NAVAL ARCHITECTURE: 1815-1893

by

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You-you -- if you have failed to understand
The fleet of England is her all in all
On you will come the curse of all the land,
Which Nelson left so great -

. . . .

You-you -- who had the ordering of her Fleet,
If you have only compass'd of her disgrace,
When all men starve, the wild mob's million feet
Will kick you from your place -
But then too late, too late.

--- Lord Tennyson

(Times of April 23, 1885)

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INTRODUCTION

From pre-historic times man has been challenged and fascinated by the sea. So even before the dawn of civilization he had built a 'dug-out' by hollowing the tree trunks which he used to cross the river or stream. Gradually he became more and more civilized and with the civilization his knowledge of shipbuilding also improved. The Egyptian, Athenian and Roman ships clearly show that change.

As the time passed man's knowledge of science and technology improved which in turn influenced the shipbuilding. During Roman times, ships were built of oak. The planks were placed edge to edge and were fixed with dowels and pins. Accounts of the invasion of England by Julius Caesar in 55 B.C. show that the Celts also had ships whose hulls were more flat than those of the Romans. This was done because of the shallowness and tides of the English Channel. By 450 A.D. Viking types of long boats were built by the Scandinavians who used this type of ship to invade England. These vessels were also built of oak with a heavy shaped keel reaching well below the skin of the ship. Transverse strength was obtained by a number of ribs and frames. One of the most important characteristics of this type of ship was that they used to be double-ended with high bow and stern and with single mast and sail. By 900 A.D. further changes were made in ship designs of Scandinavia and England was not far behind in this respect. Alfred the Great saw the value of sea-power and built vessels to fight against the Danes. The design of his ship was not different from that of the Vikings but the form of the ship was changed to suit better the rough water of the English Channel. The Norman rulers of England also did not make any change in the design of the ships. From this time until 1400 A.D. there is little knowledge of the development of ships except for the pictures given by the seals of some of the English towns.[1] During that period England used her navy, except under Henry V (1413-1422). He had a fleet of 1500 vessels to provide transport for his troops to France[2] during the campaign which led to Agincourt.

Gradually, by the sixteenth century, with the creation of new trading routes, an improvement in the British navy can be traced. Henry VIII in 1512 issued letters patent to Sir Edward Howard to take charge of the king's ship and all matters of crew and cost.[3] He set up the dockyards at Woolwich and Deptford and began to make Portsmouth more suited for naval work. In 1514 he issued a charter "for the relief, increase and augmentation of the shipping of this Realm of England."[4] The numerical strength of ships was increased during the reign of Elizabeth. From then onwards the number of ships increased without a considerable change in the design and method of shipbuilding. So from the sixteenth century to the later part of eighteenth century there was hardly any change in the construction of ships.

A change can be traced in the ship design and method of shipbuilding from the second decade of the nineteenth century. Naturally the question arises why this sudden change came? Was it due to political, economic or

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[1] Sir Westcott Abell, The Shipwright's Trade, (New York: Caravan Publishers, 1963), 19.

[2] Ibid., 20.

[3] Ibid.

[4] Ibid., 27.

or industrial and technological developments or was it due to the development of armor and guns? In the following chapters an attempt will be made to show whether all these factors played the same role or one of these had the more effect than the other.

CHAPTER I

POLITICAL AND DIPLOMATIC SITUATION FROM 1815 to 1893

> "The first article of an Englishman's political creed must be that he believeth in the Sea..."
>
> -- Marquis of Halifax (1694)

What the Marquis of Halifax said on this occasion epitomizes the idee fixe of the English nation since ancient times. During the nineteenth century one of the great economic forces at work in the world was the mechanical inventiveness of the British, which gave them an increasing control over nature. By the end of the eighteenth century England had attained a degree of personal freedom undreamt of by other continental powers; she provided the mechanism and much of the capital which transformed agricultural into industrial states.[1] So naturally the quesion arises whether the English in the nineteenth century still had faith in these developments and tried to improve or rebuild the navy to match these economic and technological changes. Again if they improved the navy then what led them to do so: foreign rivalries, economic development, scientific discovery or technological change? The following section of this work attempts to show whether or not the political situation affected the nineteenth century British navy.

The navy, during this period, altered its essential purpose it changed its traditional role of knightly warrior to that of police constable

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[1] L. C. A. Knowles, Economic Development in the Nineteenth Century, (London: 1932), 3.

keeping order amidst the new global conditions created by the Industrial and French Revolutions.[2]

When the twenty year old Anglo-French War was over in 1815, a long period of peace began. In spite of this, the sea was still unsafe due to the activity of pirates who preyed on peaceable merchantmen using the regular trade routes. The Royal Navy, aided by a U.S. naval expedition to the Barbary Coast, continued to put down piracy and finally freed the sea from its depredations. The Royal Navy also committed itself to getting rid of the Slave Trade throughout the world. At the same time peace was maintained, not only a peace for Britain but the peace of Britain: the celebrated Pax Britannica;[3] and the important role of maintenance was for various reasons performed by the Royal Navy.

The military and naval might of the continental land powers was so weakened by the Napoleonic Wars, as to leave the Royal Navy supreme in the world at a time when sea power was of increasing moment. Great Britain was the only major nation to take advantage of this factor; indeed apart from the United States, she was the only nation in a position to do so. Unfortunately she did not foresee the necessity of changing her naval system in any fundamental way.

By 1820 steam was introduced in the Royal Navy but the attitude of the government and the public was not favorable toward the steamship. Henry Dundas and Lord Melville, the First Lord of the Sea (1812-1827), stated in the 1820's:

> Their Lordships feel it their bounden duty to discourage to the utmost of their ability the employment of the steam

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[2] Michael Lewis, The Navy in Transition: A Social History 1814-1864, (London: 1965), 10.

[3] Michael Lewis, The History of the British Navy, (Penguin, London: 1957), 213.

> vessel, as they consider that the introduction of steam was calculated to strike a fatal blow at the naval supremacy of the Empire.[4]

The main fear of and objection to the steamship in British eyes was that it created a more effective bridge over the Channel; that it could enable the strong French army to cross the sea easily and quickly and to attack the British coast suddenly, not being as dependent on the wind or on the physical labor of the crews as was the sailing ship. This fear of French invasion, bolstered by traditional Anglo-French rivalry, combined with the many remarkable scientific discoveries to mould British naval developments and policy during the greater part of the century.

From about 1830 to 1839, the English public, especially that part of it living on the South coast, suffered from the obsession that the introduction of the steam warship and the steam transport enabled the hostile French suddenly to invade the defenseless shores of England. For it was a commonplace, if paranoiac, attitude that the French wished to take revenge not only for Trafalgar and Waterloo, but also for Crécy and Agincourt. Moreover, this fear was not entirely baseless. Because Portal, the French Minister of Marine, "advised the French Government either to abandon the institution to save expenses or to increase the expenditure to save the institution"[5] and finally convinced the French Government to use a greater effort and to spend a huge sum of money to build up a strong navy. Eventually they made such great progress that some of the French Admirals, when the Syrian crisis of 1840 developed, thought their country was more than prepared to hold her own. Thus the development of steam navigation and the

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[4] Michael Lewis, <u>The History of the British Navy</u>, 224.

[5] Bernard Brodie, <u>Sea Power in the Machine Age</u>, (Princeton: 1939), 40.

growth of the French naval power not only alarmed the public, but Lord Palmerston,[6] then the Foreign Secretary, as well. One of the main causes of panic was a pamphlet published in 1844 by the Prince de Joinville, son of Louis Philippe, who was in charge of the navy at that time. In this His Highness said:

> The steam war vessel lessened for the French navy its chronic embarrassment for an adequate supply of trained seamen, that it made more feasible the transposition of condition of land warfare (by means of boarding) in which the French supposedly excelled, to maritime combat and that it greatly enhanced the commerce harrying potentialities of the guerre de course, as well as the feasibility of overnight raids on the British coast.[7]

When the entent cordiale was destroyed by the incident of the Spanish marriages, the French Chambers passed the great naval program of 1846 providing 93 million francs for new construction. For by 1845 the French had turned resolutely to the construction of the steam navy hoping to find a naval force of more mechanical character to compensate for their poverty in seamen. France knew that she had to face many difficulties to fulfill her ambition. Still she was determined to build a strong navy which if not great enough to cope with that of her powerful rival on equal terms, would at least be able to challenge English dominance. The navy envisaged by the French in their Law of 1846 was not intended to dominate but to prevent all domination on the seas by the English. Half a century later we find the same attitude, expressed by von Tirpitz and von Bulow and in the preamble of the German Navy Bill of 1900.

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[6] William Temple, 3rd Viscount Palmerston (1784-1865), entered Parliament 1809, Secretary of War 18 - 182 , Foreign Secretary 1833-41, 1846-52, Prime Minister 1855-58, 1859-65.

[7] As quoted by Bernard Brodie in his Sea Power in the Machine Age, 50.

When the Whigs returned to office in England in 1846, Palmerston, as Foreign Minister, at first declared to his colleagues that France could throw twenty to thirty thousand men across the Channel in steamers in one night. By 1848, Palmerston, the Duke of Wellington, who was Commander-in-Chief of the land forces, and Lord Auckland, the First Lord of the Admiralty, thought that the French might complete no less than seven ships of the line and thirty steamers within two years. Lord Auckland was especially perturbed, still more so by the wide dispersal of the British fleet over the seven seas, and by the difficulty of raising men rapidly in Britain to serve either ashore or afloat. He said:

> I feel nevertheless that no dispostion nor possible augmentation of our naval force could altogether secure our coasts from aggressions of a desultory, or even worse those of a serious character, and that this country cannot be regarded as safe until it shall be in such a condition as may enable the government, to collect at a very short notice large bodies of men well trained to arms.[8]

While the Cabinet was discussing the problem of coastal defense and the reconstitution of the militia, the public suddenly became highly agitated by the publication in early 1848 of a letter written almost a year before by the Duke of Wellington to Sir John Burgoyne, Inspector General of Fortifications.[9] In this letter the Duke asserted that the development of steam navigation had exposed all ports of the British coasts to invasion with the result, that from Dover to Portsmouth there was not a spot on the coast, save that immediately within range of the guns of Dover Castle, "on which the infantry might not be thrown on shore at any time of tide,

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[8] Quoted by C. J. Bartlett in Great Britain and Sea Power 1815-1853, (Oxford: 1963), 191.

[9] Illegitimate son of "Gentleman Johnny" Burgoyne, the playwright general commanding the British forces who surrendered at Saratoga (1777) during the American Revolutaionary War.

with any wind, and in any weather."[10] The brief panic produced by this letter was promptly made worse by Russell's[11] proposal of an increase of five pence in the income tax in a year of financial distress.

All of this forced the British public to believe that the French would invade England suddenly without any declaration of war, and there was a widespread fear in the country that the national defense was inadequate. Sir Charles Wood, a member of the Parliament, described this saying that people had got into the habit of talking of the landing of the French on the Sussex coast as a circumstance to be expected, almost as a matter of course.[12] Even Lord Palmerston believed that peace could only be maintained if the British navy remained supreme; as he put it, "....the best way of keeping any men quiet is to let them see that you are able and determined to repel force by force...."[13] However, he himself admitted on many occasions between late 1846 and 1852 that there would be no immediate danger. What he was afraid of, Professor Bartlett thinks, were the possible consequences which might arise from one of the many Anglo-French incidents, occurences of which were unavoidable, since the subjects and the interests of the two powers were opposed in so many parts of the world.[14] But the

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[10]James P. Baxter, Introduction of the Ironclad Warship, (Cambridge:

[11]Lord John Russell (1792-1878), younger son of sixth Duke of Bedford, later created First Earl Russell, entered Parliament in 1813, Home Secretary 1832-39, Prime Minister 1846-52.

[12]Quoted by C. J. Bartlett in Great Britain and Sea Power 1815-1853, 192.

[13]C. J. Bartlett, Great Britain and Sea Power 1815-1853, 186.

[14]Ibid., 185.

French navy of 1846, in spite of all the fears, could not in any sense be considered as the equal of her British counterpart of that period. Richard Cobden pointed out that the English looked at the French figures and never at their own. It was a repeated phenomenon in the early twentieth century during the Anglo-German rivalry. A slight increase in the French naval budget was dissected and every item analysed in the British Parliament. In this light can the British naval scare of 1848 be explained. The French tried hard to secure a naval strength of at least two-thirds that of the British navy, but this alarmed the British so much that the naval budget was increased and number of ships also raised. The British did this even when the two states were supposedly cooperating to try to put an end to the political confusion and turmoil in Portugal. It seems that the British hierarchy had no confidence either in the power of the French Government nor in its honesty. This was clear when in 1849 the French Government wished to open negotiations for a reciprocal reduction in the naval race, the British refused on the ground that Great Britain would never be reduced to the policy of fixing the size of her navy with reference to the force maintained by any other single power. The same attitude can be traced again in 1889 when England declared her Two Power Standard against France. Thus the nature of the fear hardly changed in the international situation of the nineteenth century as the method of handling these situations remained much the same.

The coup d' etat of December 2, 1851 in France and the approval by plebiscite of Louis Napoleon as the President of the Republic with almost autocratic powers gave a new and more vigorous life to the invasion fear than before. There were floods of sensational pamphlets and speeches which led Britain into a major panic. Palmerston carried an amendment strengthening Lord John Russell's proposed Militia Act and the Admiralty hastened preparations to ward off a surprise attack. Professor Baxter has commented that the proclamation of the Second Empire in 1852 reminded the British of earlier invasion scares, and produced an electric effect upon the whole country.[15] The people talked of invasion as if it could be accomplished in five minutes. The Times, in this case reflecting, rather than attempting to mould, public opinion, criticised naval policy with a cartoon depicting an ass with its tail pointed at a row of French guns and braying "no danger."[16] This forced William Stanley, 14th Earl of Derby to assure his fellow peers and the public:

> My Lords, I believe that our naval forces were never in better or more effective condition than at this moment. I believe that for all purposes whether as regards the protection of our own shores, the defense of numerous and distant colonies which form our empire or for the protection of that extended commerce which crosses every sea and fills every port in the wide world, I believe that, for such purposes, our navy was never in a more effective state than it is now.[17]

In 1851 Granville, Landsdowne, and Russell concluded that Louis Napoleon wished to keep peace for the moment. Still Russell thought that if the French made further concentrations of war steamers then the British squadrons on the Tagus would have to be recalled for he could not trust a Bonaparte. However, the French navy was definitely weaker than that of the English during this time. Still the fact remained that France was her most likely and most dangerous rival. Even, in November 1853, when England and France jointly entered into Crimean War, the First Lord of

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[15] J. P. Baxter, Introduction of the Ironclad Warship, 98.

[16] Ibid.

[17] Ibid., 281.

the Admiralty felt that he could not ignore the character of the French naval development and tried to improve the British navy. Thus from 1815 to 1854 the fear of war with France was mainly responsible for the development of the British navy because whenever there was any improvement in the British navy the public thought the French would immediately imitate them and would probably have a better navy.

In August 1855 that French Commission Superiure Centrale had proposed a program of new construction which comprised 40 screw ships-of-the line of 70 to 90 guns, 20 frigates, 30 corvettes, and others.[18] However, this 'new program' had hardly any effect on British naval construction. By February 1857 the results of tests upon the new rifled guns had convinced the French that the use of armor had become imperative if ships were to live through an action and thus they concentrated their attention on the building of an ironclad fleet.

In March 1858 the great revolution came into naval architecture when the first four ironclads were ordered by the French Navy namely: the wooden hulled La Gloire, L'Invincible, La Normandie and La Couronne. The design of La Gloire was based upon that of Napoleon, a screw line-of-battle ship, allowing some 500 tons more of displacement and increasing the waterline length 19½ feet but retaining almost the same beam and draught so as to secure finer lines to permit of equal speed with the same engine power. In England the idea prevailed for many years that La Gloire was merely a wooden warship that has been raised, armoured, and renamed.[19]

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[18] Oscar Parkes, British Battleships from 1860 to 1950, (London: 1957), 2.

[19] J. P. Baxter, Introduction to the Ironclad Warship, 98.

As a matter of fact, La Gloire was an entirely new ship, built from the keel up, and her principal dimensions and general construction were "profoundly modified" from those of Napoleon. The deplacement of La Gloire was 5620 tons, 500 tons more than that of Napoleon. M. Dupuy de Lôme, the designer of La Gloire, proposed to obtain equal speed from the same horse power by giving her 6 metres more length on the waterline than his Napoleon, with practically the same beam and draft. Despite the increased tonnage, the immersed midship section was of only 101 square meters. The elimination of deck structures and the great increase in the weight of the ship's side caused by the armour, raised problems of transverse strength which were met by introducing a layer of sheet iron under the wooden upper deck, strongly fastened throughout to the sides of the vessel.

The news of the laying down of the French ironclad fleet in March reached London in May 1858 and this news created a panic in England. La Gloire and her sisters were described as 'huge polished steel frigates' and credited with power which, although they 'plunged some persons into deep distress...were manifestly put forward to excite our foolish fears'.[20]

Because of this panic a Parliamentary committee was formed in 1858 to inquire into the relative naval strength of the two countries and the report, published in 1859, showed that both England and France had 24 ships-of-the-line built or being completed while France had 34 large frigates (not including the ironclads) against 26 for England. The Admiralty soon found itself in a quandary. Their hardships were divided as to whether England should follow the French lead and outbuild them in ironclad, or build both ironclads and wooden ships, modifying the building

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[20] Oscar Parkes, British Battleships from 1860 to 1950, 2.

programs as circumstances dictated; or whether England should build up British superiority again along traditional lines with the requisite number of wooden ships. The latter was the course adopted for a short time. But soon the Admiralty realized that the greatly increased power of ordnance rendered it necessary that measures of increased protection should be taken. Finally the Admiralty decided to build the ironclads and approved plans for the first British sea-going ironclad ship, H. M. S Warrior.

The scarcity of ironclad ships threatened the feeling of security which had long characterised the British admiralty so that their Lordships increased its ironclad program from one ship to four before the end of 1859, and rushed to complete enough wooden screw line of battleships to attain the desired Two Power Standard in 1861. Soon the French ironclad program forced the British to increase their own proposed plans from four to six ironclads; the British also stopped the construction of large wooden ships except for casing them in iron. Moreover, throughout the year of 1860, the current of opinion in favor of ironclad ships grew steadily stronger. When in the 1860s the Institute of Naval Architects was founded, it was in favor of ironclad ships. Volumes of Hansard for the period also reveal the growing anxiety lest France had taken a too long a lead in the new course of naval construction.[21]

II

From the naval standpoint, the Crimean War serves, in many ways, as an unnatural climax to the period and

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[21] J. B. Baxter, Introduction to the Ironclad Warship, 164.

> for this and other reasons it may well have had a distorting effect upon mid-nineteenth century naval history.[22]

To explain just why this was the case involves an examination of the Crimean War.

Sir Laird Clowes has contended that by 1854 the British could have possessed a fleet of fast, screw, armored capital ships and gun boats, armed with large-calibre, rifled ordnance.[23] Yet, during this period more interest was shown in iron and armor protection than the Admiralty was nominally credited with. Political and financial circumstances, the various responsibilities of the navy during war and peace time and the advantages which Britain was known to possess in naval warfare as it then was, worked together with undoubted conservative sentiment to inhibit progress. The dogged ranks of senior officers found it difficult to adapt themselves to the new condition of warfare. At first they looked upon steamers as unworthy of duties other than those of lowly tugs or dispatch boats and only sued them as such. Until 1827 no steamship was entered on the Navy List. Only in 1845 was the paddle abandoned and the screw propeller finally adopted. Although there was a shortage of timber, iron was not accepted until just before the Crimean War as a shipbuilding material because early tests appeared to show that an ironship was more vulnerable to shell fire; the holes could not be stopped and a single broadside might sink a ship. So during this period the administrative body of the navy, instead of preparing for new kinds of ships, was attempting to

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[22] C. J. Bartlett, Great Britain and Sea Power 1815-1853, 331.

[23] Sir W. L. Clowes, The Royal Navy: A History from the Earliest Times to the Present, (London: 1903), Vol. VI, 303.

perfect the former types by fitting conventional ships of the line and frigates with shell guns and some even with auxiliary steam power. Their success in this direction perhaps left them ill-prepared for the revolutionary changes that were to come during and after the War.

In 1848 the longest ships to be fitted with the screw propeller were the four-(ex-third)-rate ships, which were being converted into block-ships for harbor and coastal defense. A second-rate, with steam power, had been ordered, and there was talk of converting three more second rates to steam. Progress remained tentative, because of the continuing unreliability of the steam engine, its great bulk, and its heavy fuel consumption in proportion to the power produced. Machinery and coal took more space, so that in the case of the sixty-gun blockship, Hogue, it was suggested that the gross over-crowding in that ship could be relieved by the sacrifice of one-third of its armament.[24] Yet progress in the design of steam engines and machinery was continued; the transatlantic mail ships of Samual Cunard and others proved that as boiler pressure crept up so fuel consumption fell. In the smaller classes of warship, steam power of some form was becoming almost indispensable. By January 1852, work upon all sailing ships of the line had been suspended in the expectation that all capital ships would at least be steam assisted within ten years. It seemed sufficient merely to seek an adequate margin of superiority in steam over France, and at this time Britain possessed seven such ships, afloat, being converted or on the stocks, against only two French ships.

In August 1853 a naval review was held at Spithead which served the purpose of a warning to Russia. At first sight, the assembled ships differed

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[24] C. J. Bartlett, Great Britain and Sea Power 1815-1853, 325.

little from those which fought at Trafalgar. On closer inspection they were somewhat different; by this time England had seven screw-powered and three-sailing line-of battleships, four screw frigates, four paddle frigates, four each of screw corvettes and of sloops and one paddle corvette. The only difference between the steam-powered, screw-assisted sailing ships and the traditional ships of the line and frigates was that they were longer editions of the latter. In May 1854, the government petitioned Parliament for £252,674 for the purchase and repair of steam machinery with the comment that it was to be used to apply "that power which experience has proved indispensable to all the ships of the new construction as they were launched."[25] Having reached the conclusion that it was expedient to have a reserve force at home, the government determined all the vessels of that fleet should be steam powered. Of the Allied fleet sent into the Black Sea, only two of the ten line-of-battleships were equipped with steam, and these were seven smaller ships and all but one were paddle steamers. Later these ships were joined by twelve additional steamers and two sailing ships. A naval expedition to the Baltic formed part of the offensive against Russia in 1854, but it accomplished little because most of the ships were of too heavy a draught for inshore work in that shallow sea. The fleet had no local pilots and merely harassed the Russians by capturing their merchant ships and blockading their ports.

Great Britain and France entered the Crimean War believing that the sailing line-of-battleships in their fleets might still be of some use. But action proved that in the company of a large number of steam men-of-war, ships propelled only by sail were useless. Moreover, the

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[25]Bernard Brodie, Sea Power in the Machine Age, 70.

use of the shell gun was also having its effect upon ship construction. At the start of the Crimean War, the destruction of Turkish ships by the Russian shell fire scared both England and France and finally the naval architects of both countries decided that ironships would be less affected by shell fire than wooden walls and attempts were made to build the former.

In 1857, at the end of the Crimean War, the First Lord of the Admiralty, Sir Charles Wood, on reading before the House of Commons a comparison between the English and French fleets declared, "At this time...the sailing vessels ought, almost, to be left out of consideration, for I do not think that except in case of urgent necessity any nation would dream of sending a sailing squadron to sea."[26] In addition to the question of age, condition and lines of the hull, the British requirements in stowage rendered that decision necessary. After conversion of 9 sailing line-of-battle ships to steamers of the same gun capacity, it was found that the change reduced by more than one-half the space available for stores and provisions, which had the effect of limiting the cruising range of the vessels. To the British this was unsatisfactory because to reduce the gun component drastically was likewise impracticable. The only solution was to build new vessels of larger size, a solution they were soon forced to accept.

The vessels built in these last days of the wooden ship averaged from 25 per cent to 50 per cent greater in tonnage than their predecessors in each class. For instance, H. M. S. Duke of Wellington, and Duke of Marlborough, of this period ranged from 3,000 to 4,000 tons burden, whereas the greatest ships of the pre-steam era had not exceeded 3,000

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[26] Hansard, Series 3, CXLV, Col. 426.

tons. Indeed the new steam frigates were as large as the old three deckers at Trafalgar.[27]

The naval rivalry between England and France was not a very prominant feature of the 1870's and in consequence no considerable change or improvement can be noticed during this period, in contract to the 1880's. The Admiralty was opposed to a great battleship program in the eighties because to keep pace with France required many technological changes and development. These and the rapid scientific discoveries usually made vessels obsolete in a short space of the time. The government also did not want to accept an inferior naval position in comparison to that of France but it had to reverse its attitude and in March 1889 the Naval Defence Act was introduced. It increased the number of the battleships and provided for 8 first-class battleships, which were larger than any previously built, two second class battleships, nine large and 29 small cruisers, four fast gunboats and eighteen torpedo gun boats; in addition the Two Power Standard was officially adopted. The populace in general felt a little safer than before, a sense of security visible in Admiral Bacon's writings, when he expressed the idea that there was no doubt that if England should go to war with the French then the latter might well have been swept off the face of the globe. The Naval Defence Act as well as providing security had in fact saved the country.[28]

The naval scare and the subsequent Naval Defence Act of 1889 led the British public to take an interest in the Royal Navy. Indeed the newspapers behaved so sensationally during this time that they were responsible

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[27] Bernard Brodie, Sea Power in the Machine Age (Princeton: 1941), 74.

[28] Quoted by A. J. Marder in The Anatomy of British Sea Power, (Hamden, Conn.: 1964), 119.

to some extent for the naval scares and panics. This is perfectly described by J. A. H. Hobson in his Physchology of Jingoism:

> The modern newspaper is a Roman arena, a Spanish bull-ring and an English prize fight rolled into one. The popularisation of the power to read has made the press the chief instrument of the burtality.[29]

The various naval scares, because of Anglo-French naval rivalry, and the Crimean War made a large contribution in changing and consequently in improving the British navy of the nineteenth century. Thus this century saw a new epoch in English history because the whole navy changed its essential character, as Michael Lewis has noted in his book The Navy in Transition.[30] The navy changed both in nature and in purpose. Ship Construction was revolutionised to a large extent during this period, and in its turn changed the nature of vessel operation. The people trained to work the old full-rigged wooden walls, propelled by the airs of heaven and armed with broadsides of smooth-bore, solid-shot guns, had to learn how to handle great iron-hulled, iron-armored monsters, propelled by steam and firing by means of huge built-up guns there new elongated and rotating shells. The following chapters will attempt to illustrate the technological changes in ship construction, and show why they were important.

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[29] J. A. H. Hobson, Psychology of Jingoism, (London: 1953), 29.

[30] Michael Lewis, The Navy in Transition, 9-10.

CHAPTER II

ECONOMIC CONSIDERATIONS

> We tore the iron from the mountain's hold,
> By blasting fires we smithied it is steel;
> Out of the shapeless stone we learn is mould
> The sweeping bow, the rectilinear keel.
>
> --John Masefield: The Ship

Man has always desired to dominate nature and to explore all her mysteries; hence the motivation behind his desire traverse oceans and to discover unknown lands. This adventurous and inquisitive spirit led him to build boats at the very dawn of civilization; through the ages he has developed and improved the method of constructing such ships.

Since ancient times wood had been used to build boats. By the time of the Tudors, however, the English forced the problem of supply of timber with which to build ships. The danger in the past had always lain, and would still in the future lie, in the shortage or even the unavailability of timber suitable for maritime purposes. This problem was rendered more acute in the eighteenth and early nineteenth centuries, not merely by the shortage of timber, but also by the fact that wooden hulls decayed very rapidly when they had to perform the increasingly arduous duties expected of them at that time. Thus this basic position remained unchanged. British naval strength relied heavily upon the fruit of the forest.

Although many people sought to conserve forests, the demand for timber in an increasingly industrial age was voracious and tended to outstrip supply. Apart from the greater needs for timber for shipping, more was being used for the domestic arts. With greater population more land was brought under tillage; since this gave more profit than from woodlands, which tied up money for long periods.[1] From 1760 to 1805 the Royal Navy grew from 320,000 tons to over 700,000 tons, with more than 900 vessels, of which some 180 were ships of the line. By 1810, tonnage had risen by another 100,000 tons.[2] Out of the 700,000 tons raised by 1805, the Royal Navy had used up over 1½ million loads[3] of timber.

Much oak had traditionally come from the Baltic, though by 1809, the spread of Napoleon's power had checked very attempt of the British to secure timber from the ports dotted around the entire European coast from the Baltic to the Black Sea. The "little corporal" however, could do nothing to prevent the use of timber from North and South America, Asia and Africa.

But soon the supply of timber from the United States was also almost at a standstill. This occured because Jefferson inaugurated a policy of "peaceful coercion," in reprisal for the British attitude toward neutral ships; and because of this trade with England was permitted for only ten months from 1807 onwards. The Embargo Act of 1807, forbidding all trade, was followed by the Non-Intercourse Act in 1808, which prohibited trade with England. This alarmed the Navy Board for the future of dockyard

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[1] Sir Westcott Abell, The Shipwright's Trade, (New York: 1963), 95.

[2] Robert G. Albion, Forests and Sea Power, (Cambridge, Mass.: 1926), 404.

[3] The unit of timber measurement was the 'load' of fifty cubic feet. Roughly, the average oak of timber size contained about a load of timber and made nearly a ton of shipping. It weighed about a ton and a quarter. In 1804, straight oak timber ranged from 4.3s to 7.16s, a load, according to its size, the oak of average dimensions being about £7.

supplies and they began to search remote corners of the whole world for trees which had not been considered in the survey of 1804. It was, however, quite difficult to transport timber from distant forests. Oak had begun to come from Canada; this supply was increasing rapidly in magnitude, but except in the case of timber suitable for the great masts, its quality left much to be desired. Skilled lumbermen were scarce, transportation was difficult and expensive, and after the trees were cut, and even after they were brought to England, the quality of timber often cried out for its rejection.

The extreme need for timber during the Napoleonic period also led to several efforts to relieve the shortage by building ships in foreign or colonial ports. The most successful attempts to relieve the time shortage by foreign shipbuilding came from the use of teak in India which was later recognized as the best ship timber in the world. The distance between England and India, the old policy of building all warships in England and the lack of cooperation by East India Company, which occasionally diverted timber from naval construction to their own ships, all had tended to prevent a further use of this possible source of relief. As for the furture the Thames builders strongly opposed Indian shipbuilding because they were afraid that the high quality of teak and cheap labor might ruin their business.

The supply of English oak was also slow in recovering from the tremendous drain of the Napoleonic era. The plantings stimulated by the shortage around 1810, taking some 40 years to mature to usability, could not be of service when they were most needed.

One of the surprising features of the whole naval timber problem was the seriousness with which it was taken in 1860-61, the very last years of wooden capital ship. Although the Admiralty, because of Paixhain's shells and the results of Crimean War, built ironclad warships, it was still unconvinced that the days of wood were over. Even in later days there were plenty who could say with a certain dockyard official: "Don't talk to me about ships of iron--it's contrary to nature." The shortage was felt acutely in the matter of certain pieces of large English oak in parts of the frame where foreign timber could not be used, like the construction of the stern post, for the increase in the size of the ships of the line necessitated trees of larger diameter than ever before for that purpose. Great trees were cut down only to be found rotten, and ships remained uncompleted on the stocks while the woods were searched for the rare trees of suitable size and soundness. When such trees were found, there was not time for seasoning, and much green oak had to be used. By 1859 the woods of England could not meet the demands of naval building programs of the day.

By the nineteenth century, England had almost reached the apex of that development which resulted from the Industrial Revolution, and consequently this century differed from all previous ones. Prior to this time agriculture had been the basic means of production in society, but in the nineteenth century, industry had replaced it as such. Population grew, and rate of increase in Britain was particularly high between 1780 and 1820; by 1840 the population was being supplemented at the rate of 300,000 persons every year.[4] The century between 1801 to 1901 saw an increase in the British population from nine to thirty-two million. The census of 1871 retraced the ground and arrived at the following figures for the total population

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[4]W. H. B. Court, A Concise Economic History of Britain from 1750 to Recent Times, (London: 1954), 13.

of England and Wales estimated to mid-year in each case:

1801	9,192,810
1811	10,467,728
1821	12,190,175
1831	14,070,681
1841	16,049,554
1851	18,109,410[5]

The demand for, and consumption of, industrial products of all kinds increased enormously. "A civilization based on the plough and the pasture perished--in its place stood a new order, resting perhaps dangerously on coal, iron and imported textile materials."[6]

The possibility of a stoppage in the trade in pig iron with Northern Europe between the period 1796 and 1801 and its realization during the winter of 1800-01 stimulated the English to increase their own production of iron and to discover improved methods of iron making.[7] Pitt, the then Prime Minister, increased the duty on all imported iron and by 1798 it became 3.15s.5d per ton.[8] This affected the English iron workers tremendously as Professor Ashton described:

> It appears by the Scarcity and Dearness of Iron since the Dispute with Russia and Sweden, that there is not Iron enough made in Great Britain to supply the consumption. The Iron Masters take every Advantage of a Scarcity to raise the Iron, while the Manufacturer of goods cannot raise his price, which is very hurtful, and keeps many industrious Tradesmen from reaping the fruits of their Labours.[9]

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[5]H. L. Beales, The Industrial Revolution, 1750-1850, (London: 1958), 68-69.

[6]Ibid., 30.

[7]T. S. Ashton, Iron and Steel in the Industrial Revolution, (Manchester: 1924), 145.

[8]Ibid., 145.

[9]Ibid., 146.

In 1801 and 1802 there were no fewer than 22 new furnaces in blast and 25 in process of erection[10] and by 1803 English iron effectively replaced Russian and Swedish iron. At the end of the Napoleonic Wars the English iron industry again found itself with a capacity for production in excess of the immediate peacetime needs of the country, and there was a general fall in iron prices as is shown by the following figures relating to the average prices per ton of forged pig iron in the Midlands:

		s	d
1801	6.	15.	0
1802	6.	0.	0
1803	6.	0.	0
1804	5.	16.	0
1805	6.	8.	0
1806	6.	15.	0
1807	6.	1.	3
1808	6.	5.	0
1809	6.	5.	0
1810	6.	6.	0
1811	6.	5.	0
1812	5.	10.	0
1813	5.	2.	6
1814	6.	0.	0
1815	5.	0.	0
1816	3.	15.	0
1817	4.	5.	0
1818	5.	10.	0
1819	6.	2.	6
1820	4.	10.	0
1821.	4.	0.	0
1822	3.	15.	0
1823	4.	0.	0
1824	5.	0.	0
1825	7.	10.	0
1826	5.	0.	0
1827	4.	10.	0
1828	4.	0.	0
1829	3.	12.	6
1830	3.	8.	9[11]

Gradually Great Britain reached the stage by 1849 where she processed half the pig iron of the world and within the next thirty years she trebled her

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[10] Ibid.

[11] Ibid., 150.

output of this commodity.[12] Between 1830 and 1850 the west of Scotland became a producer of more than a quarter of Britain's pig iron. In 1854 official mineral statistics were first collected. These were to show for the following year over 500,000 tons of iron ore, with an average content of something like 55 per cent of iron had been absorbed by Scotland, South Wales and Staffordshire. The output of processed pig iron from those same three districts had risen in 1855 to something like 260,000 tons. The rise and fall of the absorption of ore and the production of pig iron by the main areas of the iron industry over the thirty years following 1855 was as follows:

[12] J. H. Clapham, An Economic History of Modern Britain, Vol. II, (London: 1952), 47.

		1855	1865	1875	1885
Staffordshire	Tons of ore raised	2,500,000	1,485,000	1,654,000	1,830,000
	Tons of pig iron made	855,000	899,000	712,000	545,000
Wales and Monmouth	Tons of ore raised	1,665,000	484,000	538,000	68,000
	Tons of pig iron made	871,000	917,000	597,000	833,000
Scotland	Tons of ore raised	2,400,000	1,470,000	2,452,000	1,838,000
	Tons of pig iron made	827,000	1,163,000	1,050,000	1,004,000
Yorkshire: West Riding	Tons of ore raised	255,000	575,000	354,000	127,000
	Tons of pig iron made	91,000	123,000	267,000	166,000
North Eastern District	Tons of ore raised	1,155,000	2,882,000	6,182,000	5,972,000
	Tons of pig iron made	298,000	1,012,000	2,049,000	2,478,000
Shropshire	Tons of ore raised	365,000	274,000	240,000	178,000
	Tons of pig iron made	122,000	117,000	121,000	45,000
Cumberland and Lancashire	Tons of ore raised	538,000	1,504,000	1,983,000	2,438,000
	Tons of pig iron made	17,000	312,000	1,045,000	1,384,000
Derbyshire	Tons of ore raised	409,000	350,000	218,000	18,000
	Tons of pig iron made	117,000	189,000	272,000	361,000
Lincolnshire and Northampton	Tons of ore raised	74,000	489,000	1,660,000	2,349,000
	Tons of pig iron made	------	26,000	192,000	426,000[12]

[12] *Ibid.*, p. 49.

After 1815, Britain expanded her trade with the newly independent countries of South America which had previously been part of the mercantilistic system of the Spanish and Portuguese Empires. In her trade with these countries, Britain favored laissez-faire principles. Previously she had been a 'mercantalist' country, and her own Empire was largely to remain so, until the free trade boom of the 1840s. But having witnessed the serious defeat of her major imperial rivals, Spain, Portugal, Holland, and France, she became the trading company of the world and consequently the ruler of the seas by sheer dint of having to protect both her newly won, and her old imperial, trade routes. The change in her prevailing economic policy, from mercantilism to free trade was primarily a result of necessity, but had a firm doctrinal basis in the teachings of Adam Smith and his laissez-faire followers of the late eighteenth century. This school argued that Britain, as the first industrialized nation in the world, must be free to trade throughout the world without the artificial hindrances of the mercantalist system. Only thus could a nation of small shopkeepers survive. Hence the period of thirty years after 1815 was one of gradual change from mercantalism to free trade, a slow change within the increasingly neglected remains of her first great Empire, but a speedier change in the case of trade with the one time possessions of her defeated enemies, outside the bounds of this empire.

This change brought with it another in Britains'

> whole conception of what the seas were for; from 'seas which are ours' to the "Mare Nostrum' idea to the 'Freedom of the Seas' with its inevitable corollary, 'the Safety of the Seas'. 'All seas freely open for all became her watchword'. 'Let all increase the volume of their traffic there on, and all be the gainers'.[13]

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[13] Michael Lewis, The History of the British Navy, (London: 1957), 214.

The protection of the Empire and its continued expansion after 1850 was one of the main functions of the Navy in the nineteenth century. In 1800 the empire consisted of about one and a half million square miles,[14] the vast majority of which had been gained in the previous half century. This imperial expansion increased the relative weight of England's overseas possessions in the balance of power within Europe. During this period more emphasis was given to the trading bases upon which the Empire continued to rest. Hence the addition to it, of places like Singapore in 1819, Cyprus in 1878 and Zanzibar in 1890. In the acquisition of each of these the navy played an important role. Even in military operations the navy helped the army by providing it with heavy artillery, as happened during the Boer War.[15]

The main reason for this imperial expansion, as already stated, was the economic revolution which made Britain the workshop of the world. In 1801 her exports totalled 80 million tons; in 1901 1,467,000. At the same time, especially after the construction of the ironship, there was a remarkable expansion of her mercantile marine. In 1815 its gross tonnage amounted to 2,400,000; in 1850 to 3,505,000, and in 1880 to 6,575,000.[16] Production was so high that foreign trade was more important to the national economy than ever before, for it was the means of supplying not only the luxuries and comforts of life, but food and raw materials required for the daily subsistence and employment of the mass of the people.[17]

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[14] Christopher Lloyd, The Nation and the Navy, (London: 1954), 225.

[15] Ibid., 226.

[16] Ibid.

[17] Op. cit., 78.

The Royal Navy's role in this scheme was thus vital. As Vice-Admiral Sir John Fisher,[18] First Sea-Lord, in 1905 said:

> The Navy is the 1st, 2nd, 3rd, 4th, 5th...<u>ad infinitum</u> Line of Defense! If the Navy is not Supreme, No Army however large is of the slightest use. It's not <u>invasion</u> we have to fear if our Navy is beaten, <u>IT'S STARVATION</u>.[19]

Moreover, the rise of private yards for building men-of-war gave the concept of British naval supremacy additional support in both parliament and public opinion. Thus in the nineteenth century the navy was still the first line of defense. By 1815 England entered upon a new era of international commerce and competition, and this new era demanded not merely a new type of warship, but of merchant vessel as well. It had to be much faster than the ships of even twenty years before and of much greater carrying capacity.

The introduction of iron into the navy was to prove of great value to England if for no other reason than just to free her from the timber problem; yet in these first year of the 1860s when all signs pointed to iron as the coming material, the Admiralty still called for more timber and set its face against innovation. In spite of this, the end of the era of wooden warships came suddenly. By 1866, though timber was still needed in

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[18] Fisher, John Arbuthnot, First Baron Fisher of Kilverstone (1841-1920), was born in on the 25th January 1841. He entered the Navy in 1854. He served in the Baltic during the Crimean War. In 1874 he was chosen to serve as President of the Committee, which was appointed to revise "The Gunnery Manual of the Fleet." He became the Director of Naval Ordnance and Torpedoes in October, 1886 and he remained in the post till May, 1891. He served as A.D.C. to Queen Victoria (from 1887 to 1890). He also served as Lord Commissioner of the Navy and Comptroller of the Navy during 1892 to 1897. He was Vice Admiral in 1896. He was awarded K.C.B. in 1894 and G.C.B. in 1902. He became First Sea Lord in 1902 and served in that capacity to 1909. He had a predominant influence in all the far reaching new measures of naval development and internal reform. In November, 1909 he was created a Peer, and retired in 1910. He again became First Sea Lord from 1914-15 and he was consulted over the Gallipoli Campaign of 1916.

[19] As quoted by A. J. Marder in <u>The Anatomy of British Sea Power</u>, p. 65.

small amounts for the teak backing of armor plates and for deck planking, iron had become the main material for the navy.

The Admiralty wanted to build ships of timber, but because of the industrial revolution, because of the increase in the availability of iron ore, and because of the timber problem the Admiralty was forced to use iron for construction of ships. Thus economic conditions were largely responsible for the change in ship construction.

CHAPTER III

TECHNICAL DEVELOPMENT OF SHIPBUILDING INDUSTRY

> In the cosy security of the Victorian era, warfare and science took the floor together and commenced their dance macabre.
>
> --Sir Stephen King-Hall (Sea-Saga)

I

In the 1850s and 60s, despite her great technological lead in industry and her vast merchant navy, Britain did not produce any great naval advances. It has been said: "She imitated changes introduced by France and America; and imitated so clumsily that naval shipbuilding passed through a baroque phase."[1] But still, because of the industrial revolution and because of the pressure of public opinion, which have already been mentioned, and especially because of technological advancement, the Admiralty was forced to make changes in the navy throughout the nineteenth century, which put the navy well on the road to becoming the "Navy of Fisher, of Jellicoe, and of Cunningham."[2]

The small supply of timber and availability of cheap iron led the shipbuilders to become interested in ironship construction; whereas a wooden ship cost about £16.10s. per ton, an iron ship could be built

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[1] David Thomson, England in the Nineteenth Century, (1815-1914) (London: 1950), 98.

[2] Michael Lewis, The Navy in Transition: A Social History 1814-1868, (London: 1965), 9.

for not much more: £18.10s per ton.[3] Moreover, the destructive force of shell fire against the wooden walls was more clearly realized from the 1840s, and especially during the Crimean War, so that the governments of the principal maritime powers made numerous efforts to find some means to minimize the damage inflicted by these shells. Finally some naval architects decided that the ironships would not be least affected by shells. Moreover, iron construction and the adoption of armor were interdependent in that the iron-hulled ship was better suited to the carriage of heavy metal plates than the wooden ones. Shells had made the large wooden ships exceedingly vulnerable objects. The abandonment of wood not only lessened this weakness but also removed the rigid upper limits on size which the use of the timber had imposed. The preeminent position of Britain's metallurgical industries facilitated this development which was due not to the need to protect against the shells, but to the superiority of the iron over the wood as seaworthy material. Early experiments, however, were with iron construction in the merchant marine rather than in the Royal Navy.

The main reason why the Admiralty did not encouarge the ironships was that they did not believe iron would float. Again, if iron vessels did not sink under their own weight, the engines, the Admiralty thought, would cause them to say, while the reciprocating motion of the engines would cause fractures of the plates. Moreover, there was a fear that the introduction of iron warships would be greatly to the disadvantage of the Royal Dockyards[4] as these were more suitable to the great wooden line-of-battleships.

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[3]E. C. Smith, A Short History of Marine Engineering, (London: 1937), 97.

[4]Ibid., 96.

The first iron steamer, the Aaron Manaby, was built by the Horsley Company of Staffordshire for the Seive, under a patent taken out in 1820 in France for an iron steamboat.[5] But the Admiralty ignored this second great technological development of the century.[6] In 1839 the John Laird Company who had proposed a design for an iron frigate in 1836, found the East India Company less conservative than the Admiralty. For the Company it constructed in 1838 two iron paddle steamers namely: the Plaegethon and Nemesis, which were used effectively as gun boats in the First Opium War of 1839-40. Only then did iron begin to oust wood as the basic material for hulls. In 1845 the Admiralty ordered a number of iron frigates, but that authority now was ahead of public opinion. A popular outcry of "Hands off our wooden walls" checked the Admiralty's enterprise and forced it to retreat. Thus the iron frigates were degraded to the status of troop ships.[7]

I. K. Brunel[8] realised the need to give lengthwise strength to a vessel 322 feet long, 51 feet broad and which weighed some 3600 tons at 18 feet draught of water. The skin was carried on transverse ribs of iron and fixed there by iron rivets. At the bottom part of the ship were laid ten deep lengthwise beams above which ran an iron deck (not water-tight) fixed by rivets to angle bars at the upper part of the beams.

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[5] Bernard Brodie, Sea Power in the Machine Age, (Princeton: 1949), 133.

[6] David Divine, The Blunted Sword, (London: 1964), 21.

[7] Michael Lewis, The History of British Navy, (New York: 1959), 225.

[8] Isambard Kingdom Brunel (1806-1869) was the only son of Sir Marc Isambard Brunel. At the age of seventeen he began to work in his father's office in London where various designs for bridges were under way. He worked for the Great Western Railway. On his advice the Great Western Steamship Company was formed in 1836 and settled a design for an ironship which was started in 1839. In 1851 he became engineer to Australian Mail Company and built two ships. He was best known for the great magnificent failure, Great Eastern.

This in effect formed a "double bottom." The angle ribs, some 20-24 inches apart were carried up above the upper deck. Two lengthwise bulkheads, running from the top to the bottom of the ship, one on each side, added to the lengthwise strength and formed the sides of the boiler room. The side spaces were used as coalbunkers and were tied to the ribs by cross-beams to form a strong member for transverse strength and to support the thin iron skin. Brunel, instead of using beam knees, used angle struts to form a closed triangle fixing the beam ends. There were five main bulkheads across the ship which added to the transverse strength and being watertight gave greater measure of safety after damage. There were two decks of wooden planks carried by iron beams to the ends of which were fixed heavy wooden water ways scarphed and bolted to the frames and to the iron "stringer" plates fitted at the side of the ship. The top or sheer strake of the side plating was made stronger by an outer strap run lengthwise and 6 inches wide and an inner strap 7 inches wide - both one inch thick - which were fixed to the plating by rivets.[9]

Advocates of iron construction argued that it increased the strength, solidity and durability of ships and reduced the fire risk. It decreased the hull-weight, increased the cargo space and facilitated water-tight subdivisions. It saved money in construction and repair, and would make possible the building of much larger vessels and the better utilization of the screw, which produced leaks in the sterns of the wooden ships. They pointed out that several iron ships which had run aground had sustained remarkably slight injuries. However, they never said that these vessels would prove inpenetrable to shot and shells; in

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[9] Sir Westcott Abell, The Shipwright's Trade, 114-116.

fact what they actually said was that a single 10 or 12 inch shell exploding at the water line might sink a frigate or even a ship-of-the-line. Such projectiles, it was believed would have far less effect on an iron ship, passing through both its sides and leaving a smooth round hole, which dould be easily stopped. Actually their argument was that iron was of superior quality to wood as a material for shipbuilding.

Attempts were made at Portsmouth in July and August 1851 to ascertain the effect of 8 inch and thirty-two pounder shot on vessels with plates 3/8 or 1/2 inch iron with regular timbers throughout instead of iron ribs and on vessels having 5/8 inch iron ribs with teak planking outside and inside, instead of iron plates. The conclusions were that all shots would pass through 3/8 inch iron without splitting, but that solid shot would sometimes, and hollow shot would very generally, split on passing through 1/2 inch iron with high charges; that the injury to the farther side of an iron ship would be severe and that even with a vessel planked with wood, shot striking iron ribs as compared with shot striking wooden timbers would cause more dangerous splinters and greater danger to the far side of the ship.[10]

English experiments conducted between 1846 and 1851 convinced the Admiralty of the unsuitability of iron vessels for war service because of this weakness, and influenced decisively the course of the naval construction in Great Britain. The weakness of ironships can be summarised as follows:

> 1. The holes made by the shot were not irregular but are clean and open; all parts of the shot passed right through the iron and the timber and then spread abroad with considerable velocity; parts of the iron plate and a few very small pieces of shot were sometimes retained in the timber.

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[10] James P. Baxter, Introduction of the Ironclad Warship, 38.

2. With high charges the splinters from the shot were numerous and severe, with the addition in this, of the evils that other vessels were subject to, that of the splinters from the timber.[11]

So by 1850 the Government informed the contractors carrying mails to British possessions that after 1850 no iron vessel would be approved even for mail service. Hence the iron frigates which the Admiralty had previously ordered had to be converted into transports. Despite the strong prejudices against iron which prevailed at the Admiralty, 58 of 286 gun and mortar boats and vessels built by contractors for the Royal Navy between 1854 and 1857 were constructed of iron.[12] In the state of metallurgic development of that time, iron was more vulnerable to shell than oak as the tests between 1846-1851 proved. The splintering of the iron made a hole much larger than the size of the shot itself and one almost impossible to close during the course of an engagement. Yet solid shot penetrating wood left a clean hole which, because of the tendency of wood to expand and partially close the opening, could be easily plugged. Moreover, when a wooden ship went into action, the ship's carpenter usually took a position below the gun deck, where he could plug shot holes as soon as they occured. The ironships were so new that no such system was considered.

The government and the public did not believe that iron could float. By the time the government attitude and public opinion became favorable to the iron ship, the Admiralty realized the problems involved in the building and the maintaining of the ironships. The construction

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11 Nathaniel Barnaby, Naval Development in the Century, (London: 1902), 143.

12 Baxter, Introduction of the Ironclad Warship, 38.

of ironships involved new methods and very few men were conversant in them. Thus there were very few craftsmen in this field. This change in building ships from wood to iron has been described in the following manner:

> So long as the frame of the earlier ship had been built of naturally curved timbers of Italian and English oaks. Her inner planking and trussing were of English, African or Dantzic oak; and this structure, apart from the outer planking, had been formed into a compact solid water-tight structure, which, even unplanked, would have floated securely.
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> She had been built by shipwrights, aided by sawyers, blacksmiths, joiners, millwrights, and caulkers. Shipwrights had fashioned wooden moulds in the mould-loft for cutting out and trimming the timbers to agree with the curves and lines of the "drawings of the ship"; they had trimmed the timbers and planks with axe, adze and plane; they had made moulds for all iron forgings, they could make her masts and yards and boats.
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> Her timbers and planking would now be useless; the art of preparing moulds for them is practised no longer. Even the boats which the ship carries are now steam vessels; and the art of wooden mast-making is a lost art in His Majesty's Dockyards. The ship might himself has well nigh vanished. There are still men bearing that name and using axe, adze, plane and anger, but outside the Royal Dockyards the shipwright has no longer anything to do with building the structure of the ship. The art of shipbuilding has passed into the hands of platers, riveters, cautlers, fitters and other workers in iron and brass, and their Unions have shut out the shipwright. The Shipwrights Union now only claims to make moulds, to fair the fraiming by ribbands to make and break stages, to lay decks, to lay blocks and to launch ships. Boiler makers now call themselves iron-ship builders and engineers undertake all ship fittings.[13]

The major problem of maintaining the ironship was to control erosion and fouling, especially in foreign ports. Oscar Parkes, in his British Battleship 1860-1950, has discussed it vividly. Both toredo worn and marine growth could be countered by Copper Sheathing,

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[13] Nathaniel Barnaby, Naval Development in the Century, 40-41.

> in which the anti-fouling properties are due to the action of sea water forming oxychdondes and other soluble salts which do not adhere to the uncorroded copper, and are continually being washed away, leaving a smooth surface upon which plants and animals can not become attached... The attachment of the copper sheets presented no difficulties as they could be nailed directly on the wooden skin; but with an iron hull any such intimate connection leads to galvanic action between the copper and the iron, and even a very indirect connection is sufficient to produce gavanism with consequent pitting and erosion.[14]

But the copper was expensive and this expense led to experiments with other materials like blunz metal and zinc; however, nothing came of them.

The developments in shipbuilding were possible because of general development in the iron industry. Development in the iron industry was due to five great inventions: these, together with the earlier discovery of the artificial blast to accelerate combustion, brought the transition to the modern era in the metallurgy of iron. These five revolutionary changes were: (a) the employment of coke instead of charcoal in the reduction of the ores, (b) the puddling process and the utilization of the reverberatory furnace, (c) the invention of the rolling process, (d) the hot-blast process and finally, (e) the invention of the steam engine.[15]

In the beginning the iron industry was dependent on the use of charcoal as a fuel in the blast furnaces. The supply of charcoal depended on the supply of suitable timber was

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[14] Oscar Parkes, British Battleships, Warrior 1860 to Vanguard 1950 (London: Seeley Publishers) 1957, 166.

[15] Bernard Brodie, Sea Power in the Machine Age, (Princeton: 1941), 131.

becoming increasingly scarce, considerably hampered progress in the iron industry. The substitution of coke for charcoal in the smelting process brought about a major progressive change in the iron industry during the early eighteenth century. This was effectively introduced by Abraham Darby. Coke smelting was directly applicable only to the production of cast iron. Until the middle of the eighteenth century the new process seems to have been almost entirely confined to the Shropshire iron district and after that time it spread rapidly throughout England, Wales, and Scotland. As the century advanced coke-smelted cast iron encroached on the sphere of wrought iron.

Employment of coke was important but "its results were less momentous than those that were to follow the use of mineral fuel in the fining process.[16] The first reason for this, as mentioned above, is that coke was applicable only to the production of castings and of forge pits of low grade, so charcoal was still required to make bar iron of moderate and good quality. Secondly, charcoal was cheaper than coke for smelting the iron because 16 cwts. of charcoal would be sufficient to produce a ton of pig iron; but to make a ton of bar iron about a ton and a half of pigs was required and 24 cwts. of charcoal was consumed in the operation.[17] If malleable iron or steel was required, the "sow" and "pigs" of cast iron had to be broken up, reheated, and hammered at the forge to get rid of the excess carbon content. The reduction of the carbon content in the pig iron could be made if the pig iron were reheated

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[16] T. S. Ashton, Iron and Steel in the Industrial Revolution, (Manchester: 1924), 87.

[17] _Ibid_.

without coming into direct contact with the fuel. This could be done by a special refining furnace between the operations of the blast furnace and the forge. Throughout the early eighteenth century many experiments were made with reverberatory furnaces, in which the metal was kept separate from the fire, and heated by the action of the flame in reverberating or shrinking down from the roof of the chamber.[18] In 1766 the process was successfully introduced by Thomas and George Cranage at Coalbrookdale. Their method immediately became a commercial success.

Another process of reducing the proportion of carbon in the pig iron was by stirring or "pudding" the molten metal while it was still in the reverberatory furnace; this exposed the carbonic impurities directly to the heat and burnt them out. Puddling seems to have formed part of the Cranage's process. In 1784 patents for puddling processes were taken out almost at the same time by Henry Cort and Peter Onions. With his puddling process Cort combined and improved the rolling machinery, which he had patented in 1783. Thus the combination of puddling and improved rolling process facilitated the production of superior bar iron and it avoided the necessity for reheating the metal and thus saved both time and fuel.[19]

In 1824 the hot-blast process was patented by Neilson. This greatly reduced the amount of coal expended in the manufacture of each ton of iron.

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[18] Arthur Redford, The Economic History of England, 1760-1860, (London: 1924), 35.

[19] Ibid.

In the mid-nineteenth century the world was moving from the iron to the steel age.[20] In 1856 Sir Henry Bessemer of England discovered the process of making steel, a process since named after him. Because steel was lighter, stronger, more flexible, and cheaper to make. The new process brought about a minor revolution in Western Europe and America. The process "consisted of blowing air into a crucible containing molten pig iron. The air caused the pig iron to burn and thus removed most of the carbon and silicon. The result was a substantial increase in the output of iron and steel..."[21] This process required ores free from phosphorous; thus it decreased English dependency on imported Spanish iron-ore.

In 1764 James Watt invented his steam engine and between 1775 and 1785 the importance of the new type of engine had been generally recognized. The rotary motion made it possible to apply steam powers directly to all kinds of industrial undertakings and steam engines affected all the processer of the iron industry. In 1779 steam engines were used for blowing furnaces and for working pumps in the collieries. By 1780 there were engines to produce a blast for the smelting of iron. A further stage in the application of steam power to the iron industry came when the first forge hammer was moved by an engine. Finally to the third and final process in iron production, rolling and steampower were applied in 1789. Thus there was a general development in the industry throughout the eighteenth century.

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[20] Anthony Wood, Nineteenth Century Britain: 1815-1914, (London: 1960), 333.

[21] Bernard & Fawn Brodie, From Crossbow to H-Bomb, (New York: 1962), 125.

II

In the age of wooden vessels, the construction of the ship was uniform in all navies. According to William Hovgaard: "During several hundred years its development had been extremely slow according to modern ideas of progress, but with the introduction of steam power and the use of iron as the ship building material, a new era commenced."[22]

The first steam warship was Demologus, also called Fulton the First, which was designed and built by the American, Robert Fulton[23] in 1812. The following year, Fulton submitted his plans to the President of the United States in 1814 Congress authorized the construction of this type of vessel. The British Admiralty also encouraged steam experiments and in 1815 England built Thames. Almost forty years elapsed between the appearance of Robert Fulton's Clermont on the River Hudson in 1807 and the adoption of steam by the major navies. The Royal Navy was no exception. The introduction of steam propulsion into ships made slow progress for it was first used only to move the greater ships clear of the land. Other than this, there was neither any merchant vessel till 1822 nor any armed vessel till 1828, under steam propulsion in the Royal Navy.[24] Although in 1819 Savannah, the American ship which weighed more than 300 tons, made a voyage

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[22] William Hovgaard, Modern History of Warships, (New York: 1920), 1.

[23] Robert Fulton was born on November 14, 1765 and died February 1815.

[24] Bernard Brodie, Sea Powers in the Machine Age, (Princeton: 1941), 22.

from America to Europe, she had no influence on the early projects for transatlantic steam navigation.[25] Launched as a sailing vessel, she was afterwards fitted with a single-cylinder steam engine and with paddle wheels which could easily be unshipped.

David Divine has claimed that much of the reluctance to use steam was due to the difficulties in the supply of coal fuel.[26] But this argument cannot be completely accepted because there had been a sea-borne coal trade for a hundred years and coaling stations could easily have been established, as they were afterwards.

Steam, while still in its infancy, was less efficient as a method of propulsion than sails. In addition, the use of steam power for large warships was strongly opposed to many naval men. Hovgaard has quoted from the English Steamship Manual of 1860 on this point:

> Engines and machinery are liable to many accidents, may fail at any moment, and there is no greater fallacy than to suppose ships can be navigated on long voyages without masts and sails.[27]

These objections cannot be refuted. Early engines were liable to a breakdown that could be fatal in an engagement. The total weight of the machinery including the coal was more than that of the sails and their masts and rigging. Paddle wheels, the only form of propulsion before the invention of the screw propeller in 1835, were exposed to the fire of the enemy shells; the speed was relatively low and use of steam drastically cut down the

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[25] E. C. Smith, A Short History of Marine Engineering, (London: 1937), 34.

[26] David Divine, The Blunted Sword, 21.

[27] Quoted by William Hovgaard in Modern History of Warships, 3.

cruising radius of a ship. Van Loon has suggested that the class of men to which the naval officers of that day usually belonged regarded everything associated with engineering as decidedly beneath their rank and dignity.[28] Moreover, the Government was against the steamship because of the Channel problem and French invasion scare. The only tactical and strategic advantage of the steam warship in the 1860's was its independence of wind and tide; in every other respect it was a less effective warship.

Though the Government and many naval officers did not accept the use of steam in the ships, Rear-Admiral Sir John Ross[29] and Captain W. Bowles emphasized the value of the armored steamships for coastal defense, and for operations generally in the narrow seas.[30] At this Joseph Hume commented, on 21 February 1825: "The Discovery of steam navigation has altered the nature of maritime warfare altogether. Come war when it might, the mode of warfare in the narrow seas would be very different from what it is at present."[31]

The widespread reluctance to adopt steam for battleships was eventually overcome by the development of the screw propeller, the actual invention of which James Phinney Baxter has described as one of the five great naval

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[28] Hendrick Wilhelm Van Loon, Ships and How They Sailed the Seven Seas, (New York: 1935), 228.

[29] John Ross (1777-1856) was a Rear Admiral and Artic Navigator - 1794 he entered into the service of East India Company. In 1832 he became commander and between 1839 and 1846 he was Consul at Stockholm.

[30] C. J. Bartlett, Great Britain and Sea Power: 1815-1853, 201.

[31] Ibid., 201

revolutions.[32] The first British ship which was ever moved by a screw was the Government transport Doncaster. It left England for Gibralter in 1802, having on board a shaft and screw propeller and some rope pulleys. In Gibralter the necessary framing pulleys were placed out board, the propeller was shipped and the ropes were rove.[33] Doncaster, however, was a sailing vessel.

The adoption on a wide scale of the screw propeller was due however to Francis Pettit Smith,[34] a Middlesex farmer, and John Ericsson,[35] a Swedish engineer in 1835.[36] With Smith's Francis Smith and in Ericsson's Francis B. Ogden and Robert F. Stockton, the world possessed her first practical screw-driven vessels. Ericsson's screw propeller at first consisted of a short drum, like a belt pulley, with blades around the circumference. Then he used two propellers, a right-handed and a left-handed one, the outer, being fixed to the propeller shaft, revolving in a sleeve which carried the inner propeller. This sleeve was driven by toothed gearing and the propellers revolved in opposite directions as they do in a modern torpedo.[37]

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[32] J. P. Baxter, Introduction to the Ironclad Warship, 3.

[33] E. C. Smith, A Short History of Marine Engineering, 65.

[34] Born in 1808 to a Middlesex farmer. In 1835 he build a model ship which was propelled by a screw propeller. He acted as the adviser to the Admiralty till 1850. In 1860 he became the Curator of the Patent Office Museum. He was knighted in 1871.

[35] John Ericsson, a Swedish Army engineer who had deserted to compete against George Stephenson in England with Steam Locomotives, invented the screw propeller. He built a small vessel, Francis B. Ogden, after the then American Consul in England. While the British Admiralty did not accept the merits of screw propeller he came to America and through his influence got the Navy to authorize the building of the screw steamer Princeton. In the early 1840s he developed a stronger gun barrel by shifting from brittle cast iron to wrought iron.

[36] E. C. Smith, A Short History of Marine Engineering, 67.

[37] Hovgaard, Modern History of Warships, 5.

Until the screw propellers were used the steam driven warships were propelled by paddle wheels which, because of their vulnerability, were not suitable for seagoing warships. Their use made possible the removal of paddle wheels and the placing of machinery below the waterline where shot was not likely to penetrate. Combination of screw propeller and broadside seemed to secure simultaneously free movement and free fire power. The Admiralty, however, ignored the importance of the screw propeller; they said:

> even if the propeller had the power of propelling a vessel if would be found altogether useless in practice, because the power being applied in the stern it would be absolutely impossible to make the vessel steer.[38]

The delay in the adoption of the screw propeller in warships was due to the fact that the Admiralty thought that the engines would be different from those used with paddles and that new designs meant prolonged experiment.[39]

John Ericsson later went to the United States and through his political influence got the United States Navy to authorize the building of a screw steamer, Princeton, which was the first such naval vessel. With the appearance of Princeton, the Royal Navy was convinced of the merits of the screw propeller and in 1842-43 had the screw-sloop Rattler built. By 1850 the Navy List included the names of about 50 screw vessels. Some of these vessels were old sailing ships converted to screw ships, the Agamemnon being the first line-of-battleship designed as a screwship.

Particulars of a few of the larger Screw Ships in Navy Lists of January 1850:

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[38] Quoted by David Divine in The Blunted Sword, 25.

[39] Bernard Brodie, Sea Power in the Machine Age, (Princeton: 1941), 34.

	Displacement Tons	Guns	Nominal H.P.	Indicate H.P.	Engine Makers
Agamemnon	3750	91	600	1838	Penn
Ajax	3090	56	450	846	Maudslay
Amphion	2025	34	300	592	Miller
Arrogant	2615	46	360	774	Penn
Blenheim	2790	60	450	938	Seaward
Dauntless	2150	33	580	1347	Napier
Highflyer	1775	21	250	702	Maudslay
Hogue	3054	60	450	792	Seaward
James Watt	4950	91	600	1543	James Watt & Co.[40]
Sans Pareil	3800	70	400	1471	

It is interesting to take a survey of the period between 1860 to 1870, because this period is of peculiar concern to all who are familiar with nautical affairs. The comparison of the battleships and mercantile marine of 1860 with those of 1870 provides many striking constrasts. In 1860, though steam was used, the greater part of the work at sea was still being done under sail. Though the British mercantile marine included some 700,000 tons of steamships, the sailing tonnage was some seven times larger.[41] Though, in the case of battleships, steam was used to a greater extent than in the mercantile fleets, they still depended largely upon sail.[42] With the return of Edgar in 1870, the last of the line-of-battleships, after visiting South America, the Cape, Australia, Japan, Honolulu, the Valparaiso, the era

> bid goodbye to wooden ships, to sails and yards, to the old Navy of Nelson's time. Henceforth came the era of steam and iron, of torpedo and electricity; of what is called sciences versus keen observation which gained

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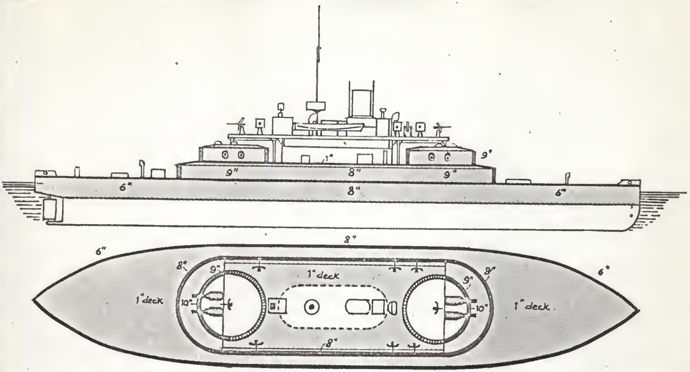
[40] E. C. Smith, A Short History of Marine Engineering, 75.

[41] Ibid., 161.

[42] Bernard Brodie, Sea Power in the Machine Age, 23.



CERBERUS

Dimensions	225' x 45' x 15·3' = 3,340 tons. Hull and armour = 2,640 tons. Equipment = 700 tons.
Guns	4 10-in. M.L.R. ("Magdala" 1892 4 8- in. B.L.).
Armour	Sides 8"-6"; breastwork 9"-8"; turrets 10"-9". Deck 1½"; breastwork deck 1"; backing 11"-9".*

*Parkes, p. 167.

every advantage possible to be taken from wind and weather and which used to be called Seamanship.[43]

The decade 1860-70 was an era of great changes in the character of Warships which was illustrated by Smith with the examples of Victoria and Devastation. In 1860 the finest British battleship was H. M. D. Victorian an unprotected wooden sailing fighting ship with a full rig of sails and steam power acting only as an auxiliary. Her length was 260 feet, breadth 60 feet, and she had a displacement of about 7000 tons. Her engines developed 4200 horse power and her armament consisted of 121 guns. Victoria was launched in 1859 and exactly ten years later, in 1860, H.M.S. Devastation was launched and completed in 1873. Devastation was the first of the "mastless" turret ships. Her length was 285 feet and she was of 9300 tons displacement. Her twin screw engines developed 6600 horsepower and gave her a speed of 13 3/4 knots. She was built of iron throughout, carried four 35-ton, 12 inch guns, mounted in two turrets and was protected by 2540 tons of iron armor, the thickness of some of which was 14 inches. She carried no sails and had only a single mast for signalling and for lifting boats. Victoria's shots could pierce about 3 inches of iron, but Devastation's more than 12 inches.[44]

By the beginning of the seventies the Admiralty generally recognized that sails were a liability rather than an asset in an armored battleship and, therefore, vessels built in the future were developments of the Devastation. During 1867-68, when the question of Colonial Defence was under consideration, the colony of Victoria in Australia wished to build a monitor

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43 E. C. Smith, A Short History of Marine Engineering, (London: 1937), 162.

44 Ibid., 163.

for the defense of Melbourne. There were financial restrictions which limited size and it was also suggested by the Victorian authorities that a monitor fitted with a Coles turret passing through the deck would be adequate. This both the First Lord and the constructor, Reed, refused to consider because of difficulties in making the deck water-tight. After a long discussion Reed agreed to a new type of monitor designed specially with careful regard to the harbour at Melbourne, and he found the requirements as regards ordnance and armor very difficult to meet under the restrictions imposed. Nevertheless, Cereberus[45] was built to this design and was noteworthy as being the first of a series of "breastwork" monitors incorporating Reed's ideas as to the principles upon which low-freeboard turret ships should be based. Two other ships, Magdala and Abyssinia, were built on the same design of Cereberus. These ships formed a connecting link between the first phase of ironclad design which ended with Sultan and Monarch and the second phase commencing with Devastation.

In Cereberus there is to be found the germ idea of the principle upon which all battleships from 1885 to 1905 were based: the placing of the main battery in armoured positions fore and aft with uninterrupted bow and stern fire and wide arcs of bearing upon either beam. Oscar Parkes has given a detailed description of the construction of the Cereberus. She was built by Palmers and Company; laid down on 1 September, 1867, launched on 2 December, 1868, and completed in September 1870. The cost was 117,556. With a gross tonnage of 3,350, her dimensions were 225'x45' x15'3'; her hull and armor weighed 2,640 tons; her equipment weighed 700

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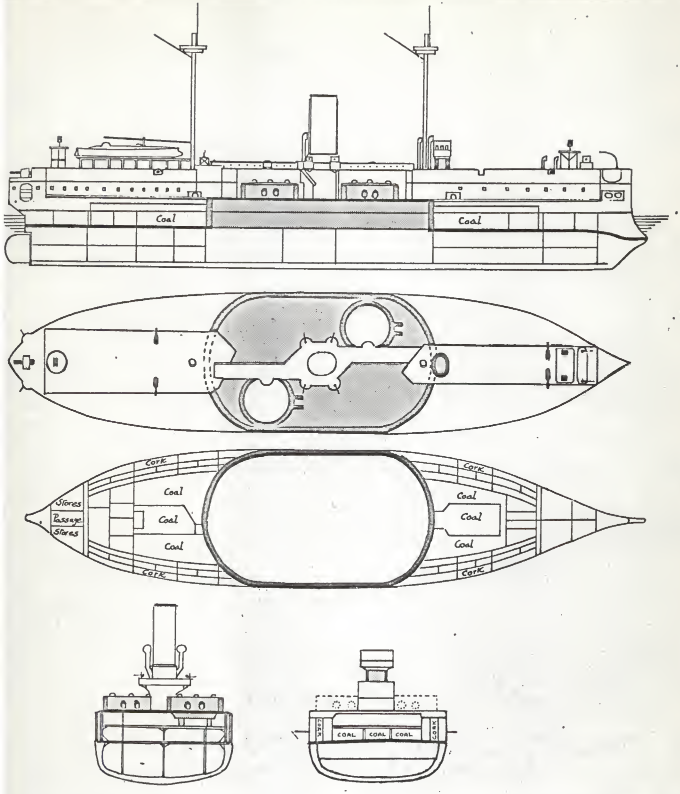
[45] All the information about the Cereberus are taken from Oscar Parkes's, British Battleships, 166-69.

tons. Her armament consisted in four eighteen-ton, ten inch M. L. guns which were retained by Cereberus throughout her career. She was also well armored. Her turrets were 26¼ feet in diameter with nine inch armor on an 11 inchbacking, except over the faces, where it was 10 inch with 9 inch teak behind, these turrets always being hand worked. The hull sides received 8 inch-6 inch armor with 11 inch-9 inch backing, the deck being of 10 in teak with 1½ inch plating. Heavier protection was given to the breast work which had 9 inch-8 inch sides and ends, with a 1 inch iron deck on 10 inch teak. Her complement was from 120 to 155 men and, carrying a maximum of 210 tons of coal, her cruising speed was 9.75 kwts.

In these ships twin screws and a balanced rudder ensured optimum maneuver ability and wholly replaced sail power, as once at their destination they would never be required to make long open sea voyages. The special pioneer features of the Cereberus, as Parkes has revealed, were: she was the first British ship to have low freeboard; the first to have breastwork protection; the first to have a central superstructure with fore and aft turrets; and the first in which sail power was dispensed with altogether.

In everyway Cereberus was a complete break from established tradition. The hull had a freeboard of 3½ feet only, with a central breastwork for 112½ feet amidship rising 7 feet above the deck. This did not extend to the full beam by the width of a gangway on either side. Between the turrets and extending well over them were the raised shelter deck for the navigating positions and boats. By such structural expedients Reed kept the characteristic low freeboard of the monitor but raised his turrets to allow for their being in action clear of wave wash, with the provision even of a hurricane deck.



COLOSSUS AND EDINBURGH*

*Parkes, p. 289.

During the period between 1864 and 1871 a series of Coastal Defense Turret "breastwork" monitors were built and these were:[46]

	Date	Tons	Knots	Armament
Cereberus	1868	3,340	9.75	10" ML
Magdala	1870	3,340	10.6	10" ML
Abyssinia	1870	2,900	9.59	10" ML
Glutoon	1871	4,910	12.1	12" ML
Cyclops	1871	3,480	11.	10" ML
Gorgon	1871	3,480	11.1	10" ML
Hecate	1871	3,480	10.9	10" ML
Hydre	1871	3,480	11.2	10" ML

The production of a stell suitable for the construction of ships was due to the efforts of the French Naval shipbuilding expert, J. Barbara (later Chief Engineer of the Gensot Works). It was another French Naval construction engineer, L. deBussy (later Director of Naval Construction), who first employed this new material on a large scale in the construction of three warships, namely, in Le Redoubtable, La Tonnerre, and Le Tempete, laid down in 1873.[47] The British Admiralty followed the French example in 1875, ordering two despatch vessels, the Iris and the Mercury to be built wholly of steel. At first the cost of steel was higher than that of iron and it was lacking in the qualities of ductility, malleability, and uniformity of strength. The main reason for these drawbacks was that at the beginning the steel was too hard to be manufactured with qualities so satisfactory for shipbuilding as to produce such required special precaution and experience in handling, especially when subjecting the raw material

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[46] James Dolby, The Steel Navy: A History in Silhouette - 1860-1963, (London: 1962), 30.

[47] Hovgaard, Modern History of Warships, (New York: 1920), 357.

to heating. These difficulties disappeared when steel of softer quality, known as mild steel was introduced.

After the development of a process of making mild steel two British battleships, Colossus and the Edinburgh, were constructed of this material in consecutive years 1886 and 1887.[48] Their dimensions were 325 feet by 68 feet by 25·3 feet/26·3 feet. Total weight was 9,150 tons, of which the hull and armor amounted to 6150 tons and equipment to 3000 tons. As far as armament went: Colossus could boast of being the battleship in which M. L. guns, iron construction and iron armor were all discarded for the first time; both Collossus and Edinburgh had four 45 ton, 12 inch B. L. guns, five 6 inch B. L. guns, four 6 pounders (added later) and 20 smaller guns. Both ships also had two 14 inch torpedo tubes placed forward in a transverse battery, under the armor deck yet above water. The armor of both ships was as follows: their citadels measured 123 feet along the middle line, compared with 104 feet in Ajax and 110 feet in Inflexible, and shaped in a broad oval so that all but the most direct of hits would be converted into glancing blows; it was of 18 inch thickness on the sides and 16 inch at the ends, and extended from 6 feet 6 inches below water (6 inch deeper than in previous ships) to the main deck height of 9 feet 6 inches. In short, the measurements of the compound armor were as follows:

Citadel		18"-14"
turrets		16"-14"
deck		3"-2½"
skin		1"
teak		22"-10"
Total	2,414 tons	(26.3%)

[48] All the information about the Colossus and the Edinburgh are taken from Oscar Parkes's British Battleships, (London: 1957), 288-292.

In these ships steel was first used in general construction, only the stem and stern posts being made of iron. In Edinburgh both turrets and citadel were of steel-faced iron. Both ships had a complement of 396, and carried 850/950 tons of coal. These were the first British battleships to carry breech-loaders, first to have compound armor generally in place of iron, first in which steel was used for general construction. They were the last of the citadel ships proper and they had a metacentric height of 9 feet.

Though there was a considerable development in the technology which consequently evolved ship construction in the latter part of the nineteenth century, still in the eighties the British Admiralty faced problems. The Russian scare of 1879 accentuated the complete lack of strategic and tactical organization for the conduct of naval warfare and for the protection of English commerce and overseas possessions. So the government formed an all powerful committee to make a thorough investigation of the whole problem. The report which the committee published showed that the Navy was not big enough to perform all the duties which it was expected to fulfill and that its strength would have to be increased as soon as possible, which would involve additional expenditure requiring a rise of three pence in Income Tax. So between 1880 and 1884 the armored tonnage laid down and expenditure on shipbuilding and Ordnance amounted to:

		Tonnage	Shipbuilding and Ordnance
1880	Collingwood	9,500	3,425,803
1881	Impericuse	8,400	3,736,669
	Warspite	8,400	
1882	Howe	10,300	
	Rodney	10,300	
	Camperdown	10,600	4,156,644
	Benbow	10,500	
1883	Anson	10,600	4,245,382
1884	Hero	6,200	4,607,237[49]

[49] Oscar Parkes, British Battleship, (London: 1957), 324.

After the invention of the torpedo boat in the 1880s the Admiralty faced a problem made clear by Lord Northbrook, First Sea Lord. In one of his speeches he said:

> When the noble Marquis (Lord Sidmouth) said that it would be desirable that the Admiralty should have an unlimited amount of money to spend on the present type of ships of war, he felt bound to say that he was not of that opinion. The great difficulty the Admiralty would have to content with if they were granted 3 or 4 millions tomorrow for the prupose referred to would be to decide how they should spend the money. Anyone who had paid attention to the progress made in the construction of guns must be aware that the guns put on board the newest type of ships would be able to destroy any armor which could be put on a vessel ... Some of the best naval officers in this country thought that, in the event of another naval war, the torpedo would be the most powerful weapon of offence, and would be able to dispose of the most formidable ships in the service of this or any other county. Therefore it would be most imprudent greatly to increase the number of these enormous machines.[50]

Although the torpedo boats were still small and averaged under 100 feet in length they were tending towards larger sizes and greater speeds. Experiments showed that boats attacking by night on fleets at anchor or at slow speed ought generally to be successful. It was also determined that an attack could only be repulsed by gunfire when not more than one boat attacked one ship and that night attacks must always be in favor of the torpedo. Experiments made by the Royal Navy showed that even if the ships were being fitted with larger numbers of machine guns there was still no guarantee that these had the power to stop a torpedo boat.

Certainly the presence of the torpedo boat made the future of the big ship decidedly hazardous--just as it has been when shell fire was first directed against wooden hulls.

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[50] _Ibid._, 325.

Lord Northbrook finally decided that it was desirable to steadily increase strength in armor-plated ships and cruisers. This heralded the "Northbrook Program" of 1884 by which 3,100,000 of additional money was provided for new construction during the next five years and resulted in the battleships Victoria and Sans Peril, seven belted cruisers of the "Australia" class, six torpedo cruisers of the "Archer" class and fourteen torpedo being built.

The technological developments of shipbuilding industry reveals that it was one of the most important factors why naval architecture changed. However, improvements in naval armaments also played a very important role in determining the naval ship design. So in the next chapter that aspect will be discussed.

CHAPTER IV

Perhaps more valid Armes,
Weapons more violent, when next we meet
May serve best to us, and worse our foes,
Or equal what between us made the odds,
In Nature none---
   He who therefore can invent
With more forcible eve may offend
Our yet unwounded Enemies, or arme
Ourselves with like defence, to mee deserved
No less than for deliverance what we owe.
-- Paradise Lost, Bk. VI

I

Since antiquity the history of warfare has shown innumerable attempts to secure an immediate tactical advantage by some new contrivance. The essential purpose in such inventions is to obtain one's end before the opposition party can bring the counter measures. In the development of naval weapons up to 1600 the role of the scientist was non-existant.[1] The great revolution in naval warfare came slowly depending upon the development of the sailing ship and on the evolution of weapons using gunpowder. By the sixteenth century the standard fighting ship in the British Navy became the galleon, a two-or three-decked ship with main batteries in the broadside and lighter, quick-firing pieces fore and aft. Even the merchant ships mounted culverins and demi-cannon. The sixteenth-century culverin was the ancestor of the long eighteenth-century gun.[2] The seventeenth century saw

[1] Brodie, Bernard and Fawn, From Crossbow to H-Bomb, (New York: Dell Paperback, 1962), 62.

[2] Ibid., 65.

almost continuous naval warfare but there was very little advance in naval technology although the Royal Navy had more and heavier guns. There was hardly any change in the naval armament in most of the eighteenth century. The cannons were still smoothbore, muzzle loaders made of cast iron or bronze. The thirty-two pounder, a three ton gun of about six-inch calibre, was the biggest which a line-of-battleship could handle in its broadside. Naval guns were still extremely inaccurate, having an effective range of less than 300 yds. At that time good gunnery meant speed and therefore volume of fire and not accuracy.[3] Even the gun carriages were still primitive, heavy timber frames riding on four small wheels. The first decisive change, as Brodie points out, in the nature of naval projectiles came at the end of the eighteenth century, with the use of Mercier's shell gun during the siege of Gibraltar, 1779-1783.[4] This new projectile was a 5.5 inch explosive shell with a short fuse fired from a 24-pounder mortar. But these shells, "because of their real or presumed sensitivity, had to be tossed with small propelling charges at high angles, othersiwe they might explode within the bore."[5] Thus till the eighteenth century the guns were basically same though there were minor developments.

With the advent of nineteenth century there came some revolutionary developments not only in naval construction but also in the naval armament which in the second half of the nineteenth century passed through a series of transformations, increasing its power manifold from decade to decade. Professor Brodie notes that this

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[3] Ibid., 113.

[4] Ibid., 115.

[5] Ibid., 115.

> It affected basic constructional machinery and ordnance--the latter being a term which covers both guns and armor. The same metallurgical advances that made possible the forging of thicker and more resistant armor plates and the plates and framing of the iron hulls, also made possible the construction of stronger guns."[6]

II

Of Baxter's five great naval revolutions of the nineteenth century -- steam, shell guns, the screw propeller, rifled ordnance and armor -- only one, that is the shell gun, has had great influence on ship design and equipment. The introduction of shell upset the balance between offense and defense at sea and the need for armored ships became overpowering.

In 1815 the warships were still armed such as they had been for the past four centuries. The introduction of the paddle wheel cut down the number of guns a vessel could carry and this stimulated experiments toward developing more effective gun-fire with fewer ordnance. These experiments led to closely related developments; bigger and stronger guns, better shells and shell guns, rifling, and breech-loading guns. Experiments after 1815 toward solving these problems were directed chiefly to strengthening gun barrels to enable them to fire heavier projectiles with heavier charges without bursting.

Paixhan's shell gun appeared in 1820. It was shorter and lighter using smaller charges than guns of the same calibre designed for solid shots. The shells were not only capable of tearing large holes in the wooden sides, which were difficult to stop, they also endangered the safety of the ship by their incendiary power, and the splinter effect was apt to

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[6] Ibid., 161.

cause a great number of casualties. Though both the French and the English adopted the Paixhan gun in late 1830's, (Shell guns were only adopted by the British officially in 1839.)[7] it was regarded merely as a special purpose weapon, secondary to solid-shot ordnance. Shell exerted its effect not through crushing impact but by producing a destructive explosion either in the timbers of a ship or inside its hull. Until the introduction of the shell gun, the 32-pounder was the standard heavy broadside weapon of British line-of-battleships. The 68-pounder, introduced into the British Navy about 1840, was only used as a pivot gun but one of this type was carried even by the largest warships. In the early forties Ericsson developed a stronger gun barrel by shifting from brittle cast iron to wrought iron.

The idea of strengthening the decks or the sides of a ship so as to make her invulnerable to the enemy was almost as old as the naval gun. It has already been mentioned that one single shot from Paixhan's shell gun of 1820 was sufficient to destroy the largest ship. A partial answer to this was the iron ship for iron is less a combustible material as there would be no wooden splinters. But the French answer given by Paixhan was armor which kept the shell out. Thus armor was better. General Paixhan suggested that line-of-battleships should be protected by a layer of seven or eight inches of iron armor.

In 1841 an American engineer, Robert L. Stevens, and his brother Edwin A. Stevens, submitted to the United States Government plans for an armored vessel, known as the Stevens Battery. Its construction started in 1854. The ship, although never completed, influenced both American and

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[7] Brodie, Bernard, Sea Power in the Machine Age, (Princeton: Princeton University Press, 1941), 181.

English naval architecture of the later decades. Hovgaard has given a detailed description of this ship:

> The hull was built of iron, and special attention was given to longitudinal strength. The machinery was housed entirely below the water line, and was, moreover, protected by the armor deck..forward and aft of this so called casemate. The armor deck was entirely flat and somewhat below the water line when the ship was in fighting trim. The sloping casemate armor inside which were housed the steam engines for training the guns, was 6 3/4 inch thick and was made up of several layers of iron plates, placed on heavy wood backing. The horizontal part of the deck was 1 1/2 inch thick. Armor was fitted also below the edge of the inclined armor outside the bottom plating to a depth of four feet below the water-line.[8]

Before she was completed Ericsson invented a gun which could easily pierce plates of that thickness. Each improvement in armor was follower by the development of more powerful guns that could penetrate it.

The destructive power of the shell was proved in the Schleswig-Holstein War, when a Danish line-of-battle ship and a frigate were destroyed by shell fire in 1849. The Crimean War showed more conclusive evidence in this respect. In 1853 Russian squadrons attacked the Turkish fleet at Sinope and destroyed it completely. In a battle which showed that wooden hulls and even the unarmored iron hulls could not stand up to the fire of shell guns.

III

These events showed the necessity of protecting the side of the battleships by armor, and so armor was introduced in the 1850's. In the beginning of nineteenth century, guns were cast-iron, smoothe-bored, muzzle-loading, and fired solid cast-iron round short or explosive spherical shells

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[8] Hovgaard, William, Modern History of Warships, (New York: Spon Chamberlain, 1920), 5.

and the muzzle-loading gun was the standard weapon in all navies. About 1840 the 68-pounder gun was introduced into the British Navy. But this was used only as a pivot gun and one of these was always carried on even the largest warship. This was too heavy, slow burning and violent in action to be used as a broadside gun, but Professor Brodie pointed out that it made an admirable weapon for inflicting a few powerful blows during an approach.[9] Although during the fifties breech loading rifled guns, firing elongated projectiles with ogival heads, were constructed in various countries, yet till the middle of the nineteenth century England used muzzle-loading guns. It was not until after the Crimean War that serious research began in the field of explosives and metallurgy.

Rifled ordnance appeared at least as early as 1832 but were not perfected and were not introduced until the middle of the century. Rifling was not introduced for the sake of greater penetration in naval ordnance at sea but for better performance in the field. The use of improved rifles had given such increased range and accuracy to the infantry and weapons that field artillery, whose usefulness depended in good part upon the greater range of the field gun over the land firearm, had rapidly lost its importance. So naturally there was great enthusiasm in using rifling in the naval service against unarmored ships. About 1860 ironclads were built which was protected by armor of 4 1/2 in. thickness and this was hardly perforated by the guns of the time. This forced the gunmakers to direct their efforts toward manufacturing more powerful ordnance. According to some, the best result was attained by large caliber smoothebore guns which crushed and broke up the armor. It was argued also that

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[9] Brodie, Seapower, 182.

in rifled guns only small charges could be used so only small velocities could be attained.

In 1859 the 8-in. 4 3/4 ton, cast iron, smooth-bore gun of Warrior was the most powerful weapon afloat in the British navy, but rifled, breech-loading guns were made by Armstrong, and proved superior in range, penetration and accuracy to smoothe-bore guns of the same calibers.[10] In the same year breech-loading was accepted in all navies. Thus the introduction of rifling had a great influence upon the early development of armor-piercing ordnance. Since the introduction, the Armstrong-breech loading guns was a source of difficulty, especially the 110-powder, as there were many accidents with them, resulting in many guns needing or actually undergoing repair. The behavior of the breech-loaders, as Oscar Parkes writes, during the action at Kagosima in August 1863 practically settled their fake job.[11] Of the ships engaged which carried Armstrongs, the

Euryalus	(35)	mounting	13 B.L.	had	14	accidents	in	144	rounds	
Perseus	(17)	"	5 B.L.	"	5	"	"	111	"	
Argus	(6)	"	1 B.L.	"	4	"	"	22	"	
Racehorse	((4)	"	1 B.L.	"	4	"	"	51	"	
Coquette	(4)	"	1 B.L.	"	1	"	"	37	"	12

In addition to the accidents the breech-loader's shootings was erratic and often much delayed, shells going "anywhere but straight forward and as much as 600 yds. to the left" and a lot failed to explode. For these reasons the 110-pound were withdrawn after this action, and thus the first breech-loading phase came to an end in 1864.[13] Now the Navy was faced with

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[10] Hovgaard, Modern History of Warships, (New York: 1920), 387-388.

[11] Parkes, Oscar, British Battleships, (London: Seeley Publishers: 1957), 34.

[12] Ibid., 34.

[13] Ibid., 34.

the problem of finding an armor-piercing gun for the ships awaiting completion. Although the 68-pdr. gun with steel shot could perforate the 4 1/2 inch plate and 7-inch timber of Warrior, there was no pressing reason why the 68-pdr. should be displaced by a longer gun or armor increased beyond 5 1/2 inch in thickness. Moreover, the British Navy believed that with 4 1/2 to 5 1/2 inch plating and 68-pdrs. it would be able to cope with the French and American navy. Although Armstrong held the difficulties could be overcome, he yielded to the opinion of the naval authorities and constructed a new type of rifled muzzle-loader, which proved satisfactory also with heavier calibers. This is known as the Somerset gun and it fired 100-pound shot. With the introduction of Somerset further development of smooth-bore gun was continued and in 1865 four "exceptional monsters" of 13-inch caliber muzzle-loader were built which fired 600-pound shot.

During the period 1863 to 1878 the smoothe-bore heavy guns grew as follows:

Gun tons	Proj lb.	Charge lb.	
9-in. 6¼	100	25	Woolwich "Somerset"
10.5-in. 12	156	35	Woolwich
13-in. 22½	600		Armstrong not accepted[14]

There were two other significant developments during this period. The first was the armor-piercing projectile designed by Joseph Whitworth. This projectile was constructed in the shape most suitable for penetrating armor, and the second was the introduction of a tough and hard steel which would neither break into pieces nor absorb work-energy in altering its own

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[14] Ibid., 37.

shape. During this same period Capt. A. T. Blakely of Royal Navy demonstrated the working of hooped guns. Blakely was the first to propose guns formed of concentric tubes having different degrees of elasticity, the inner tube being the most elastic because of the greater demands made upon it.[15]

According to Professor Baxter the influence of these new weapons on the history of the ironcladships, before the Battle of Hampton Roads had three phases: first, the destructive power of the new guns proved an irresistable argument in favor of defensive armor; second, several years of experiments proved wrought ironplates 4½ inch thick resisted the best of the old guns and the first of the new so successfully that England began a large program of ironclad warships; and finally, the temporary success of the 4½ inch plates led the makers of ordnance to redouble their efforts.[16]

The introduction of the muzzle-loading rifled gun of sixteen centimeters in 1855 in the French fleet contributed powerfully to the decision by the French Ministry of Marine to adopt defensive armor. At first this armor served only a defensive purpose. The temporary superiority of the 4½ inch armor over the best guns of the day led to the evolution of naval architecture and not only in France and England but the second rank maritime powers also began to build armored vessels. In the meantime the British Admiralty received hundreds of proposals for the improvement of armor. These suggestions consisted of steel, iron with its outer surface case-hardened, lead, wire rope, hemp matting, or alternate bars of iron and wood. As Baxter notes: "While many suggested new ways of fastening

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[15] Brodie, Sea Power, 198.

[16] Baxter, James P., Introduction of the Ironclad Warship, (Cambridge: Harvard University Press, 1924), 196.

doing away with the backing altogether, and putting the wood in front of the plates, a few thought corrugated armor would afford adequate resistance with reduced weight."[17]

On March 13, 1860, the Special Committee on Iron Plates and Guns reported to the War Office that vessels protected by wrought iron plates of 4½ inches thickness were "to all practical purposes, invulnerable against any projectile that can at present be brought to bear against them at any range." It also demanded "that they should be backed as strongly as possible, and firmly golted and nutted."[18]

Some experiments were made of wrought-iron embrasures in fortifications during 1859-1860 and forced the Ordnance Select Committee to report that there was "very good ground for believing that iron screens or targets would resist the heaviest shot and would prove of the greatest value in protecting casemates."[19]

In 1862 the Warrior target was pierced by a spherical shot of 150 pounds fired from an Armstrong 200-pounder constructed as a smoothe-bore.[20] Professor Brodie thinks that this penetration by a gun entirely practical for mounting on ship board was the most significant victory of the gun over the armored ship since the sea-going ironclad had been introduced.[21] In less than six months time the Warrior target was completely perforated at 600 yds. by a Whiteworth 130-pound flat-headed shell loaded with a 3½-lb. bursting

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[17] Ibid., 200.

[18] Ibid., 201.

[19] Ibid., 201.

[20] Hansard Series 3, CLXVI, col. 765-7,-April,1862.

[21] Brodie, Sea Power, 200.

charge. Two months later a shell of 151 pounds weight with a 5 pound bursting charge penetrated a 5-inch plate and burst in the backing. In 1863, a 610-pound steel shell containing a 24-pound bursting charge was fired from an Armstrong 13-inch gun at a range of 1,000 yds., and smashed a large hole entirely through the Warrior target, exploding at the instant of its passage through the plate. In March, 1863, in the House of Commons attempt was made by Lord Paget, one of the members of the opposition party, to repute Whitworth's assertion of piercing any armor plating not only with shot but with shell.[22] It seemed that the only answer to this would be to strive for heavier armor and to build bigger ships to carry it. By 1864 the Bellerophon was built which had six inches of armor plates over 1½ inch iron inner skin with 10 inches of teak backing between--and at that time it was considered the strongest ship afloat. It had a 9-in. 12 ton rifled gun which threw 250-lb. projectiles capable of perforating 10-in. of armor at a range of 1000 yds.

During the year 1861-1864 further tests were made. These did not prove that a 4½ inch plate would not offer greater resistance, especially to spherical shot, when placed obliquely than when placed vertically. The tests also concluded that a given weight of iron would afford more protection if disposed in vertical plates than if disposed in thinner plates, of necessarily greater surface, placed obliquely to protect the same vertical area. Attempts were made to eliminate the wood backing behind the armor. But the experiments proved the necessity of wood backing, showing that:

> However much the armor plates may be supported by direct contact with a rigid backing of iron, and however

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[22] Hansard Series, 3, CLXVI, Col. 1354.

> desirable it may seem to exclude wood or other perishable material from them, yet the concussion is so injurious to the fastening of a rigid structure, that in the present state of our knowledge it would be unwise to recommend the abandonment of wood backing.[23]

For the three new ironclads, Agincourt, Minotaur and Northcumberland the Admiralty reduced the wood backing from 18 inches behind the plates of Warrior to 9 inches, while it increased the thickness of the armor plates from 4½ to 5½ inches. By 1865 the principle of armor definitely became defensive, but it also became a problem to keep pace with the rapid improvement of naval armament. Thus the whole subsequent history of protection on the battleship involved both the development of armor in thickness and quality to meet the constantly increasing offensive power of the naval gun and also the limitation of the extent of that armor on the sides of the ships to save weight and this made possible extension of other desirable qualities.[24]

According to Brodie in this long race between ordnance and armor there are certain factors which it is important to consider. First, the projectile designed primarily to penetrate armor cannot also be designed to have the maximum bursting effect upon impact. It must have thicker walls than the shell that is not required to perform such work, which leaves less room for an explosive change. Second, the mere fact that armor can be perforated does not mean that it is useless in actions, for the conditions under which it is penetrable may occur only infrequently in battle. Third, the armorclad might be penetrable even in the region of its

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[23] Quoted by Baxter in Introduction of the Ironclad Warships on 203 from the First Report of Special Committee on Iron, 1860.

[24] Brodie, Sea Power, 211.

thickest armor, but if so, it was penetrable only by the largest ordnance. It could not be perforated by small guns. The opposition would not be dangerous unless it carried the largest ordnance, a requirement which inevitably reduced the number of its guns and their role of fire. Fourth, as guns increased in power they were utilized at longer ranges, armor which failed to exclude shot at 3,000 yds. might be quite effective against 6,000 yds.[25] In 1864 France adopted two new guns, one of 7 3/4 tons and the other of 15½ tons. These guns made the armor inadequate even before ships were completed. It became necessary in 1865 to build ships with heavier armor. So the ships, which carried at the water-line 8-inch plates upon a backing of 32½ inches of timber, were projected. But even before the first of these ships was launched in October, 1868, its armor proved insufficient against the 23-ton guns which then came to use.

Before the construction of the Bellerophon, which has already been mentioned, was completed, the construction of the Hercules with 9-inch armor was projected. Of this Lord Paget said, "In other respects she will be very similar to the Bellerophon, and as regards her armament, she will be armed with the newest fashion of guns, whatever that may be in next year."[26] The board of the armor on Hercules was 40 inch teack backing and 2¼ inches of additional iron plate. In 1869 it was necessary to begin a ship carrying a water line belt of 10-inch to 12-inch armor and a turret plating of 14 inches. Devastation was completed in 1873. She was armed with 35-ton muzzle-loading rifles. She has been called the first modern battleship, since she combined for the first time in a large sea-going

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[25] Ibid., 211-212.

[26] Hansard Series 3, CLXXVII, Col. 1158.

vessel the use of the turret system in the housing of the batteries and complete freedom from perils.[27]

Before Devastation was completed, it was necessary for England to build a new type of ship which would keep pace with the recent battleship development in Italy. The great Italian constructor Benedetto Brin planned to lay down two ships called Dhilio and Dandolo in 1872. Carrying four 100-ton guns in a heavily armored citadel they introduced the monster guns and created a big impression.[28] They had a thick belt amidships and relied upon a protective deck and internal subdivisions for integrity fore and aft. They were the largest and most powerful battleships of their day and served as a model for British battleship Inflexible.[29] Inflexible was completed in 1881. Her dimensions were 320' x 75' x 24'5'/ 26'5'=11,880 tons. She carried 4 16-in. 80-ton muzzle-loaders and 6 20 powders. Her most interesting features were, as Parkes pointed out, echelon turrets amidships carrying the heaviest guns in the service; an impregnable citadel carried in a hull having high fore and aft superstructures, with the ends covered by an armored deck below water above which was exclusive subdivision to localize flooding; thicker armor than any ship before or since.

Inflexible is one of the milestones in the history of British naval architecture because it was the precursor of central citadel ships and as the first capital ship in which the under-water armor deck was used in place of vertical armor along the water line. She was a complete

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[27] Brodie, Sea Power, 216.

[28] Parkes, British Battleships, 245.

[29] All the information about Inflexible are taken from Parkes, British Battleships.

departure from all previous standards of design, and of gun power, armor thickness and disposition of armament. It has already been noted that it carried 16-in. muzzle-loading guns which fired a 1,684.16 pound projectile with a muzzle velocity of 1,950 ft. seconds and able to pierce 23 in. of iron at 1,000 yds.[30] The firing rate was about one round per gun per minute. The armor was 24 inches thick. Armor never increased in thickness for two reasons: its quality improved, which meant that it had equal or superior resistance power and the coming of the quick firer in the secondary armament necessitated the temporary abandonment of the citadel type of protection. Thus the armor had proceeded since the days of Warrior from 4½ inches to 24 inches in the days of the Inflexible and the armament had proceeded from 68 pounders of 4 3/4 tons to 16-inch rilfes of 80 tons. So almost till the end of the seventies muzzle-loader was the standard gun in the British Navy. From that time on, calibers and velocities steadily increased, and although the thickness of armor likewise went on increasing, the perforating power of the guns in general kept well in advance of the resistance offered by the armor which can be proved by mentioned the case of the Dreadnought (1875). It was protected by 14 in. armor and it carried 12½ in., 38-ton guns which fired 820-lb. projectiles with a muzzle-velocity of 1575 ft. which was capable of perforating 17 3/4 in. of iron at 100 yds.

In the seventies slow-burning powder was invented and by the 1880's it was introduced generally. With this the initial velocity of the projectiles could be raised from about 1600 to 2000 ft. per second and the perforation power greatly increased. However, slow-burning powder, in order to develop its energy, required longer guns, in which it was difficult

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[30]Parkes, British Battleships (London: 1957), 489.

to perform the loading operation through the muzzle. Therefore it forced the adoption of breech-loading system. There were other technical advantages of this system, such as a more stable trajectory resulting in greater accuracy of fire. There was also the advantage that the men were less exposed when loading and that the smoke was discharged outside the turret instead of the recoil bringing the still smoking muzzle inside on return to the loading position.

The earlier breech-loaders had been dangerous because they could be fired without the breech properly closed. However, these breech-loading guns overcame that problem by developing automatic safety devices attached to the breech which prevented the gun being discharged until the interrupted screw action had locked. The breech-loading gun was reintroduced in 1878 and gradually better mechanical devices were adopted and finally by 1880 the English adopted them and at the same time the Woolwich system of construction was abandoned because it was decided to use steel for all parts of the guns. The Colossus and the Edinburgh completed respectively in 1886 and 1887, were the first British battleships to carry breech-loaders. They carried a main armament of 9,150 tons, of four 12-in., 45 ton breech-loading guns, five 6-in. breech-loading guns, and twenty smaller guns. Apart from carrying the breech-loading guns, they were first to have compound armor generally in place of iron, the first in which steel was used for general construction, and the last of the citadel ships proper.

It was originally planned that Colossus and Edinburgh would carry four 38-ton M.L.R. and four 6-in. B.L. But in 1882 when Woolwich guns were completely discarded the Board of Admiralty armed the ships with 12-in. 25 caliber breech-loading guns. At the end of eighties cordite was introduced in England and completely took the place of old-time gunpowder for artillery purposes. Cordite was smokeless and, being very slow burning and efficient, allowed a further increase in the length of guns and in the developed energy.

Not only guns and projectiles but also their mountings and sights also had improved during the period. All these naturally resulted in an increasing thickness of defensive armor. As such added weight tended to impair ships' speeds, the metallurgists turned their attention to this problem. Compound armor consisting of a hard steel face with a soft iron backing, was introduced in 1879 and permitted a reduction to 18 in. in thickness and a consequent valuable saving in weight. By 1890 all steel armor came in use and in 1892 it was discarded in favor of nickel-steel alloys with hardened face.

IV

Bushnell was the first man to show that a change of gunpowder can be made to explode under water. This is of tremendous importance because successful use of the mine in naval warfare depends upon it. Mines had been used previously in the 1790's but proved ineffective because the energy of the explosion was dissipated by expansion of the gasses in the air. Bushnell realized that in order to be effective, a mine must be well submerged below the surface. He devised means for exploding gunpowder under water and constructed mines of various types.

About twenty years later, Robert Fulton experimented with submarine mines and was the first inventor of the anchored mine. He proved the effect of underwater explosions by blowing up small vessels in France and England. However, the British naval authorities were strongly opposed to this weapon, because it threatened the supremacy of the British on the sea, and Fulton was not encouraged any further. After his return to America in 1806 he asked the United States Government to support his inventions and submitted projects for several different "torpedoes"--which term was used at that time to describe all kinds of contraptions for exploding gunpowder under water. Mines were used in Schleswig-Holstein War (1848-51) and in the Crimean War (1854-56).

After the American Civil War the mine became the permanent link in the naval defences throughout the world and a more systematic development began which soon influenced the design of the warship. Finally the term "torpedo" became restricted to such weapons as towing and spar torpedoes and specially automobile torpedoes by all of which the explosive charge in some way or other was actively carried or propelled against an enemy ship and the tem "mine" was applied where the explosive charge was used in a passive, usually anchored, manner. Gradually two types of mines were developed; "observation" and "contact". Either the observation mines rest on the bottom of the sea or they are buoyant and moored at a fixed distance from the bottom. They are fired at will by an electric current when an enemy ship is observed to be near the mine and are controlled from a station on shore. Contact mines are designed to explode when struck by a ship; they are usually kept at a certain depth below the surface. Many modern mines are activated by impulse.

In the sixties, mines and spar torpedoes[30] introduced a minor water-tight

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[30] Spar torpedoes consisted of small charges of gunpowder or dynamite fixed on the end of long poles fitted to smaller craft. They were used in all navies and were used in the Russo-Turkish War 1877-1875.

subdivision of warships. However, being limited in their applicability, these weapons could not influence naval architecture. In the seventies efforts were made to produce automobile torpedoes "by means of which submarine attack could be carried out from ships or boats at a relatively great range from the enemy;" and before the end of the decade a successful solution had been found in the Whitehead torpedo. In 1870 Whitehead exhibited a torpedo which was 14 ft. long and maintained a speed of 8 kts. over a range of 300 years; it carried 67 lb. of gun cotton. The Whitehead torpedo was rapidly developed to a practicable and powerful weapon and by 1880 was being introduced in all navies,[31] and so torpedo boats appeared. The essential secret of the early Whitehead torpedo[32] was the mechanism by which the machine could be made to run at any required depth. Torpedoes threatened the supremacy of the armored battleships which caused much concern in the great navies. The destructive power of the torpedo and the failure of the ships to resist its attack led people to believe that the battleship armed with heavy ordnance and protected by thick armor was destined to disappear at once and there therefore only small vessels armed with light guns or perhaps with a single heavy gun ought to be constructed.[33]

In England, small, fast, heavily armed cruisers, protected by an armored deck and a cellular layer, were advocated by Lord Armstrong. These arguments were as Hovgaard writes: "To resist the most powerful guns afloat,

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[31] Hovgaard, History of Modern Warships, 452.

[32] Whitehead Torpedo was introduced by Robert Whitehead, an Englishman, who was a manger of an engineering factory at Fiume in Hungary.

[33] Hovgaard, History of Modern Warships, 452.

armor of at least 2 feet in thickness is required, whence it has been necessary to rebuilt the area of armor surface to even-narrowing limits, leaving a large portion of the ship without protection." Ironclads are no more secure against the attack from torpedoes and rams than unarmored vessels. The function of armor may in a very considerable degree be fulfilled by coal, if judiciously applied for that purpose. Sail rigging should be abandoned, whereby a greater supply of coal can be carried and the coal protection can be improved. By introducing an under-water deck with divisional spaces, comprising cork cofferdams and coal spaces above the deck, an unarmored ship may be rendered almost incapable of being sunk. For the cost of one ironclad may be had three unarmored ships of higher speed, carrying collectively three armaments, each equal to that of the armored vessel. If matched in combat, the three smaller ships would be able to overwhelm the armored ship with their fire or, if the armor was impenetrable to the guns, they could destroy the ironclad by ramming or by using their torpedoes. Hence, ironclads can not be needed for the purpose of opposing ironclads; for this, as well as for all other service, a numerous fleet of smaller and swifter unarmored vessels carrying a powerful armament are preferable. It appears expedient that the chief expenditure should be upon this class of vessels.[34]

For the naval contractor it is quite important to know the effects that are likely to be produced by the explosion of mines and torpedoes on a given structure and to provide the best means of protecting a ship damaged in this way. Various countries made experiments on this but

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[34] Ibid., 454.

according to Professor Hovgaard the results have been kept secret.# The results of the experiments which are known are all after 1893. For this reason present writer will not discuss these experiments.

In short because of the torpedo a new type of ships appeared. First came the small, fast torpedo boat, designed to carry torpedoes as its main armament; secondly, torpedo-gunboats and destroyers, in other words anti-torpedo boats; and finally came the submarine whose success depended mainly on the Whitehead torpedo.[35]

V

As soon as the torpedo boats became a part of the navy, naval architects developed counters in the quick-firing gun and the torpedo-boat-destroyer which soon made the simple torpedo boat obsolete, only to re-usurp itself the functions of the boat it had been created to destroy. At the same time protection against locomotive torpedoes seemed to be assured for ships at anchor by the use of nets. These were of the early Bullivant type made up of steel wire rings 6½ in. diameter joined by small steel rings, and weighing only 1 lb. per sq. ft. They were slung out on long booms triced up high above water by stays from the derricks or mast heads and hung to hull depth; extended trials proved them capable of stopping the slow 14-in. torpedo which it was feared might then explode and destroy the net. The booms were carried along the sides in turret ships, but usually stowed inboard in broadside ships except for a pair triced up at

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#As far as can be determined, none of these experiments has since come into print.

[35] Ibid., 534.

the bows and stern. The cumbersome ceroline took a long time to get fixed into position and longer still to restow, and could only be used with the ship at anchor.

The first idea of armor protection against under-water attack was made by Reed in 1884. In his proposal he designed a ship with an armored double bottom 4 in.-3½ in.-2½ in. with the thickest portion over the sides with the 8 ft. space between it and the outer bottom subdivided transversely and longitudinally. This armored screen ran under the machinery, boilers and magazines and, as he described it:

> The torpedo will be stopped and compelled to explode outside the inner bottom, and the debris of that bottom will be dashed against the inner armor which will of course be vastly more difficult of penetration by this debris than the ordinary 3/8-in. steel plating which at present is all that separates the boilers etc. from the outer bottom.[36]

The scheme was satisfactory as regards weight. But the deep double bottom raised the boilers and engines so that they were partially above the heater line and directly exposed to gun fire which could penetrate the belt. For this reason the Board of Admiralty rejected his proposals. In the seventies "machine guns" of various types (Gatling, Nordenfelt) made their appearance as defence against torpedo boats. They evolved from small arms and rich calibers of 1 in. to 1½ in. All the early machine guns had several barrels.

Due to the growing size of the torpedo-boats and the greater range of the torpedoes, it was necessary to increase the power of the guns that were to fight this new enemy. The multiple-barrel type was too heavy and the automatic principle was not applicable to guns of greater caliber. So the "quick-firing" or "rapid-firing" guns, single-barrelled weapons characterized by a quick-acting system of operation, and by the use of cartridge cases,

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[36] Parkes, British Battleships, 326.

which at least for the smaller calibers contained both the powder and the projectile, came into being.

During the last years of the eighties, Armstrong made several important improvements in the center-pivot mountings, which contributed greatly to the success of the quick-firing guns.

Another great advance was made in about 1890 by the introduction of smokeless powder, which gave higher initial velocities and was practically free from the smoke formation which hindered a rapid firing of guns and the used cartridge were gradually discontinued for the large calibers. About the same time high explosives began to be used for bursting charges in the shells, and the manufacture of armor-piercing projectiles was much improved.

By the beginning of nineties there were not only machine-guns and light quick-firers, such as the 3 in. Q.F. gun, suitable for use against torpedo-boats, but also more powerful quick-firers capable of piercing armor of light and medium thickness, and of demolishing unprotected structures by a great volume of shell fire. Armstrong specialised in quick-firers of great caliber, and, besides the 4.7 in. gun, constructed 5.5 in. and 6-in. guns. According to Professor Hovgaard these Q.F. guns took the place of breech-loading guns.

The quick-firing gun and the attendant torpedo-boat destroyers were quite adequate to fend off torpedo attacks. Only against stationary ships were torpedo attacks already to have any success and for that reasons torpedo boats were painted in black, so as to achieve surprise at night.

Though these are some of the most important developments in armaments in the Royal Navy during the period 1815-1893, however, this was a near universal trend because of the increasing attention paid by such countries as the United States, Japan, Italy and Germany to the strengthening of their naval forces.

CONCLUSION

This descriptive essay shows that the British navy of the nineteenth century had definitely experienced certain changes which ultimately put the navy well on the road to becoming the "Navy of Fisher, of Jellicoe, and of Cunningham."[1] These changes were mainly due to technological expansion and the advancement of armaments. These were, however, not the sole causes; the political rivalry between France and England and the economic prosperity of the latter were also responsible for the changes and the developments which the nineteenth century British navy accomplished. It can be said that the political rivalry and the economic prosperity led to the general technological growth which ultimately changed and improved the British navy of the last century. Thus it can be concluded that the evolution of the technology was directly responsible while the political rivalry and the economic prosperity were indirectly responsible for the growth and betterment of the English navy of the last century.

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[1] Michael Lewis, The Navy in Transition, 9.

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NAVAL ARCHITECTURE: 1815-1893

by

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ABSTRACT

Man started to build boats of sorts before the dawn of civilization. Gradually the methods of constructing ships were completely changed. However, until the nineteenth century the process of change was very slow in comparison with modern ideas of progress; the warship of Horatio Nelson was largely that of Drake and construction was uniform in all navies. But with that century came a revolution in the naval architecture, which made the battleship of Fisher and Jellicoe a very different entity from that of Nelson. What was the reason behind this revolution? A close examination of the English political situation shows that the long period of peace after the Napoleonic War, weakness of the continental land power and specially the Anglo-French rivalry on the question of naval supremacy played a very significant role in this revolution. On the other hand the importance of economic conditions cannot be ignored. The Industrial Revolution began in England about the middle of the eighteenth century and resulted in Britain being the prime industrial nation of the world for most of the nineteenth century. During this time there was an increase in the availability of iron ore which consequently became very cheap, while at the same time there was an acute problem of a dearth in supplies of suitable timber for ship construction. The destructive force of shell fire rendered wooden walls obsolete; therefore, shipwrights began to use iron for ship construction and the first iron-steamer, the Aron Manaby, was built by the Horsley Company of Staffordshire in 1820. But the Admiralty ignored this important revolution. With the use of two iron paddle steamers

namely Plaegathon and Nemesis as gunboats in the First Opium War of 1839-40 the iron ousted wood as the basic material for hulls.

The technological developments had the most influence in the revolution of naval architecture. Both in the introduction of steam power and in the use of iron as the ship building material, a new era commenced. Though the Admiralty built the Thames, the first steamship in England, in 1815, because of the extreme conservativeness at first it was reluctant to accept steam vessels. This reluctance to adopt steam for battleships was eventually overcome by the development of the screw propeller. By late 1830s the world possessed her first practical screw driven vessels. Characteristically the Admiralty refused to accept the screw propeller. The delay in its adoption in warships has been attributed to the fact that it required engines different in design from these used with paddles and that new designs meant prolonged experiments and loss to vested interests. In 1870s the naval contractors tried to use steel for the ship construction. But the Admiralty did not accept the steel ships because at the beginning steel was more expensive than iron and it lacked ductility, malleability, and uniformity of strength. These difficulties disappeared when steel of softer grades, known as milder steel was introduced. In 1886-87 Colossus and Edinburgh were the first battleships built in steel by the Admiralty.

In 1815 the warships were still armed such as they had been for the past four centuries. The introduction of the paddle wheel cut down the number of guns a vessel could carry and this stimulated experiments towards developing more effective gun-fire with fewer ordnance. These experiments led to closely related developments; bigger and stronger guns, better shells and shell guns, rifling and breech-loading guns. Paixhan's shell gun came out in 1820. It was shorter and lighter using smaller charges than guns of the same calibre designed for solid shots. The English officially adopted it in 1839. The destructive power of Paixhan's shell gun showed the necessity of protecting the sides of the battleships by armor so armor was introduced by 1850.

The submarines appeared in the last quarter of the eighteenth century but until the American Civil War it did not become the permanent link in the naval defenses throughout the world and soon a more systematic development began which influenced the design of the warship. In the seventies torpedoes were introduced. As soon as torpedo boats became a part of the navy, naval architects developed counters in the quick firing gun and the torpedo-boat-destroyer which soon made the simple torpedo boat obsolete, only to resume itself the functions of the boat it had been created to destroy. The machine guns and "quick-firing" were also invented in the seventies to fight against the torpedoes.

Though these are some of the most important developments in armaments in the Royal Navy during the period 1815-1893, however this was a near universal trend because of the increasing attention paid by such countries as the United States, Japan, Italy, and Germany to the strengthening of their naval forces.