wales and Victoria.

On the 18th of November, 1844, H.M.S. "Vestal" sailed into Sydney Harbour. She was sister ship to the lost "Eurydice" and "Atalanta," and originated a type of very broad-beamed frigates, which were termed the "Vestal class," whose object was good sailing power, combined with great stability. Her visit to the capital was quite an event, but no one, of course, had any idea that her unfortunate relatives would have made such a noise in the world as they did in later years.

On the same day, the ship "Sydney," in which we had taken our passage for England, left the Circular Quay, and anchored a short distance from "Pinchgut," now "Victoria," Island, close to the spot where the S.S. "Austral" sank. If Mr. Plimsoll had seen that vessel of ours, I am very sure he would not have "passed" her, as she was too deep in the water for safety, and I am almost certain that, had it not been for good Captain White, and excellent chief officer Reid, a first rate crew of real Jack Tars, and the absence of storms on the voyage, we would all have gone to the bottom. As it proved, however, a flush deck and very small freeboard made the ship a very wet one, indeed. Close to us lay the frigate, and in the near distance we could see Government House and the Botanic Gardens, and also the beautiful surroundings of a harbour which is considered by many the finest in the world.

On November 20th, we took our departure for England. Although very young at the time, I well remember that calm, sunny, magnificent day, which was to be our last in that part of the globe. Again, through the mist and shadow of years, I see my native land, and the closing scene is once more before me in all its beauty. The anchor was weighed in the tedious "See, saw, click, click, click" style, and in a little time, the tide was sweeping us out, but, to the captain's great annoyance, it almost bumped the ship against Pinchgut.

Farewell, Sydney! joy and peace be with you; good bye, "Vestal,"

> "The anchor's a-peak and away we go,
> Cheer, boys, cheer, for England, O."

The city was receding, the Heads were approaching, and at last the blue main rose to view. The swell of the ocean was coming in; the breezes of the Pacific were again upon us. The end of the jibboom commenced dancing upon the horizon, and the sea began to swish upon the deck. Captain White paced about, giving orders, and the mates saw them executed.

"Now then, Mr. Reid, look sharp! don't you hear what the commander tells you? Set the courses, jib, and fore staysail, shake out the fore and main topsails, hoist away and sheet home. Let us have the topgallants next, and then crowd on all sail at the mizzen. Bear a hand, you jolly Jacks, as quick as you like, and 'yeo ho' as much as you please. Pull away at the halliards and braces; all together, and with a will—that's right."

"Set the royals, sir?"

"No, thank you; very kind of you to mention them."

"Fasten the anchor securely for the present; stow away the colours, and make everything trim and snug. Well done!"

"Steersman, here's your course,—East-south-east,—and keep her steady. We go by Cape Horn this time, as the trade wind suits."

Our ship has now spread all sail to the gale, and London is already a little nearer than it was in the morning.

> Adieu—adieu! my native shore
>   Fades o'er the waters blue;
> The night winds sigh,—the breakers roar,
>   And shrieks the wild seamew.

One last look, ere we go below, at the sunny land which is fading away, and then, farewell Australia!

Our first night at sea was a rough one. It was *solid* water—not spray—that came over our bows, and swept the deck from stem to stern, and came down the skylight, and flooded the cabin. Captain White said he would never again permit the owners to load the ship so deeply, as the lowest plank of the bulwarks had to be removed for the purpose of enabling her to free herself quickly when inundated. This, however, allowed the water to come in upon us more easily at all times, and for a long period we had indeed very little dry ground to stand on.

As far as Cape Horn we did well, that is, we had a fair breeze, and good daily runs of about 190 miles, but, in the tropics, had many baffling winds and calms, and on one occasion three whole days were occupied in sailing over twenty-four miles of our course. The heat was intense, the surface of the water often like a millpond, and the morning and evening glories by which we were surrounded truly magnificent. Such exquisite moonlight and starlight scenes we had! and plenty of time to look at them, too, as the ship frequently made so little progress.

Many years ago, a brother of the writer commanded one of Brocklebank's Calcutta liners, and on a certain occasion breakfasted on some fish which had been caught the previous day, and carelessly left out in the moonlight. Those who had eaten them were quickly seized with a distemper which caused their heads to swell most painfully, and with much inflammation. The danger, however, passed away. Some said the heat had spoilt the fish. Had it, though? Well, there is nothing like practical science for enabling people to find out a first cause for most things, so two more were hooked and experimented upon. One was draped, and the other left uncovered, but both were hung up all night as before, and in the morning the former was quite in good condition, whereas the latter was putrid.

At another time, the same individual was on a voyage to Valparaiso in the Pacific S.S. "Magellan." One afternoon, a sheep was killed for the use of the passengers, and next morning part of the animal was cooked for breakfast.

"Nice cutlets, these," said the Captain to one who sat by him.

"Very fine, indeed; I'll take a little more, please," was the reply.

In the course of the day, something seemed to have gone wrong with the ship, or the passengers, or both together. Was it an epidemic?—or a plague?—or what in the world was it? A number of ladies and gentlemen had suddenly and mysteriously become very ill; the captain, purser, and doctor dangerously so.

"Wha-at ha-ad you for breakfast?" faintingly inquired the latter of a lady who came to him for advice.

"Mutton cutlets."

"Good gracious! that is just exactly what I had myself."

The secret was at last discovered—it was ascertained that the carcase of the sheep had been carelessly left all night exposed to the moon's rays, had thus become poisoned, and produced the results we have mentioned.

Just one more scientific fact out of many connected with the sea:—The Brocklebank captain just referred to was one calm day far out upon the ocean, bound for Calcutta. While below in the cabin he heard a noise as if some one had been scraping the side of an iron ship, and yet there was no vessel near them that they could discover.

"Did you make that scraping noise?" he said to a sailor, upon going on deck.

"No sir."

"Did you hear any scraping noise?" the chief officer was asked.

"No sir."

"Well that *is* strange! I am positive I heard it, whatever the cause may have been, and yet no vessel is in sight—can it be a delusion?"

Shortly afterwards they passed an iron ship, which at this time was hull down on the horizon. "Were you doing anything to your vessel three hours ago?" was a question put to the stranger. "We were hammering and scraping our sides," was the reply. Thus it turned out that the noise *had* been a reality after all! It appeared, however, that such a marvellous transmission of sound through the sea and over a distance of about fourteen miles was due partly to the state of the air and water at the time, and also to the fact that the wooden sides of the Calcutta liner were good conductors of sound.

In certain places the sea bristles with wonders, a few of which might be appropriately referred to in this chapter if space permitted. Those, however, who are curious in such matters will obtain much interesting and valuable information from all the books relating to the H.M.S. "Challenger" expedition, in which the latest discoveries in engineering and other sciences were made use of in every possible manner.

One of the numerous marvels of the ocean has been the depths of its waters, concerning which the most absurd ideas formerly existed. We remember the time when it was said to be "bottomless" in some places, and no doubt people had good reason for thinking so. Ships were sent out on scientific expeditions and returned with most astonishing reports. One of them said that in the south Atlantic she had let out 50,000 ft. of line, but could find no ground. No wonder, then, that false impressions were made upon the public mind in this respect, or that able articles appeared in the scientific magazines of the period in support or refutation of such ideas.

Now, the "Challenger" expedition exposed this fallacy, and proved indisputably that the sea was not nearly so deep as it was supposed to be, because all the latest and best resources of modern engineering were utilised by those on board that ship, to enable them to prosecute their investigations with ease and accuracy in every department of science, and especially so in this case. The reason why the ocean depths were gauged so exactly was because the sounding lines used were small in diameter and immensely strong, and the sinkers of peculiar shape and of about one hundred weight for every thousand fathoms. In addition to this, they had a most efficient and simple checking gear, or "accumulator," which enabled the action of the heavy sinker, while passing through the water, to be carefully ascertained. On reaching the bottom, however, it was disengaged from the line, which, along with an attached tube, containing a specimen of the ocean bed, was run in by means of little engines on the deck of the ship.

The "unlimited soundings" referred to were caused by a *thick* sounding line that was carried away in long bends by the force of deep sea currents, which the 68-pound shot, generally used at the time, was incapable of counteracting. Under these circumstances it was utterly impossible to obtain even a fair idea of ocean depths.

The "Challenger's" numerous sections of the ocean bed, extending in a systematic manner between points many hundreds of miles apart, are very interesting and explanatory. From them, as well as from her various charts of general soundings, we learn that, both on the

American and British coasts, the depths inside of the hundred fathom line decrease gradually towards the mainland, whereas, outside of the same boundary, they fall away very rapidly to somewhere about 2,000 fathoms. After that, the Atlantic bed becomes an undulating plain for hundreds of miles at a stretch within certain areas.

In the Atlantic, the deepest soundings of 3,875 fathoms, or about 4½ miles, were discovered at a point 80 miles north of St. Thomas, and the greatest known depth in the world lies in the narrow channel between the Ladrone and Caroline Islands, in the Pacific. This depth is 4,575 fathoms, or 5¼ miles. The Island of Bermuda is very flat, and yet from 8 to 10 miles off its coast line about 2,000 fathom water has been found in some places. On the north-west coast of Australia, too, between the mainland and Timor, the greatest depth in the Indian Ocean, 3,020 fathoms, was discovered. In short, many of the islands in the Pacific rise immediately from similar depths, thus indicating extreme irregularities in the outline of its bottom.

This ocean is quite a hotbed of volcanic energy which indicates its presence in many ways. Here, however, we find the small calamities of the natural world preventing those which are infinitely greater. The floor of the Pacific is like the shell of a gigantic steam boiler, and were it not for those beautiful safety valves—the volcanoes—which stud its area and surroundings, a large portion of a hemisphere would have been torn up, blown up, and transformed in a manner unknown since the Creation. The force capable of doing this is simply the high pressure steam which is made in enormous quantities, by cataclysms of water rushing through fissures in the earth upon its incandescent interior, and held in check by volcanic outbursts, which, comparatively speaking, do little mischief.

Upon reaching the Channel we engaged a pilot, to whom Captain White resigned the entire command of the ship, and shortly afterwards arrived at Deal, where we found the inward bound "Greenlaw," which had sailed from Sydney a month before us. We also came in for two Sundays in one week, because we had gained a day by sailing round the globe. This, I may remark, is the point upon which the story of *Round the World in Eighty Days* hinges, and which enabled the gentleman who undertook the journey to win his handsome wager by one second. We lay in the Downs all night, and next morning were towed into London, after having been four months and ten days on the voyage.

Things have changed since then. Steam navigation has completely altered everything. The old-fashioned "eight months to India" style of ship has disappeared, and we have now magnificent, swift, hotel-like steamers which make a voyage to or from Australia a mere holiday trip, instead of a long and dreary passage such as I have described.

An Orient or a P. and O. steamer on the voyage is quite a little floating world, where all classes of society and every possible shade of taste and disposition are thrown together during the trip. A great variety of employments occupy the minds of the passengers, and amongst them the following may be mentioned: Cricket and lawn tennis, of a certain kind; quoits, bowls, and curling, for which circles of rope are utilised. "Sling the monkey," a favourite and exciting game; also racing, which includes hopping races, walking backwards, races for girls and boys, etc.

Other sources of amusement for all consist of duly advertised "Two days' athletic sports," with the making up and presentation of prizes at the end. Dancing holds high rank in calm moonlight nights, upon the spacious upper deck; but there is nothing, perhaps, which gives such intense enjoyment as the preparation for a theatrical performance, or a "fancy dress ball." What with the painting of high art programmes and flaming posters, in the very loftiest style,—what with dressmaking, and got-up costumes not to be seen in any city in the world,—what with one thing and what with another, from first to last, the ladies, at least, have a delightful time of it.

Concerts are given, and assizes held. A newspaper has plenty of contributors to its columns, so long as the foolscap of the ship lasts. Scientific people, too, have *their* special recreations, while the captain takes care that the regulations of the Company are attended to, and that no one interferes with the discipline of the vessel, or abuses in any way his or her privileges.

On Sunday, "church" is held on board, in which a good choir, who practice during the week, give able assistance. These remarks will indicate a few of the occupations of passengers on board a modern Australian liner; and those who remember the state of things in this respect forty years ago, will now realize the great change which has taken place in long sea voyages.

CHAPTER XXVIII.

ENGINEERING OF THE PAST AND PRESENT.

James Watt and his followers—What Engineering has done in the Past—Effects produced by simple Improvements—Application of different kinds of Motive Power—Hydraulic Power on a vast scale—Great Compressed Air Schemes—Hydro-Pneumatic System of Sewerage and Drainage—Atmospheric Gas Engines—Electric Motors for Launches, &c.—Cunard S.S. "Umbria" and "Etruria"—The "One Man" system—Charles MacIver—Engineering in the Newcastle District—Allusions to Messrs. Denny and Messrs. Laird—The "Practical Man" in fancy and in reality.

Upon taking a retrospective glance at what engineering has done during the last eighty years, one cannot but feel astonished that so many centuries rolled away before the science assumed a really practical form, and that it should have been left to James Watt to put into proper shape a force which the ancients touched upon so closely. And yet, after Watt had made his great discovery, it is amazing how rapidly the new and mighty power effected a complete revolution in our preconceived ideas of travel and manufacture, and gave rise to new discoveries which have been successfully developed by many talented engineers who followed in his wake.

To Mr. Patrick Miller, of Dalswinton, we owe the first important movement regarding steam navigation, which paved the way for its general introduction some years afterwards. And, after its introduction, we find Caird and Napier, in Scotland, and Penn and Maudslay, in England, amongst the leaders of those who have done so much to perfect the marine engine. We also find Whitworth and Fairbairn, in their respective branches, also Stephenson and other engineers, all concentrating their energies in different lines of thought, but, nevertheless, individually and unitedly, developing that branch of modern science termed Mechanical Engineering, which has brought about so many beneficial changes.

One curious fact connected with some of them is the extreme simplicity of certain arrangements which have proved absolutely invaluable. Take, for example, the fast and loose pulley for driving machines; the bolt and nut with standard screws, for fastening their parts together; the slide rest, for turning out rapidly and accurately work that formerly was done in a very slow and imperfect manner by hand labour; and, among very many other important improvements, may be mentioned Fox's corrugated furnaces, which enable engineers to use steam pressures previously impracticable. The simple process of corrugation — now applied successfully in a great variety of ways—has enabled these furnaces to possess about four times the strength of plain flues of the same thickness and diameter, and this has greatly facilitated the introduction of the triple and quadruple expansion engines.

At no period in the history of Engineering have so many advantages been placed within the reach of employers of power as at the present time, since manufacturers and constructors of every description can, at small cost, obtain engines exactly suited to their requirements, whose motive power may be steam, water, electricity, compressed air, or gas, according to circumstances.

For instance, where coal is cheap and plentiful, and considerable power is required in driving machinery, nothing could be better than the steam engine; but where intense and concentrated pressures of an intermittent character, such as those which are in use for cotton presses, the management of dock works over a large area, and the various processes in engineering spread over towns and cities, hardly anything can be so conveniently or so economically applied as hydraulic power. Here, however, the steam engine must be employed to pump water into "accumulators" until the desired pressure of many hundreds of pounds, or perhaps from four to five tons per square inch is obtained. For ordinary purposes, the institution of Public Hydraulic Power Companies has been attended with very beneficial results, since by their agency a large amount of the intermittent and extremely varied work of great communities can be performed at little cost.

One of the most novel applications of water power is to be found in a Parisian Hippodrome, the large circus of which is supported upon numerous hydraulic rams which allow the arena to be lowered into a reservoir, thus forming a lake upon which various aquatic performances may be produced.

For light work in general the field is greatly enlarged, and compressed air engines or machines are very extensively used; but here again, steam machinery is employed to compress the air sufficiently. In tunnelling or mining operations under ground this motive power is most valuable, as the air can be conveyed through pipes for great distances with very little loss of pressure, and, when liberated from the machine or engine, it forms an excellent means of ventilation.

Compressed air as a motive power has been for a long time successfully applied in a great variety of ways, and its sphere of usefulness has lately been very considerably enlarged, as great schemes are now in contemplation for supplying it over a large area in several towns by means of underground pipes. The object of the promoters of these schemes is to supply the above-mentioned power to supersede steam in driving ordinary engines, steam hammers, steam pumps, pile drivers, domestic motors, and a great variety of other machinery, as well as for providing air for ventilating or exhausting purposes, the working of blast furnaces, and also for discharging sewage or raising liquids.

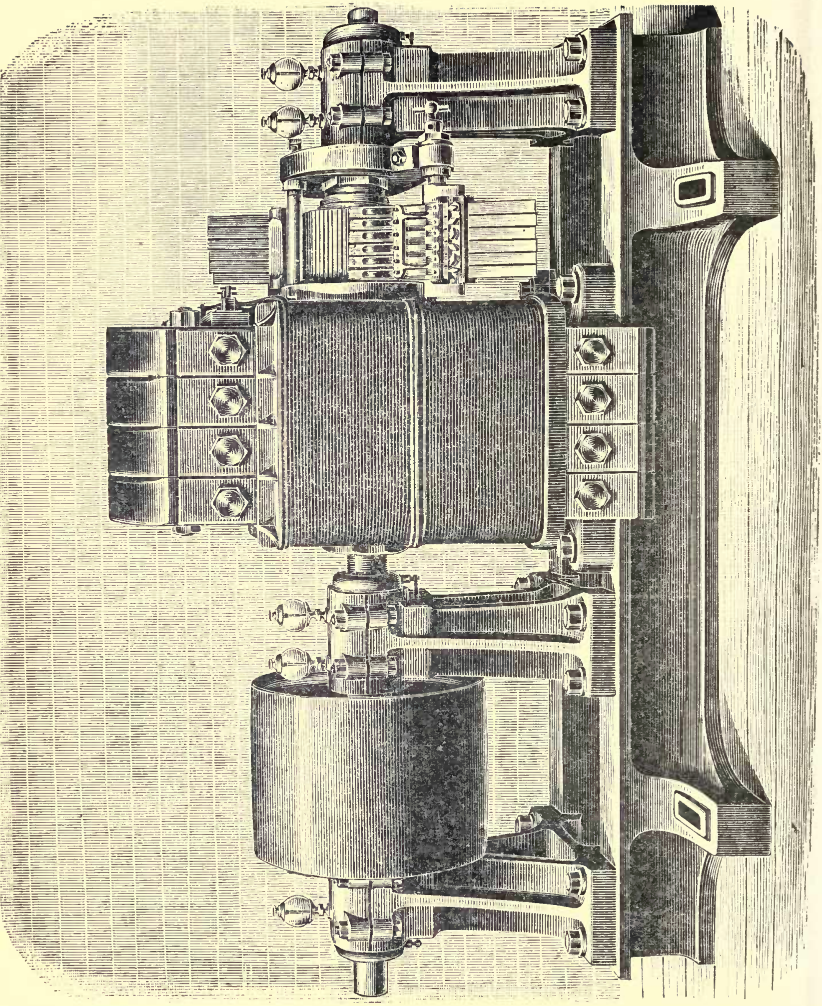
Under the superintendence of Mr. John Sturgeon, C.E., as engineer-in-chief, an extensive undertaking of this nature has been carried out in Birmingham.

The works are at present laid out for the employment of 15,000 indicated horse power by means of fifteen engines of 1,000 horse power each, and the area to be worked by this system amounts to about five square miles, but sufficient land has been acquired to allow for future extension, and also for the employment of an additional 20,000 horse power. The compressed air to be thus distributed to consumers will be conveyed through about twenty-three miles of wrought-iron welded pipes laid in concrete troughs, and varying from seven inches to twenty-four inches diameter, and the working pressure is intended to be forty-five pounds per square inch.

Nowhere, perhaps, has compressed air as a motive power been found more useful than in the hydro-pneumatic system of sewerage invented by Mr. Isaac Shone, C.E., of Westminster, which possesses many valuable features, and has been very successfully applied to various towns, including Eastbourne, Southampton, Warrington, and many other places at home and abroad, including the main drainage of the Houses of Parliament. In these instances the motive power is produced by means of the Atkinson gas engine air compressor, which is extremely simple, economical, and effective, and affords extraordinary facilities for keeping the air pressure constant. It also needs no other attention than that required for lubrication and occasional cleaning. The advantages possessed by Mr. Shone's system of sewerage and drainage are numerous and important, and sufficiently inexpensive to render it of great value in localities where self-cleansing sewers cannot be made on the gravitation principle without incurring enormous outlay.

There is no engine which is so entirely independent of steam as the atmospheric gas engine, which has now attained a high degree of perfection. This beautiful piece of machinery is one of the most valuable innovations of modern times, as the steam boiler with its attendant dirt, smoke, space occupied, working expenses, and risk of explosion, is entirely dispensed with. The principle upon which this engine works is the propelling power of common gas by explosion when sufficiently diluted with atmospheric air, hence the term "*Atmospheric gas engine.*"

The bursting of a bomb shell inside a gas holder will do no more mischief than to cause the gas to burn away quietly in large jets until it is all used up. This was proved at the siege of Paris in 1870. On the other hand, a highly explosive compound is produced by mixing coal-gas with about eight times its volume of air, and this fact is taken advantage of in the engines just mentioned. For driving light machinery, or for hoisting purposes, they are specially adapted, and where the work is of an intermittent character, the average con-



sumption of gas has been as low as 10d. per day during three months, for a $3\frac{1}{2}$-horse power engine running constantly, and with gas at 3s. per 1,000 feet.

These engines are made with single or double cylinders, and may be either horizontal or vertical, according to circumstances, and of sizes ranging from 2 to about 40 indicated horse power.

Amongst the numerous innovations of the present age may also be mentioned the electric motors of Messrs. Immisch & Co., which are of the highest efficiency, and applicable for a variety of purposes, including pumping, hauling, winding, fan driving, &c., and also for the propulsion of launches. When used for small vessels the power is somewhat more expensive than steam, but this is balanced by compensating advantages, such as the comfort and convenience of passengers, freedom from noise and vibration, and from heat and smell. A plate of one of the above is annexed.

One of the marked features of the present day is the creation of gigantic establishments, and the vast extension of others, which, twenty or thirty years ago, were of very limited dimensions and sometimes greatly overworked. The largest establishment in Scotland is that of the Fairfield Shipbuilding and Engineering Company, on the Clyde, which occupies an area of about seventy acres; but the most extensive in Great Britain is Messrs. Palmer's, at Jarrow, on the Tyne, covering nearly one hundred acres of land. In these works,—a view of which is shewn in the frontispiece,—the raw ironstone from the Company's mines, near Whitby, is taken in at one end, smelted in the blast furnaces, passed through the rolling mills, steel works, and forges, and in a finished state is formed into engines, boilers, and ships, all the brass and iron castings for which are made on the premises.

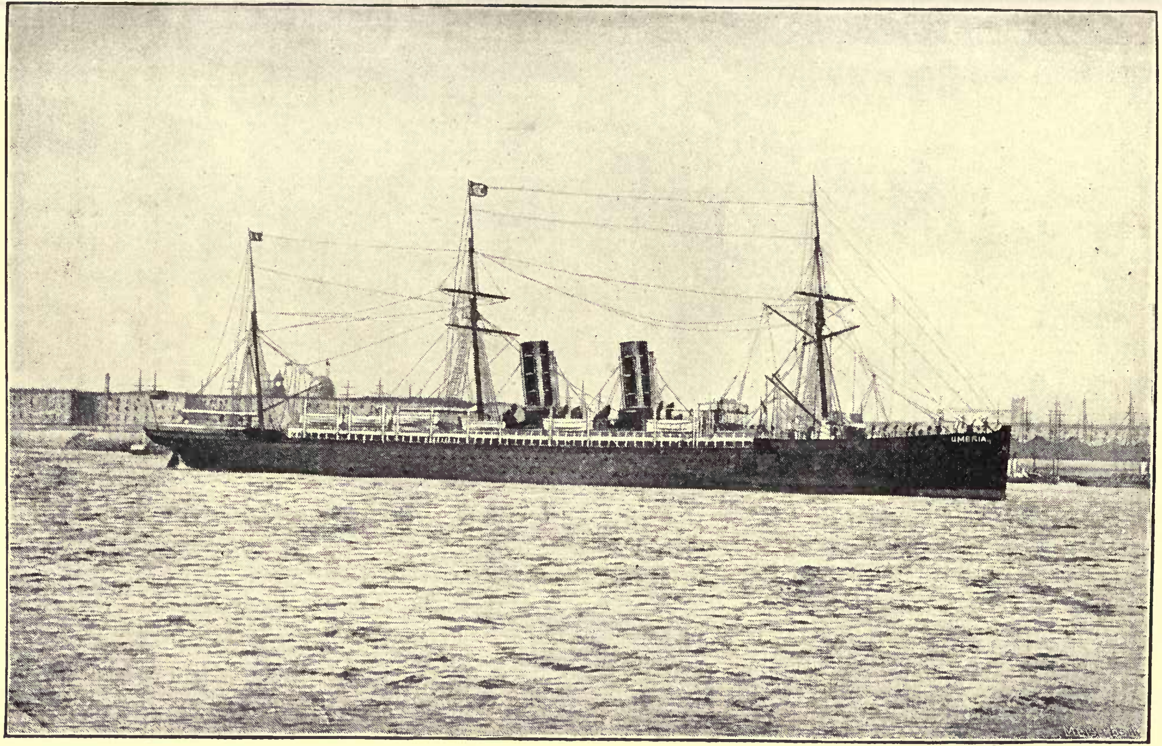
A view of the first P.S. "Comet" is shown in Chapter IV; the early Atlantic steamers have already been mentioned; and the last illustrated description of ships will refer to the Cunard S.S. "Umbria" and "Etruria." The annexed Plate is from a photograph of the former, but is equally applicable to the latter, as she is a sister vessel in every respect. Their general dimensions are as follows:—

Length over all 520 feet, extreme breadth 57 feet 3 inches, depth to the upper deck 40 feet, and to the promenade deck 49 feet. The gross tonnage of each is 8,000 tons. Both ships are built of steel, and by the division of each into ten water-tight compartments, the bulkheads of which are carried to the upper deck and fitted with waterproof doors, the danger in the event of a collision or the outbreak of fire is minimised, while at the same time the isolation which, for sanitary purposes, may be obtained by this arrangement is of no small importance.

The promenade deck, which is reserved for the use of first-class passengers only, is 300 feet long and extends over the full breadth of the vessel. The dining saloon, also the full breadth of the ship, is 76 feet long, and is seated for upwards of 300 people, but as most of the state-rooms are fitted with two berths, accommodation is provided for 720 first-class passengers.

The engines indicate about 15,000 horse power, and are of the ordinary three cylinder compound description, having one high pressure cylinder 71 inches diameter, and two low pressure of 105 inches diameter, all of which have a stroke of six feet.

During nine outward voyages of the "Etruria" in



CUNARD S.S. "UMBRIA" ON THE MERSEY.

1886, her average speed between Sandyhook and Queenstown, including summer and winter passages, was 17·7 knots per hour, and on the same number of homeward runs this was increased to 17·97 knots. On her trial trip, however, the speed realized was 21 knots per hour, and that of the "Umbria" was practically the same. The cost of each ship was about £330,000; the quantity of coals burnt per day amounts to 300 tons; and the crew, including officers and men in all departments, numbers 287.

The introduction of railways and successful ocean steam navigation, as well as of many other great movements that have taken place since the world began, have been chiefly the result of the "*One Man*" system. That is, a single individual, who, impelled by the idea that *he* was right and everyone else was wrong, persistently maintained his point against all opposition, and triumphed in the end.

This was especially the case with Stephenson, and perhaps in a modified degree with Junius Smith, while trying to introduce his own enlightened ideas regarding the passage of the Atlantic. And even after his scheme was fairly established, its development and success depended upon another "one man" who did what no one else has been able to accomplish—work a large fleet of splendid steam vessels across that ocean for forty years and never lose a life, a letter, or a ship.

The "single gentleman" in this case was Charles MacIver, whose character and magnificent capacity for organisation on a grand scale are too well known to need further comment. We may add, however, that he originated a system of management which no one apparently has been able to improve, and which no doubt many availed themselves of in their own Companies, but without obtaining similar success. Mr. MacIver's leading characteristics were comprehensiveness, steadiness of purpose, and a love of his business and associates in it, which was probably increased by the fact that he was the sole and responsible chief upon whom devolved the guidance of the vast undertaking he was placed over, and upon whose judgment everyone relied.

Not only was this the case from a commercial point of view, but in all matters regarding the construction of his steamers, during the long period we have mentioned, he decided for himself the leading particulars of every vessel. At last, however, his partners proposed changes he could not approve of, and the result was his withdrawal from the firm, which, under a new arrangement, became in 1882 an ordinary limited liability undertaking, with a capital of £2,000,000, and open to any investor who wished to possess a £20 share.

The shipbuilding districts chiefly mentioned in this volume are those of the Clyde and Mersey, simply because a long and intimate acquaintance with both has enabled me to describe them from personal knowledge. My only regret, however, is that I have thus been prevented from extending my remarks to that most important shipbuilding, engineering, and iron manufacturing locality which lies between the Tyne and the Tees, known as the "North-eastern district." Amongst the great variety of establishments abounding in that region, are to be found some of the largest and most famous in the world, and one interesting feature they possess is the extreme rapidity of development which in recent years has characterised many of them, and also the swift extension of the leading manufactures connected with them.

I have referred to many engineers and engineering firms, and especially to Messrs. Denny and Messrs. Laird, with whom I had the honour of being so long associated. The former commenced shipbuilding in the year 1817, and have now one of the largest establishments on the Clyde. In 1883 the late Mr. William Denny introduced a system of extension and re-arrangement of the premises to almost double their previous size, including the formation of a new tidal dock with the most powerful appliances for lifting purposes. A system of narrow-gauge portable railways throughout the establishment; the electric lighting of the workshops and offices; the substitution of powerful hydraulic gear in lieu of steam machinery; and the introduction of telephonic communication on an extensive scale were among his latest achievements.

The establishment of Messrs. Laird Brothers was founded in 1829, and the present firm has had a most successful career, as previously mentioned.

The "practical man" is commonly supposed to be a workman who, with soiled face and grimy hands, can accurately bore a steam cylinder, or turn a shaft, or do some good erecting, and use with facility the hammer, the chisel, and the file. The *true* practical man, however, is he who in all the ranks of life can combine *science* with practice in such a manner as to produce the most economical and advantageous results. This title is applicable to all the great engineers, and especially to the Commanders in Chief of those famous works the descriptions of which have awakened in my own mind very many happy remembrances.

CHAPTER XXIX.

TRIPLE EXPANSION MACHINERY.

Shipowners' idea of Marine Engines—Results of "Tripling" two long voyage Steamers—Cause of Economy in Triple Engines—Table of mean Pressures at different rates of Expansion—Table of Powers produced by variously Expanded Steam—Ratios of Expansion in Compound and Triple Engines—Long Voyage Experiments—Space required for Engines—Reduction of Weight—Newest style of Triple Engines—Wear and Tear—Management at Sea—Steamship performances—Trial of S.S. "Meteor"—Indicator Cards and Coal Consumption—Liquid Fuel in Steamers—Yarrow's Vaporised Spirit Engines.

There can be no doubt that the triple expansion engine has superseded the compound machinery of former years, but, as some one observed, "every dog has his day," and so also has every new fashion. We may, therefore, conclude that the Triple engines will have their's, until perhaps the Quadruples are similarly in the ascendant, or those of another design, which will be described farther on.

The late Mr. Robert Wyllie, of Hartlepool, and Mr. J. P. Hall, of Messrs. Palmer's, have contributed a large amount of valuable information on this subject derived from trustworthy sources, and to these gentlemen we are indebted for many facts that have been embodied in this chapter. Engineers and shipbuilders are generally influenced by the shipowners, who have the power of regulating the actions of both, by means of their own extensive knowledge of the commercial advantages of different kinds of engines and ships. The ruling idea in the minds of the shipowners is the relative value of any new type of machinery when compared with others, such as, for example, the Triple and Quadruple engines, etc., in contrast with the two, three, and four-cylinder compounds of the old type, and although the professionals may give their clients the very best advice on the subject, it is the commercial aspect of the question that truly forms the governing power.

It is not so much a mere question of high class mechanical movement, but of *economy* in the working, maintenance, coal consumption, and cargo-carrying capacity, etc., of ships. The old compound engines enabled long voyage steamers to do what otherwise would have been impossible, but the triples and quadruples are now accomplishing this more effectively, because, through their agency, the consumption of fuel has been greatly reduced; thus involving a considerable increase in the cargo space, with its attendant advantages.

In no branch of engineering have so many extensive modifications been made as in that relating to steamships, and the highly beneficial results obtained by the adoption of the triple expansion type of machinery, forcibly illustrate its value, and indicate the direction in which great improvements may still be attempted. To enable this to be clearly understood, we will give a few examples from the ordinary sea-going practice of steamships on long voyage stations.

Take, for instance, the Union Company's S.S. "Anglian," whose original compound machinery required a mean coal consumption of 24 tons per day, over eight voyages to the Cape of Good Hope, or about 2·1 pounds per indicated horse-power per hour. These engines had a horse-power of 1065, but upon being tripled this was increased to 1575. On the "Anglian's" run to the Cape in her altered condition, the average speed was kept exactly the same as formerly, but the fuel consumed was only 16 tons per day, and, as she was placed on a station where the cost of coal is about £2 per ton, the great benefit thus derived will be at once apparent.

The Orient S.S. "Lusitania" forms another very good illustration of what may be similarly accomplished in a larger ship. This vessel had originally a pair of 2,330 horse-power compound engines, and during a voyage from London to Sydney, the average daily quantity of coal used was 52 tons. These engines were, therefore, altered as above, and the power was increased to 3,315. With the speed of the vessel correspondingly augmented, the coal consumption was about 50 tons per day, but when the velocity was reduced to its former state, this went down to 37 tons only, and for the return voyage of 80 days to Australia the total saving amounted to 1,200 tons.

Many other examples might be given, if necessary, with the object of proving the efficiency and economy of triple engines; the above mentioned results, however, represent a fair average of those obtained from thirty sets of machinery which were designed by the late Mr. Wyllie. In addition to this, Mr. William Parker, Chief Engineer Surveyor at Lloyds, has stated that very many ships he knew of had been similarly benefited.

The question has been often asked—"Why is the triple expansion engine so economical?" The answer to this lies chiefly in the fact that high pressure steam is proportionately less expensive to make than low pressure steam, and also that the former can be more sparingly used than the latter, by taking advantage of the principle of expansion. In other words, it is simply the application of ruling ideas in general business which enable profits to be made where serious loss might have been incurred. This brings to mind the story of one of my engineering friends who was consulted about an undertaking a client of his wished to enter upon. My friend gave him the best advice he could, and wrote to the adventurer soon afterwards asking how he had succeeded, and received the following reply:—

"So kind of you to enquire about my new enterprise, I have been getting on nicely, everything doing well, but—Jer. xxxvii, 19"—"Where are now your *prophets?*"

It is well known that the higher the pressure at which a boiler will work, the greater will be the proportionate degree of economy in coal consumption. That is to say, when water in a boiler is at 212° Fahrenheit, the steam pressure is the same as the atmosphere—at 228° it is at 5·3 pounds above the atmosphere—at 240°, 10·3 pounds—at 302°, 55·3 pounds—at 324°, 80·3 pounds—at 353°, 125·3 pounds—and at 401°, 235·3 pounds per square inch, and so on.

From this it will be apparent that by firing a little harder after reaching the boiling point, the pressures of steam can be so much increased as to reduce the cost of production, and this, it may be added, is just what engineers have long aimed at, and at last accomplished.

The benefit to be derived from the expansion of steam may be thus described: If the elastic vapour is allowed to act with its full energy upon a piston from the beginning to the end of its upward or downward stroke, a whole cylinder full of steam is used each time. If, however, the steam is cut off from the boiler at half the stroke of the piston, there is a direct saving of *half* the quantity of steam and coal, etc.; and at the same time, the steam now expanding in the cylinder is doing useful work for nothing, although its pressure is gradually diminishing.

If the vapour be cut off at one-fourth, or one-fifth, &c., of the stroke, the economy is correspondingly increased, as will be seen from the following table:—

TABLE OF STEAM USED EXPANSIVELY.

Initial pressure in pounds per square inch.	AVERAGE PRESSURE IN POUNDS PER SQUARE INCH FOR WHOLE STROKE. Portions of Stroke at which Steam is cut off.					
	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
100	96·6	91·9	84.6	74·4	59·6	38·5
110	106·2	101·1	93.1	81·8	65·6	42·3
120	115·9	110·3	101·5	89·3	71·5	46·2
130	125·6	119·4	110·0	96·7	77·5	50·0
140	135·2	128·6	118·5	104·1	83·4	53·9
150	144·9	137·8	126·9	111·6	89·4	57·7
160	154·6	147·0	135·4	119·0	95·4	61·6
180	173·9	165·4	152·3	133·9	107·3	69·3
200	193·2	183·8	169·2	148·8	119·2	77·0

If the mean results due to any other steam pressures, say 50, 60, 300, or 400, etc., pounds per square inch, are desired, then allow for the half of 100 or 120, or the double of 150 or 200, etc.

Mr. Henthorn, the late president of the American Society of Mechanical Engineers, has thrown additional light upon this subject by means of the following useful table.

TABLE SHOWING THE THEORETICAL POWER DUE TO THE USE OF THE SAME QUANTITY OF STEAM WHEN USED UNDER DIFFERENT RATIOS OF EXPANSION.

POINT OF CUT-OFF.	Number of Expansions.	Horse-Power.
Full Stroke	0	100·0
1/2 "	2	169·3
1/4 "	4	238·6
1/6 "	6	279.1
1/8 "	8	307·9
1/10 "	10	330·2
1/12 "	12	348·4
1/14 "	14	363·9
1/16 "	16	377·2
1/18 "	18	389·0
1/20 "	20	399·5

"From the above table it will be seen"—as Mr. Henthorn observes—"that by working the steam under twenty expansions, as applicable in engines of the highest class, an advantage equivalent to 400 per cent. is derived from the same steam over the result obtained during the full stroke of a non-expansive engine."

Since the triples allow of a much greater number of expansions than could be obtained in the old compounds, owing, on the one hand, to the use of very high pressure steam, and, on the other hand, to the increased ratios of the high and low pressure cylinders, the successful application of the above system is only a natural consequence. In the S.S. "Anglian" the ratio of the areas of the two original cylinders was 3·07, which gave only 5·1 expansions, but, in the engines that superseded them, the number was increased to 11·74. Similar results were obtained from the "Lusitania," which had her 5·26 expansions increased to 11·85 after being tripled. This, we may add, is just where the superiority in economy of one class of machinery over another becomes distinctly visible, by using a high boiler pressure and making it perform a considerable amount of additional work gratuitously.

In 1887, Messrs. Jones & Son, of Liverpool, tested the soundness of this principle by means of a series of long voyage experiments with the S.S. "Bentinck," which was engined by them. For experimental purposes these engines were so arranged that they could be used either as double or triple cylinder as desired, and, in each case, with the full pressure of steam. This vessel has been worked on alternate voyages under both systems for many months at a time, with practically equal results.

Since the above experiments were carried out, Messrs. Leyland, of Liverpool, have altered their steamship "Algerian," of 2,821 tons, and 900 horse-power, for the purpose of giving the new system a fair trial. The improved arrangements consisted of one new cylinder of 24″, and another of 64″ diameter, having a ratio of 1 to 7; new boilers for 150 pound steam were also added. By means of these modifications the indicated horse-power, the revolutions per minute, and the speed of the ship, remained as formerly, but the coal allowance was reduced from 20½ to 15 tons per day, thus producing a gain of about 27 per cent. Several vessels owned by the same Company, and also those of others, have been similarly altered with satisfactory results.

There are other questions connected with steamship machinery that closely affect its commercial value, and may be thus stated:—

(1.) Can the three crank triples be made to occupy the same space in a ship as two cylinder compounds of the same power?

(2.) Is it possible to make new engines of the same power as the old ones, but without increasing their weight?

(3.) Will the wear and tear of triple expansions be excessive?

(4.) Will boilers using 150 pounds steam last as long as those which use only about half the pressure?

(5.) Is the new style of machinery more difficult to manage than the old?

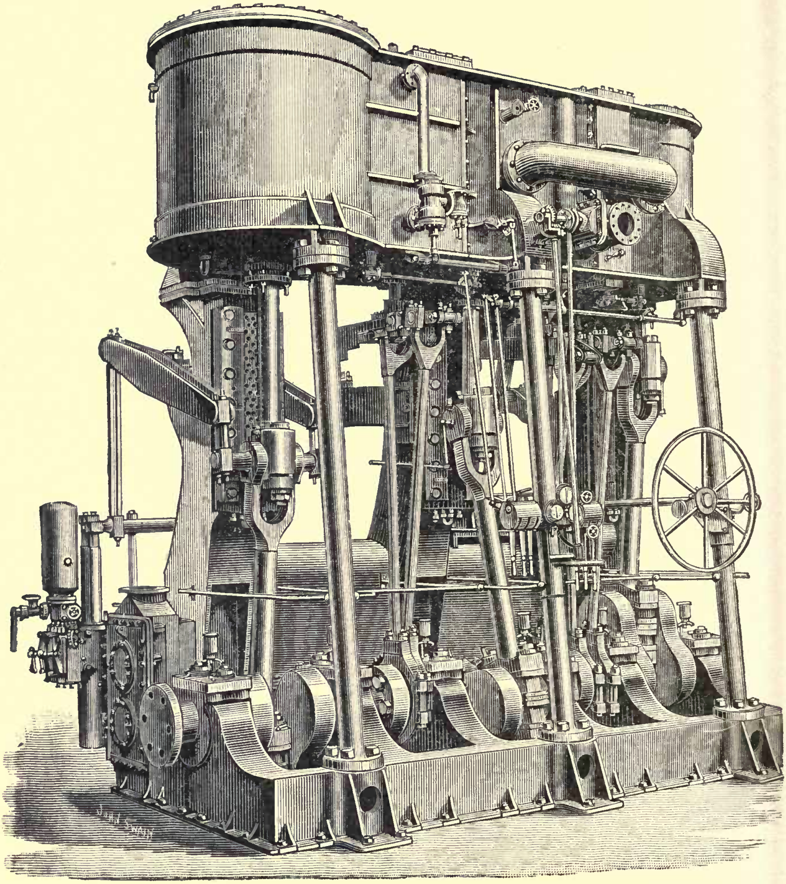
So far as question number one is concerned, it may be broadly stated that the space occupied by triples will not be more, and in some cases can easily be less than with the two cylinder compounds, according to the requirements of purchasers.

The second question can be still more satisfactorily answered, as Mr. Hall has shown in his tables of particulars of engines of both kinds, representing the practice of numerous engineering firms in the Newcastle district. From these it may be gathered that the total weight in tons for the whole of the machinery, including boilers, and the water they contain when in seagoing condition, and also Lloyd's spare gear, etc., is nearly the same in each case, and may in general be taken at about 450 pounds per indicated horse-power.

The extensive employment of steel in the very latest machinery, clearly indicates that there has been great room for reduction of weight. Mr. Sennet, late Engineer-in-Chief to the Royal Navy, has expressed the opinion that marine boilers may be thus improved by thinning the plates a little, on account of the rigid inspection and testing they are now subjected to. Theoretically the late Admiralty engineer is right, but practically it does not appear advisable to adopt lighter proportions, since the corrosive action inside of a boiler is the same for plates of different thicknesses, and therefore is relatively more destructive in thin plates than it is with those of heavier make. In other words, a reduction of one-sixteenth in the thickness of a one-inch plate, means that its strength is also diminished *one-sixteenth*, but in a half-inch plate this becomes *one-eighth*, in a quarter-inch plate *one-fourth*, and so on. Hence it will be seen that corrosion greatly influences the strength of steam generators and ought to be fully allowed for so that they may last as long as possible.

In the engines themselves, full advantage can be taken of the superior strength of the steel employed in various parts, consequently there is great room for reduction in weight so long as their rigidity is kept up. No one perhaps has more carefully studied the subject of economy in this respect than Mr. F. C. Marshall, of Messrs. Hawthorn, Leslie & Co., of Newcastle. As an illustration of this, it may be mentioned that the swift cruiser "Elisabeta," built at the Elswick Works, was supplied by Mr. Marshall's firm with two sets of triple expansion engines of 5,000 horse-power, the total weight of which, with boilers complete, including water, is under 250 tons. We have thus a set of powerful engines, with cast steel framing, etc., and mild steel working parts, reduced to 112 pounds per I.H.P., or, in other words, 20 horse-power per ton. This, however, is to some extent due to the very high piston speed now adopted in Government engines.

We may add by way of comparison, that the Cunard



TRIPLE ENGINES OF S.S. "MISSOURI."—1,300 HORSE POWER.

S.S. "Etruria" has machinery of 14,700 horse-power, and its total weight is 1800 tons—which gives 8·2 horse-power per ton; and similarly, H.M.S. "Victoria" is 14,500, 1,100, and 13·1 respectively, as above.

The plate of triple expansion engines shown opposite illustrates the latest style of machinery designed by Mr. Thomas Mudd, managing engineer of the Central Marine Works at Hartlepool. In this instance, the high pressure cylinder is placed between the other two, instead of being at the forward end, as is generally the case, thus producing very great economy owing to the heat retaining power of the arrangement.

The above firm are also the makers of an extremely compact and elegantly designed species of triples, having the cylinders placed in the usual way, but worked by piston valves at the back. These engines have done well in many ships, but the majority of superintending engineers—in a somewhat perverse manner—prefer to have the old link motion arrangement instead for cargo ships. It is not very complimentary of them to do so, and thus apparently neglect the variously "improved systems" of talented inventors who have spent so much time, and labour, and money, in their efforts to develop a better state of things.

The engines shown in the plate are of 1,300 horse power, and have cylinders 25″, 40″, and 65″ diameter, by 3 feet 6 inches stroke. The framing is open, light, and strong, and it may be additionally interesting to know that the view was taken from a photograph of the machinery of the famous S.S. "Missouri," which was the means of saving the lives of nearly 800 people from the foundering steamship "Danmark," and that it stands on the movable erecting shop foundation mentioned in a previous chapter.

If Mr. Watt—"Jeems Watt, the *inventor o' steam*," as the London policeman called him—could be with us now, and see what we had done with his famous engine, he would very likely gaze around in blank amazement, wonder, and surprise, but at the same time be delighted to find that some of his own inventions were still to the fore,—touched up and improved no doubt, but only in detail. These details, however, have required the very highest skill of the modern engineer to bring them to perfection.

The question of wear and tear in triple engines is best answered by those who have used them most extensively and for the longest period. Perhaps none are better able to give this information than Messrs. Thomas Wilson, Sons & Co., of Hull, who were among the first to discover their value, and who have since the year 1882 fitted many of their vessels with them. Their superintending engineer states that, in his opinion, triples are not more expensive to maintain in good working order than compounds, and adds that, in this respect, one of the least expensive of their fleet of sixty-five steamers is a vessel having three crank engines as above.

With regard to the last question—"Is any more skill required in the management of triple engines and boilers at sea?"—It may be said that this remains almost as it was as far as the machinery is concerned, but the high pressures now carried in boilers, necessitate greater care and judgment on the part of those who work them, and more attention to the various little details connected with them. As shipowning ladies and gentlemen, however, will not care one pin for the best kept machinery or steel-built ships, unless they can get a dividend from them, we may add that the engineers on land and sea are in no way responsible for commercial adversity in any of the Companies. The fault lies with some of the owners who recklessly destroy the vitals of fair trade and commerce, and thus almost annihilate their chances of success.

If anyone tells us that a thing is black when it *is* black, or white when it *is* white, the statement is self-evident. But when people talk or write about "*Steamship performances*," they at once enter upon a subject that is capable of extensive misinterpretation, and at no time, perhaps, is this more observable than when the deductions from official records are placed before us. From the tables of performances compiled by Mr. Hall from the log-books of numerous steamers, it appears that the average coal consumption in long-voyage ships, with triple engines, is about 1.5 pounds per horse power per hour. In addition to this, some of the most eminent authorities have already stated, that these engines save fully twenty-five per cent. of the coal used in compound engines.

On the other hand, a highly experienced superintending engineer to an Atlantic mail line has declared that, after his own careful examination of the records of numerous ships belonging to different firms, *he* concludes that the saving referred to does not, in any case, exceed 15 per cent. And, as if in confirmation of this, the late trial trip of the S.S. "Meteor" has shewn that triple machinery may indicate only a small amount of economy, even when under the most careful management. Now these are very inconsistent statements, and when accomplished engineers authoritatively give them to the world, what are we to think?—or say?—or do?

The S.S. "Meteor," mentioned above, belongs to the London and Edinburgh Shipping Company, and her registered tonnage is 692. The engines were made by

Messrs. J. and G. Thompson, of Glasgow, and have cylinders $29\frac{3}{8}''$, $44''$, and $70''$ diameter, by 4 feet stroke, the indicated horse power being 1994.

The trial took place on June 24th, 1888, during a voyage from Leith to London, when everything in the machinery department was subjected to the strictest supervision. The coal was weighed—the feed water was measured—the power was indicated every half hour—the temperature of the furnace gases escaping up the chimney was observed at intervals during the trial,—the engine and boiler efficiencies were carefully noted from time to time, as also was the speed of the ship. In short, nothing was omitted that skill, prudence, or forethought could suggest. The special experimental staff was a powerful one. Professor Kennedy, C.E., of University College, London, was commander-in-chief of the expedition, and under his directions the work of the ship was most successfully carried on by two relays of observers, aided by a few extra hands, and in supreme command of the engine-room department, was placed the invaluably co-operative, and ever *everywhere* chief engineer, Clephane. It was not usual for this gentleman to have such distinguished professionals to assist him in his peculiar duties, but he was, nevertheless, most cordially equal to the occasion.

The whole trial required continuous attention from those in charge. It was, however, eventually discovered that the quantity of coal consumed during the trip was at the rate of 2·01, or *two and one-hundredth pounds* per indicated horse-power per hour. In other words, these engines shewed that they were little better than compounds in similar condition. This was a disappointing result, especially under such extremely favourable circumstances. It is, therefore, only meet and right that we should try to throw a little light on the subject in the hope of being able to say to hypercritical critics, "We'll *meet yer* at every point of the argument, if we can."

The first ameliorating feature in the trial that presents itself is the fact that the coals were not good, and, secondly, and most importantly, that the engines were experimented upon simply in their ordinary condition, no effort having been made to race them with the object of obtaining high, though temporary, results. Perhaps the greatest benefit to be derived from this experimental voyage is, that it gives a new colouring to steamship performances, and indicates the difference between a forced trial and one of a purely commercial character.

It is generally believed that, while the old compound engines burnt fully two pounds of coal per indicated horse power per hour, the triples only require one and a half, and the quadruples one and a quarter pounds. We have thus a saving of twenty-five per cent. in favour of the triples, as mentioned by some of the highest authorities. These statements, however—with a Meteoric light around us—seem to open out a new field of inquiry regarding the manner in which the horse-powers of engines are sometimes calculated at sea.

So long as human nature is what it is, so long also will the engineers of ships continue to make their machinery show off on paper. And thus we have reason to think that many of the log-book records are obtained from engines scientifically raced to the utmost only for a very short period. This can easily be accomplished by enthusiastic engineers, and, although we would not for one moment say that they actually overdrive their ships for the sake of obtaining double extra indicator cards, we nevertheless fancy that, in slow-going cargo ships, the temptation to do so may occasionally be too strong for them, and thus the records at once become too roseate for ordinary practice.

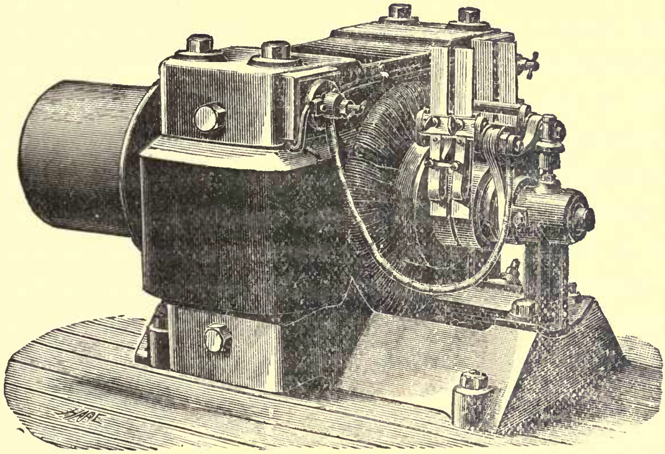
To make this clear, let us suppose that a set of engines in ordinary work are indicating 1,000 horse-power upon two pounds of coal for each of them per hour. If, however, they are made to give out 2,000 horse power merely to get a show card, the coal expenditure will apparently become one pound, and thus an erroneous impression will be created.

A more correct idea of ships' performances can be taken from the coal consumption of two long-voyage steamers exactly alike as regards tonnage, power, displacement, speed, etc., one of them having triples, and the other compounds, in the same state of efficiency. The most conclusive method, however, for everyone, is to compare the *financial* results of the ships, say, for instance, the above upon a round voyage, or for a whole year's working. Take, for example, my old friend the "Lusitania"—built in Laird's in 1870—which, after being tripled, realised for her owners £1,000 in one return Australian voyage; and, still later, the Union Company's S.S. "Spartan," which saved, in one return trip to the Cape, 500 tons of coal, or, otherwise expressed, £3,000 a year to her happy possessors.

Another source of vitiated results is no doubt the custom of comparing new triples with *old* compounds, and although the latter may be in perfect order, after the lapse of many years, the boilers may not possess the same steam-raising power they once had. Hence we have another reason for triple machinery, with new and clean boilers, being apparently so highly economical.

The above facts will therefore account, in some degree at least, for a few of the discrepancies already referred to, which have now become so perplexing.

Ever since the E.S. "Volta" crossed the channel in 1886, the electrical propulsion of steamers has excited the attention of the boating community on the Thames, who recognised the advantages of the new motive power. With the object of providing the desired innovation, Messrs. Immisch & Co., of London, have introduced their specially designed electric engines or "Motors"—one of which is shown in the annexed view.



ELECTRIC MOTOR FOR LAUNCHES.

In this case, the screw-propeller shaft is worked direct by an engine which receives its supply of electricity at various charging stations, floating in the river at different points, where launches can at any time be re-charged, or kept in readiness for use. Similar engines, of a modified form, for mining purposes, such as pumping, winding, etc., have already been referred to at page 435. For pleasure boats, however, thus propelled, the absence of a coal-fired boiler with its attendant heat, and smoke, and dirt, has no doubt been highly appreciated by many. The New York Elevated Railway Company employ electric engines on their various lines, and thus save at least half the coal expenses. The Overhead Dock Railway in Liverpool is the first in England to be worked by the same power, and on other lines, and in many other ways, the new motor will soon be extensively employed.

We have been induced to give considerable prominence to the subject of coal consumption in steamers, because it contains the very germs of that commercial prosperity shipowners and manufacturers are constantly aiming at, and which may be more fully attained by the use of the liquid fuel system of firing. This system is highly appreciated on board many hundreds of naval and mercantile steamers in Russian waters, and also in locomotives and factories, owing to the low price of petroleum, and its attendant advantages. The oil-burning apparatus, which can be easily applied to marine boilers, immensely reduces the work of firing, cleaning, etc., on board ships, produces no smoke, and besides this, it can be instantly lighted or extinguished. In good furnaces, 1,000 tons of refuse oil will go as far as 2,000 tons of coal, and requires only the usual bunker space for 500 or 600 tons of the latter, thus saving, say, 1,500 tons for freight.

With the object of reducing the cost of petroleum, large ocean steamers are now being extensively built to carry the oil in bulk after being loaded through lines of pipes direct from the wells hundreds of miles away, and this has already enabled very much to be accomplished that otherwise would have remained undone.

The latest application of the liquid fuel system, as applied to steam navigation, is to be found in Messrs. Yarrow's "Zephyr" launches and yachts, the motive power of which is obtained from vaporised spirit instead of water, and whilst the necessary heat is obtained by means of petroleum firing, the economy of the system is derived in various ways from the manner in which its details have been carried out, after prolonged, elaborate, and costly experiments. The advantages possessed by this new arrangement, consist of much less weight in the machinery—50 per cent. more space for passengers—extreme cleanliness—no skill required in working, as the apparatus is automatic,—no risk of explosion, &c. In short, as Mr. Yarrow himself declares, there is everything in these beautiful little vessels to make them a source of economical pleasure to those who use them.

As a still further example of the practical application of liquid fuel, it may be stated that Mr. James Holden, the Locomotive Superintendent of the Great Eastern Railway, has successfully applied a special system of his own to the Company's engines, which can now be fired either with coal, or petroleum, or with both together, if desired. And this, too, without any alteration in the furnaces.

Facts like these are of great value, and certainly deserve the careful attention of people who wish to economise either on a large or on a small scale. We may add that this most important branch of engineering will be treated in another form, and—as the sensational authors and authoresses put it at the end of an outrageous chapter of horrors—"continued in our next," and last.

CHAPTER XXX.

QUADRUPLE AND NEW COMPOUND ENGINES.

Important Improvements—Chemistry the Destroyer—Boiler Room difficulties—Tubular and Tubulous Boilers—Strange disaster to a new Boiler—Simple Apparatus for purifying Water—Water Tube boilers and their failures—The latest type of Tubulous Boiler—Opinions of Experts—Table of Horse Powers per ton of Weight—Peculiarities of the Forced Draught System—Latest types of Quadruple Engines—Turner's new two cylinder Compound Engines—Their performances compared with Triples—Extended use of Manganese bronze Propellers—Willis' "protected" Propellers—Steamships of the future—Conclusion.

So many real improvements have recently been made in quadruple machinery, that further advances in this direction will be somewhat retarded. There is, however, much to be done, in various ways, with steam generators, before the highest point of excellence is reached.

It is to this point, therefore, that the highest skill and talent of my learned brethren must now be directed. And it is here that we may yet hope to catch the sympathies of shipowners who wish to run their steamers at the least possible expense. Hence it may be said that the whole question of increased economy in steam navigation is resolved into one of boiler construction, furnace firing, and boiler management at sea.

It is very extraordinary that one of the otherwise beneficial sister sciences should be our constant and most relentless enemy. She has teeth hard enough and sharp enough for anything. She nibbles our cast steel screw propellers to death long before their natural strength is mechanically abated. She will in a few years cut to destruction our largest screw shafts if we give her a chance. And she will pit, and furrow, and destroy the plates of our boilers, and cover the fire tubes with a hard scale which greatly injures their steam raising qualities, and sometimes causes disastrous explosions, long before the inherent powers of the boilers have been impaired by legitimate work. Not only would these evils happen, but they would become of such continual occurrence as to imperil the very existence of the steam engine in ships unless we contended with Chemistry tooth and nail, and tried to baffle her at every point.

The direct cause of all these evils, so far as steam generators are concerned, lies in the chemical impurity of the water contained in them. If we could only use *pure* water—water that would leave no deposit on the parts exposed to heat—water which would neither pit nor furrow the internal plating, thus reducing its strength, the management of boilers at sea would be greatly simplified. The chemical evils just mentioned influence in the highest degree the designing of boilers, whose interiors must be so arranged as to admit of inspection, cleaning, and repairs when necessary. And the cause of so many "perfect cures" in this department of science turning out complete failures has been the want of proper attention to one or more of these vital points.

As the matter now stands, there is not a single branch of engineering which presents so many serious difficulties in the way of future advancement as that now under consideration. The engines are right enough practically and dynamically, but when it comes to the thermo-dynamic machinery of the boiler room we find that after all the time, and money, and patience, and skill that enterprising inventors have so liberally expended upon them, the marine steam generators are not nearly so perfect as we should have expected to find them. Much has certainly been done, but much more remains to be accomplished before the quadruple, or indeed any other marine engines, can give out their best results, not only in short runs under the most favourable conditions, but during long voyages when exposed to numerous disadvantages.

Various systems have been utilised with the object of accomplishing this, some of which are too well known to require further comment. Broadly speaking, these systems resolve themselves into two classes, the "tubular" and the "tubulous." The former term is applied to all boilers whose heated gases pass through a large number of brass or iron tubes on their way to the chimney, thus heating the water which surrounds them in a most efficient manner. Steam generators of this description are universal in locomotives, and very nearly so in steamships, and their great popularity is due: firstly, to their excellent steam raising powers; and, secondly, to the ease with which they can be kept in order. Hence any marine boiler which requires to use a certain amount of sea water in addition to the chemically impure fresh water from the condenser, is compelled to have its interior thoroughly inspected and cleaned from time to time.

The necessity for doing so is very fully understood by all superintending engineers, and by the engine room staffs of steamship lines. A recent accident, however, of a very peculiar nature on board a coasting steamer will practically confirm these remarks. This vessel was perfectly new, and her engines, boilers, etc., were under the careful supervision of Lloyd's surveyors while being constructed. The ship, however, had only been under steam

240 hours, when one of the furnaces collapsed and entirely disabled her.

It is a well known fact that pure fresh water is the best for boilers; but, at sea, the fresh water obtained from the condenser is mixed with impurities which corrode their interiors unless anti-corrosives are used, but this is not all. Theoretically speaking, the steam used in the engines, and afterwards changed into water by condensation, would be quite sufficient to supply the boilers, and continue the process of steam raising, steam using, and steam condensing for an unlimited period without any external aid. Inasmuch, however, as there is loss or leakage to a small extent, this must be made up by taking a little salt water from the sea, which contains fifty-six pounds of salt per ton, not to mention several other solid impurities that would rapidly destroy a boiler unless well protected from them.

While steam is being made this water is increasing in saltness, which renders it more difficult to boil and more destructive to the flues and tubes on account of the salt deposit upon them, and therefore a salinometer is employed to indicate the density of the fluid, and to show when some of it ought to be "blown out," to make room for a fresh supply. It will, therefore, be seen that if this instrument is not correct, a solid deposit may rapidly settle upon the furnace tubes, and so much impair their heat-conducting powers as to cause the plates to be overheated, and thus bring about a disastrous explosion, or—as in the present instance, a partial collapse.

This is exactly what happened on board the steamer just referred to, and—as clearly proved at the Board of Trade inquiry—the inaccuracy of the salinometer misled those in charge regarding the condition of the water in the boiler at the time of the accident and indirectly caused the failure of the furnace.

All disasters are professionally instructive; this one especially so, as it not only shows how rapidly the chemical impurities of water act upon metal surfaces exposed to their agency, but indicates the necessity for constant watchfulness on the part of the engine room staff. It may further be added, that as the solid deposit in boilers becomes intensified under very high steam pressures, it has been proposed to use water distilled on board ship, but even this is unnecessary when we can employ a very simple feed-water-cleaning apparatus which will—to a large extent—perform what is desired.

The object of the invention is to purify and heat the water before it enters the boilers. Zinc plates placed in their interior, and various anti-corrosive mixtures are only *remedial* in their action, whereas the apparatus referred to attacks the *cause* of corrosion, and has also the advantage of costing nothing whatever for maintenance. By removing the air, grease, dirt, etc., from the fluid before being used, the cost of keeping a boiler clean is reduced to about one-third, and thus the plating is protected from injurious deposit as mentioned above.

The sole makers of the apparatus are the Wallsend Slipway and Engineering Company at Newcastle, who have fitted it to upwards of 100 large steamers.

Such then in brief is the case for the *tubular* boilers, which will most likely—for the reasons given—hold their ground in long voyage steamers against all others so long as steam is used. The same, however, cannot be said of the tubul*ous* boiler. In this class of steam generator each tube is filled with water, and as the heated furnace gases play around the outside of them, they each become little independent boilers, possessing enormous strength. But, with the usual perversity of engineering, this valuable quality may be neutralised by the attendant disadvantages of non-accessibility for cleaning, and the great difficulty of stopping a leaky tube while under steam.

The water tube boiler has been exposed to a very great amount of high-toned criticism by those best capable of judging its merits. It has been put into ships with a varied amount of success, according to circumstances, and its object has been to reduce the weight, but chiefly to obviate the risk of serious damage by explosion. This steam generator has in times past, however, given much trouble, and even now it is by no means perfect. Amongst the "seventies," some of the failures indicated above occurred on board various ships. The new boilers were therefore taken out; and, in addition to other disasters, may be mentioned the total loss of two vessels through their explosion. So much valuable experience, however, has been obtained, that there is at present a better prospect of success in this direction.

The question may now be narrowed to a point, and that point Messrs. Thorneycroft's latest type of water tube boiler for torpedo boats.

The first thing that strikes one in connection with these new boilers is the large number of curvilinear tubes of small diameter in which the steam is formed, and which appear to be difficult to keep in proper order. But what does it matter, after all, whether there are few tubes or many tubes, large tubes or small tubes, straight tubes or curved tubes, so long as the wear and tear, coal consumption, weight of apparatus, and its maintenance and durability are proved to be satisfactory in actual practice at sea. Under existing conditions in the merchant service, however, we may fairly conclude that this boiler cannot be used in ocean liners, although it is no doubt very suitable for the vessels mentioned above using only the *purest* water for short runs.

This question is of the utmost value to the world at large, because the economical working of steamers now depends entirely upon the way in which it is treated, and hence the opinions of talented engineers connected with steamship Companies are most important.

When we find Mr. Manuel of the P. and O. Company pleasantly saying that he would be very glad if the Thorneycroft boiler could be used so as to obtain higher pressures, and also to get over many difficulties now existing, but that he had doubts regarding its durability, and capability for continuous steaming upon the ocean.

When we find Mr. Parker authoritatively observing that he had had experience at sea with water tube boilers up to 4,000 indicated horse-power, and that some of them had failed, and a few had been put into ships, and—taken out again. That serious accidents had happened to others; but that, in spite of all this, he wished to see a good water tube boiler introduced. When this gentleman additionally observes, that a steam generator which can be easily cleaned internally is the best; that the present cylindrical boiler can be made to work for eight years without having a leaky tube; and that he had seen one of them that had been in use for eighteen years, What are we to think?

And when we hear of Mr. John Scott of Greenock, and Mr. MacGregor *distantly* following on the same lines, and expressing somewhat similar opinions, What are we to do? We'll just exactly do *nothing* but watch the progress of events.

Mr. Thorneycroft has himself declared that the horse-power per ton of weight of different classes of boilers, including all fittings, spare gear, funnels, etc., is as follows:—

16·6	I.H.P.	per ton	in	P. and O. Steamers.
43·0	"	"	"	Torpedo catchers of latest type.
48·0	"	"	"	Locomotives of same power.
68·0	"	"	"	Thorneycroft's torpedo boats.

This table shows at a glance the comparative values of different systems, and indicates what is now being done in at least one branch of engineering practice. It is only fair to add that water tube boilers for land purposes have become very popular in America and on the Continent. Their use is also rapidly extending owing to the great increase of steam pressures, for which they are so suitable.

For a little variety, let us have a chat about "forced draught." The idea is an old one. James Watt tried it on his famous kettle with the bellows, and millions since his time have similarly utilised it in their own houses. In past years we were taught to believe that the truest economy in steamers consisted in giving them plenty of boiler power and easy firing, thereby increasing the durability of every part exposed to heat. Now, however, we are asked to try something which is said to be better, and although a very great deal has been said and written upon this subject, nothing conclusive has yet appeared.

"Coals is coals *now*," as the dealer told the little girl who complained that the last lot he sold to her were stone—or rather of a rocky formation. So they are also in many ways to the shipowner, and, therefore, the advocates of the new system of firing furnaces are doing their best to show him that he will save ever so much by adopting it in his vessels. After what has been said and done to prove this, however, it appears surprising that all the ocean Companies have not made a rush at it, but the experiences of engineering practice are, as we have said, so extremely peculiar, that we have to make our advances in red Indian style—very cautiously.

There is an old story floating about the world concerning a Highlander who hoped to make his horse do without food by reducing the allowance to the extent of one straw per day. When it came to the *last* straw, however, the horse died because he was fed too much on *air*, and if the furnaces of steam generators are forcibly supplied with an over-charge of atmosphere, is it not very apparent that the intensified heat thus produced may in time so injure the crown plates of a flue as to cause its collapse. Of course when everything is kept in splendid order this cannot happen, because the heat is passed through the metal to the water which surrounds it; but if the conducting power of the plating should be checked by chemical deposit, we may then expect its rapid and premature destruction.

This is what may be termed a practical view of the case, although only from one point of observation. Its commercial aspect has, however, been to some extent indicated by the recent voyages of Messrs. Smith & Son's S.S. "City of Venice," and also the sister steamer "B," owned by the same Company, the former vessel having been worked under the forced draught system, and the latter with natural draught only.

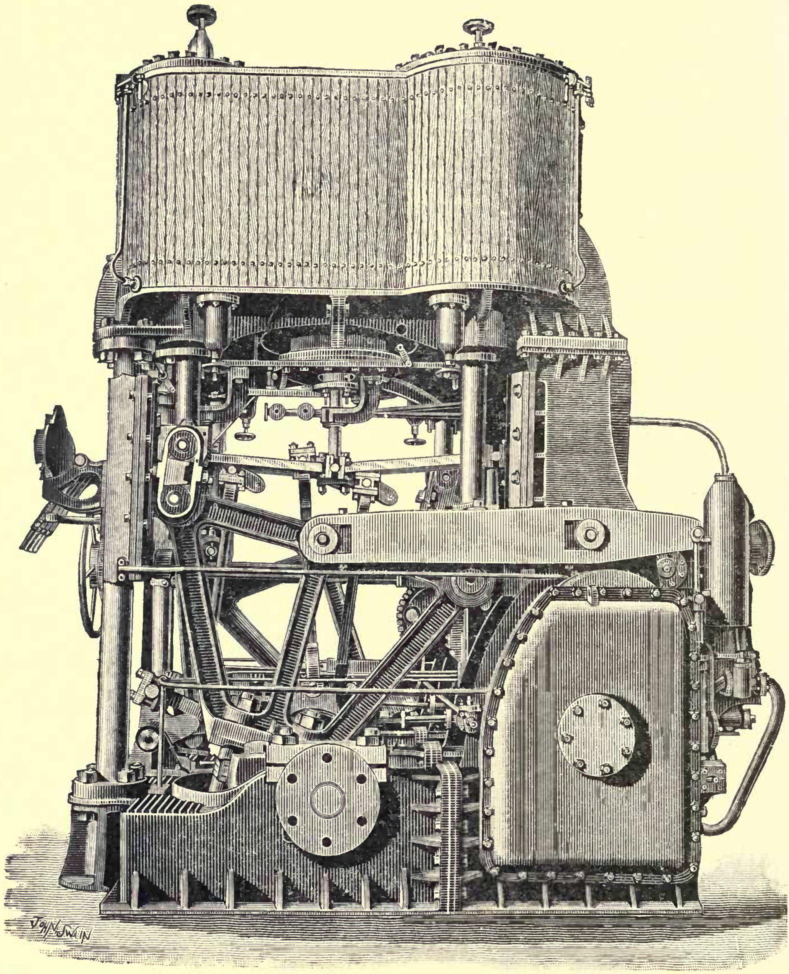
The gross tonnage of the "City of Venice" is 3,372, and her quadruple engines are about 1,700 horse-power; whilst steamer "B" has a tonnage of 3,229, and is driven by an equally effective set of triple machinery, both ships being fitted with duplicate propellers. Under these circumstances, the average daily consumption of coal by the former during the round voyage to Calcutta was 24 tons, and by the latter 32·2 tons, thus indicating a total saving of 430 tons of coal, or 22½ per cent. on the run out and home at practically the same speed for both vessels.

From this it appears that forced draught is so profitable that all the shipowners would be induced to adopt it, unless restrained by the prejudiced judgment of their superintending engineers. These gentlemen, however, have a curiously aggravating way of viewing every innovation that comes before them in an all round fashion, and of treating the enthusiastic statements of inventors as if they understood what was said, but did not quite see what was meant. Some of them, for instance, will probably enquire "how much of the 22½ per cent. gain in the 'City of Venice' is due to her quadruple engines?" Others, while acknowledging the value of such a result, will at once tell you that "if it can be satisfactorily proved that the present advantage of forced draught is not neutralised by increased wear and tear, by premature renewal of the boilers, and by other incidental considerations, then by all means let us have it."

Quadruple engines are now made of various designs, from three horse-power to 10,000 horse-power or upwards, to suit the requirements of those who wish them. Messrs. Denny are extensive makers of machinery of their own style, a handsome set of which was recently fitted to the S.S. "Buenos Ayres" of 4,300 horsepower, and having cylinders 32″, 46½″, 64½″, and 92″ diameter by 5′ 0″ stroke. Her crank shaft is 18″ diameter, and the working pressure of steam 180 pounds per square inch. If anything can improve the beauty of this class of engines, it would be the adoption of sheet steel lagging for the cylinders, instead of mahogany, as it would give them a true metallic appearance and is easily kept clean, whereas the latter looks inappropriate, and soon becomes irreclaimably dirty.

The most distinctive type is one specially designed by Messrs. Fleming & Ferguson of Paisley. Here we have two cylinders placed on each side of the crank shaft, which will be clearly understood upon reference to the annexed plate taken from a photograph of the 1,600 horse-power engines of the S.S. "Singapore."

The design is entirely out of the beaten track, one peculiarity being the arrangement of the cylinders as described, and the other the adoption of a triangular connecting rod, as shown, which by the alternate motion of the piston rod at each end, produces an effect with only two cranks directly opposite each other, similar to that obtained with four cranks at an angle of forty-five degrees with each other. By placing the whole of the cylinders on the same level, all the valves, covers, and pistons, can be examined, or taken off, or taken out, with the greatest ease. The machinery is very simple and compact, especially in a fore and aft direction, and the performances of engines already supplied to steamers have given every satisfaction, whilst in the case of the "Singapore," the coal consumption on trial trip was only 1·121 pounds per horse-power per hour. It may be added that the two valve casings for piston valves are between the cylinders, and fit conveniently into spare spaces in the design, which would otherwise remain unoccupied. Port passages to cylinders are very short, and heat radiated from casings, etc., is confined by and given out



QUADRUPLE ENGINES OF S.S. "SINGAPORE."—1,600 HORSE POWER.

again to the cylinders. There are also very few vital working parts—four main bearings, two crank pins, and two eccentrics for valves being all the revolving parts—whilst in triples there are six main bearings, three crank pins, and six eccentrics. These engines can therefore readily replace old compounds without alteration of bulk-heads.

The quadruples made by Messrs. Simpson, Strickland & Co., of Dartmouth, are of a novel type, specially adapted for launches and yachts of different sizes. A large number have now been made for various Governments, and also for many firms and yacht owners in all parts of the world, and the details have in every respect been very carefully designed with a view to simplicity and economy. It may be mentioned by way of example, that a fifty feet launch, as above, has an approximate speed of thirteen miles on a consumption of 25 pounds of coal per hour, thus making the cost of fuel per day, of ten hours, about two shillings and sixpence.

The very latest improvement in marine machinery is the Two-cylinder-Compound engine invented by Mr. Henry Turner, of Liverpool, which — for experimental purposes — was recently fitted to the yacht "Water-witch." The cylinders are 6″ and 17⅛″ diameter, by 10½″ stroke, thus giving a ratio of 1 to 9, and the boiler has been judiciously modified. Numerous trials have been made to test the efficiency of the new engines, and during one of them we had the pleasure of being an observer. The following table will show by comparison the difference between the results then obtained and those of the S.S. "Meteor" already described :—

Turner Engine.		S.S. "Meteor."
Total indicated horse-power..	54·29	1994
Pounds of water evaporated per hour from 212° ..	752	29860
„ of coal consumed per hour	66	4005
„ of water evaporated from 212° per lb. of coal	11·4	8·21
„ of coal burnt per I.H.P. per hour.. ..	1·215	2·01
Square feet of heating surface in boiler per I.H.P.	1·62	3·33
I.H.P. per square foot of grate surface	18·68	9·58
Pounds of coal consumed per sq. ft. of grate surface	22·6	19·25

The funnel was smokeless during the trial, and the machinery worked most satisfactorily. With engines on the three crank principle, having a stroke of three to five feet, also with a higher ratio of cylinder areas—say, 1 to 12—thus giving 24 expansions instead of 19 as above, it is expected that the coal consumption will not exceed one pound per horse-power per hour. Indeed, when the revolutions were increased to 480 per minute during the preliminary trials, it proved to be even less than this.

An important feature in the design is the arrangement of the cylinders and valves, by means of which the former are used alternately for steam pressure, and for forcing hot air into the ashpit of the closed furnace of the boiler. As this air is drawn from the tubes of a heater placed in the uptake leading to the funnel, it raises the temperature of the cylinders to such an extent as to prevent any loss from condensation of steam owing to reduction of heat. And as the pressure is only upon one side of each piston, the other two sides are left free for hot blast purposes.

For large ships, two or three sets of tandem engines may be used, or they may be made similar to those of the

S.S. "Umbria," etc., that is, with one high pressure cylinder supplying steam to two of low pressure of equal diameter. In this case, however, steam is used on *both* sides of the high pressure piston, expanded alternately on one side of each of the others as before, and then changed into water as usual in the condenser, which, with all its gear, remains unaltered.

The above remarks have been confirmed by a recent accident to the triple machinery of a New Zealand steamer. The intermediate engine of this vessel became disabled at sea, and it was therefore disconnected from the other two, the high pressure of which was worked as formerly. During the rest of the voyage it was shown that under the temporary arrangement the high and low pressure engines alone produced the same power and speed as before, with the same coal consumption.

Some of the leading superintending engineers, and others, have carefully watched the development of the new system, and efforts are now being made in influential quarters to utilise it on a large scale.

In previous chapters reference has been made to the varied effects of breakdowns, and also to the materials of which screw propellers are formed. The late terrible disaster to a whole fleet of ships at Samoa will help to emphasise these remarks. When the storm which destroyed the squadron was at its height, and H.M.S. "Calliope" was crawling out to sea at the rate of about half a knot an hour, with the machinery pressed to its utmost, the most insignificant accident would have caused her loss with all on board. But quite apart from this, the greatest credit must be given to her manganese bronze propellers. Had they been of *steel* the ship would still have been lost, as the very latest facts have proved that about half a knot extra may generally be expected from steamers having screws of the former metal.

This in itself means considerable economy, which is shown by the performances of various ships. For instance, when the P. and O. S.S. "Ballarat" had her speed thus improved, she saved about 715 tons of coal on the voyage out and home from Australia. Still more remarkable is the fact that the S.S. "Australia" and "Zealandia," running between Melbourne and San Francisco, had their speed increased nearly one knot by the use of bronze screws of the same diameter, pitch, and surface as before. This enabled them to perform the voyage in two days less time, and obtain the postal premium, which paid many times over the cost of the alterations.

It may also be added that some of the great ocean lines are extensively adopting the same metal, notwithstanding its high price, on account of the advantages it confers. Mr. Willis, however, informs me that the Scotch engineers are highly pleased with his method of protecting steel screw blades from corrosion. It is therefore quite possible that the shipowners throughout the country will use it before long, as they can thus obtain the above results at much less cost.

We began with the eight knot "Sirius," and end with the twenty-one knot "Teutonic." "Any advance on this?"—as the auctioneers say. Well, yes, much every way—in time.

It is said that during the first visit of a well known English frigate to Sydney, the officers were so frequently asked—"Have you seen our harbour?" or, "What do you think of it?" that the next time they came, they facetiously adorned one of the sails with the inscription in large letters—"WE'VE SEEN YOUR HARBOUR!"

To this lovely spot on the earth's surface, the future mail liners will run at twenty-one knots an hour, and very probably the "lightning" racers of the Atlantic will have a twenty-five knot speed. The aforesaid torpedo boats exceed this, and so also may passenger steamers with improved boilers and higher pressures, quick-running steel-built engines of greater power, and fine lined hulls.

The last two chapters have been unavoidably heavy, though I hope useful to many, if not to all. The worst feature, however, of technical literature is the difficulty of enlivening it. If we could only adopt a lighter style, the scientific truths intended to be conveyed would be more easily read, more clearly understood, and more permanently fixed in the mind, on account of the relief thus given to the student.

The volume now at an end was originated by a holiday visit to the Clyde after many years' absence, and by the flood of sunny memories which that visit awakened. Its preparation has been a source of great pleasure from first to last, and it would be very ungrateful if I did not here record that much of the happiness I have tried to reflect in its pages has been due to the pursuit of engineering. Her disappointments have been numerous but variously beneficial, and above all, she has most handsomely taught me to find the true rest for the weary—a rest ever present amidst the vacillations and uncertainties of life, and thus, in one sense, I have become enriched.

It would be unkind if I did not refer to my good friends the gentlemen of the legal profession, with which I have been closely connected all my life, as many of my own relatives have been in its ranks—on the Bench, at the Bar, and as solicitors. Legal practitioners are generally most courteous and humorous, but they never appear more charmingly interesting than when hilariously excited by the replies of a witness—by their own extemporaneous witticisms—or when we are honoured with their assistance in solving those knotty points of equity so frequently to be found in our own practice.

One of their order—the city Coroner of Liverpool—is a splendid specimen of his class. Some years ago the designer of a high level bridge scheme tried to explain its peculiarities to this gentleman, and after a short conversation exclaimed, "It's easily seen that *you* are no engineer."

"Exactly so," said the ever genial and witty Coroner, "exactly so, but to me it is very evident that you are not a *civil* one."

I certainly cannot close this treatise without offering my best wishes for health and prosperity to the ladies and gentlemen who are shipowners, and to shipbuilders and engineers in every branch of the service, with their wives and daughters, their sisters, cousins, and aunts, and also—their *intended* relations.

I have endeavoured to take the non-professionals of both sexes behind the scenes, and to explain to them in a free, open, unrestrained style, what I have learnt for myself in the delightful study and practice of engineering. May I therefore hope that this new edition has proved so attractive as to cause readers of every class to share in the regret with which we say to all—Farewell!

INDEX.

ABSTRACTS OF REVIEWS OF FIRST EDITION.

"It was a decidedly happy thought that prompted Mr. Haldane to write a treatise on *Civil and Mechanical Engineering* for general reading, and in this he has succeeded admirably. He has treated his subject in a broad and intelligent manner, and has interspersed some capital stories and reminiscences that give a bright, lively tone to a work of great value, which is written with conspicuous ability, and rich in instructive and entertaining matter."—*Morning Post.*

"Mr. Haldane's intention has been to try to interest everyone in the science in which he is a practical proficient, and he has, on the whole, admirably carried out his conception."—*Saturday Review.*

"It is but fair to say that most 'popular' scientific works, as generally constructed, are designed not to be read, but to be given away as gifts or prizes. There are a few, however, which have the rare distinction of being readable. To this few undoubtedly belongs Mr. J. W. C. Haldane's book on *Civil and Mechanical Engineering.*"—*The Scotsman.*

"The interest of a subject depends on the way in which it is handled; and Mr. Haldane so deals with *Engineering Popularly and Socially Considered*, that not only those who want to know what to do with their boys, but readers of all kinds will not lay down his book until they have read it through."—*Graphic.*

"The graphic description of the life of a mechanical engineer and of its achievements—the salient features of the work of a constructing and consulting marine engineer—stories of the errors of engineering, &c., make a most interesting volume.—*Scientific American.*

"This production of Mr. Haldane's is a welcome novelty in the field of engineering literature. It contains much useful information, and embodies the ideas gleaned in a thirty-five years' professional experience. Altogether the volume commends itself for both pleasant and profitable reading, and well carries out the intent of the author."—*American Engineering News.*

"A very interesting and valuable record of the great improvements already made, and of the life and experience of a practical engineer. It abounds with a variety of useful information as to the different branches of the science. In fine, we have much pleasure in recommending Mr. Haldane's most attractive book to all readers who wish to become intimate with the operations of so important a science, especially when the details are set forth with such clearness and in so pleasing a style."—*Irish Times.*

"The personal experiences of the author fill several very entertaining chapters, while the whole volume is written in a style that will greatly interest general readers. Mr. Haldane says, 'The reason why so many false steps are made in the choice of engineering as a profession is attributable, on the one hand, to a want of proper knowledge of what is required of them by those who wish to enter it, and on the other hand, to unsuitability, or want of application, on the part of those who feel somewhat inclined to study it.' The present work will be useful in enabling some of these difficulties to be overcome, by making known the exact requirements of an engineer's workshop."—*The Daily Chronicle.*

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