
THE SCIENTIFIC STUDY OF NAVAL ARCHITECTURE.*

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From the "Nautical Magazine."

WE have met together to-day upon no ordinary occasion. The institution of the John Elder Chair of Naval Architecture in this University is, in more senses than one, an unique and important event. No British University has ever before included in its curriculum anything like a complete treatment of the science of naval architecture; and this is also the first time that mercantile naval architects and shipbuilders have had an opportunity of commencing a course of scientific training which is intended to be specially and fully adapted to their requirements. Unlike nearly all the professors whom I have now the honor to call my colleagues, I have no predecessors, the records or traditions of whose life and work I can appeal to for encouragement, or inspiration, or as a pattern for imitation.

Although that is the case, however, so far as this Chair is concerned, many of the subjects which are to be taught from it have already had a far abler exponent in this University than I can ever aspire to become. The late Professor Macquorn Rankine was for many years one of the greatest authorities upon the sciences related to naval architecture and marine engineering. His immense ability and energy enabled him to achieve results in these departments of knowledge which would have made him famous had he attempted nothing else. But when we remember that what he thus did constituted but a small portion of his life-work, and was only connected with a few out of the many subjects comprised under the head of "Civil Engineering and Applied Mechanics," with all of which he dealt, we may truly marvel at what he accomplished for naval architecture. I cannot speak from personal experience of Professor Rankine's teaching in this University; but I am grateful for the opportunity of paying an humble tribute to his memory, in this place where he was so well known and so highly esteemed, by referring to what he did elsewhere.

Professor Rankine was a lecturer at the Royal School of Naval Architecture and Marine Engineering, at which I was a student; and he was one of the ablest members of, and most regular attendants at, the Institution of Naval Architects in London. There were very able men in London in those days at both the institutions I have named; and great advances were being made in the science of naval architecture, and in its application to the practical requirements of shipbuilders. Problems which had previously baffled all attempts at solution, even when made by some of the most eminent mathematicians of this and the previous century, were at length yielding to the genius and methods of modern investigators. The way was led by the late Mr. William Froude, with a paper upon "The Rolling of Ships," read before the Institution of Naval Architects in 1861.

Mr. Froude brought forward in this paper what, in his own words, "assumes to be a tolerably complete theoretical elucidation of a difficult and intricate subject, which has hitherto been treated as if unapproachable by the methods of regular investigation." I hardly need pause to say that Mr. Froude accom-

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plished his self-imposed and formidable task with marvelous success. He thereby initiated a new era in the history of naval architecture, and one in which Professor Rankine was among the most prominent and distinguished figures. Professor Rankine helped more than any one to confirm and extend Mr. Froude's theories of wave motion and of the rolling of ships; and he also devoted himself with great ability and thoroughness to an investigation of the laws which govern the resistance of ships, and to the whole question of marine propulsion.

Professor Rankine impressed the students in London with the most profound respect and admiration for his great powers, and for the original and masterly way in which he dealt with everything he touched; while he possessed the rare gift of rousing their energies by his personal enthusiasm and charm of manner. No man with whom the students of naval architecture then came in contact had so powerful and elevating an influence upon their minds as Professor Rankine; and there is no one to whom they owe more, either for what he directly taught or for the mental stimulus they received by contact with him. It is a peculiar gratification to me, remembering what Professor Rankine was to the students of naval architecture of my time, to be able to bear testimony here to the high regard we all had for him, and to the high esteem in which we hold his memory.

It has formerly been thought necessary by some, who have been called upon to advocate or initiate courses of scientific teaching of naval architecture, to defend their position argumentatively, and even apologetically. I do not feel, however, that the circumstances of the present case require from me anything of the nature of an *apologia*. It will, perhaps, be more appropriate to the occasion, and more instructive to you, if I pass on at once to attempt to show how and when the recent irresistible demand for improved scientific knowledge, in virtue of which we are here to-day, arose in the Mercantile Marine; and shipbuilders became convinced, not merely of the desirability, but of the absolute necessity, of long and severe courses of preparatory scientific study, such as their forefathers, to all appearances, got on fairly well without. Perhaps a few discursive remarks upon these and other topics of general interest to the shipbuilding profession may also prove more acceptable to you to-day than a dissertation upon purely technical or abstract subjects.

The demand for scientific training in naval architecture is a comparatively modern one so far as the Mercantile Marine is concerned. It has long existed, however, in connection with the requirements of the Royal Navy. Even so long ago as Sir Walter Raleigh's day the builders of ships of war were reproached for want of technical knowledge, and for the errors and failures consequent upon it. That celebrated author, in his "Discourse on the Royal Navy and Sea Service," calls attention to the injurious effect upon a vessel's sailing qualities which is produced by over-immersion. He says "that the ship-wrights be not deceived herein (as for the most part they have ever been) they must be sure that the ship sinck no deeper into the water than they promise, for otherwise the bow and quarter will utterly spoile her sayling." Such complaints did not apply to the war-ships of this country only, for we find one of the earliest French writers upon naval architecture, Père l'Hoste, saying in 1697 of the ships of the French Navy, "It cannot be denied that the art of constructing ships, which is so necessary to the State, is the least perfect of all the arts. . . . Chance has so much to do with construction that the ships which are built with the greatest care, are commonly the worst, and those which are built carelessly are sometimes the best. Thus the largest ships are often the most defective, and more good ships are seen amongst the merchantmen than in the Royal Navy."

It was in the construction of war-ships that the greatest difficulties formerly arose, and that the need of scientific knowledge and improved methods of design first became manifest. Merchantmen were smaller in size, and much more simple and uniform in type and proportions, than war-ships, until quite recent times. If we look at the Mercantile Marine of fifty years ago we find that there were then about 750 merchant vessels built in each year. Out of these 750 vessels, only about 40 were above 300 tons, old builders' measurement, and no more than 10 exceeded 500 tons. The whole number of ships composing the British Mercantile Marine in 1830 amounted to 19,110, of which but 168 were above 500 tons measurement. Thus more than 99 per cent. of our merchant vessels were at that time of less than 500 tons measurement. Very few were ever built of over 130 feet in length.* Mr. James Laing, of Sunderland, has been good enough to furnish me with particulars of a vessel which was built by his father, for his own use as a shipowner, in 1815. She is interesting as having been one of the first of the free traders to Calcutta after the breaking up in that year of the monopoly so long enjoyed by the East India Company. The length of this vessel was 109 feet 9 inches, breadth 29 feet 7 inches, and depth 20 feet 6 inches; the tonnage being 414. This is a typical illustration of a fine merchantman of that period, such as was employed upon the longest sea voyages. She was named the *Caledonia*, and successfully performed the voyage to India and back in about 10½ months, which was considered good work in those days.

It is clear that mercantile shipbuilders could not have been much troubled up to that time by difficult or novel problems in naval construction. They were simply occupied with the building of wooden craft of comparatively uniform types and proportions, and of so small size that not one per cent. of the whole number exceeded 500 tons in measurement. The case was quite different, and had long been different, with the constructors of war ships. From the days of Henry VII. until now, successive Sovereigns and Governments of this country have striven in a more or less degree, first to rival, and afterwards to surpass other naval Powers in the strength and excellence of their ships of war. The efforts made at various times with this view have not always been wise nor successful. Large ships which could carry numerous guns, and carry them high above the water level with safety, and without serious detriment to sailing qualities, constituted the great and ever-growing, but very difficult, requirement of the naval authorities; and formed the problem which was continually proving a stumbling-block to successive generations of naval constructors. Henry VII. built several large vessels, one of which measured, according to various accounts, from 1,000 to 1,500 tons. In the fleet that sailed to meet the Spanish Armada there were two ships which exceeded 1,000 tons in burthen. James I. built a vessel which measured 1,400 tons; while the *Royal Sovereign*, built by Charles I. in 1637, was said to be "just so many tons in burthen as there have been years since our blessed Saviour's Incarnation, namely, 1637, and not one under or over."

Coming to more recent times we find that, at the commencement of the present century, British first-rate ships of the line had increased in size to 2,000, and even to 2,500, tons measurement. These vessels were heavily laden with top hamper, in the shape of three tiers of decks with numerous guns upon them. They frequently proved to be over-draught and unstable upon trial, and deficient in weatherly qualities at sea. No questions ever came before mercantile shipbuilders in that day of such magnitude, difficulty, or complexity, as those which war-ship constructors had to deal with. Mercantile shipbuilders produced small craft of a class whose qualities had been thoroughly tested by experience and were well understood by the owners and masters who had to work them. War-ship constructors, on the other hand, were the designers of comparatively huge vessels, whose type and loading introduced elements of special difficulty and danger.

Instability required to be carefully guarded against in war-ships of the description referred to, but our naval constructors did not then understand the principles upon which stability depends. Ships frequently proved so unstable when completed that all the remedies which could be devised, such as carrying extra ballast and doubling the planking at the water line, had to be applied. It is true that mathematical treatises upon the stability of ships had long been published in France and elsewhere; but they had been of no effect in improving the practice of naval architecture in this country. Even in France, where Daniel Bernouilli obtained a prize offered by

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* Annals of Lloyd's Register, 1884.

the *Société Royale des Sciences* in the year 1757, for a *mémoire* in which the statical conditions of stability are clearly stated, high authorities upon naval architecture were unable, thirty years after, to account for a deficiency of stability in three ships that were remarkably crank.* In this country, where naval designers were much more deficient in scientific knowledge than in France, and where war ships were notoriously inferior to those of the French, mistakes were more general, and were frequently more fundamental and serious.

Mr. Wilson, a member of the first School of Naval Architecture, gives † an instructive and interesting account of the cutting down of a 64-gun two-decked ship of the line to a frigate of 38 guns, in the year 1794. He says that "so culpably ignorant were the English constructors that this operation, so well calculated, when properly conducted, to produce a good ship, was a complete failure. Seven feet of the upper part of the topsides, together with a deck and guns, weighing about 160 tons, were removed, by which her stability was greatly increased; but by a complete absurdity the sails were reduced one-sixth in area. In her first voyage the rolling was so excessive that she sprang several sets of topmasts. To mitigate this evil, in 1795 her masts and yards were increased to their original size; but as there was no decrease of ballast, she was still a very uneasy ship, and as a necessary result, her wear and tear were excessive.

Other sixty-fours were cut down, masted and ballasted in exactly the same manner, and, it need scarcely be added, experienced similar misfortunes; and although they were improved by enlarging their masts and yards, they were still bad ships. Had their transformations been scientifically conducted, a class of frigates would have been continued in the Navy, capable from their size, of coping with the large American frigates; and thus the disasters we experienced in the late war, from the superior force of that nation, would, without doubt, have been, not merely avoided, but turned into occurrences of a quite opposite character.

I may here say in passing that one of the chief reasons why shipbuilders, shipmasters and others who require to understand the principles upon which a ship's qualities depend, often remain for long periods in ignorance of the published information upon the subject is perhaps to be found in the fact that the style of treatment commonly adopted in works upon naval architecture is one which presupposes and requires advanced mathematical and highly technical knowledge in the readers. The celebrated mathematician, Euler, said in 1773, in the dedication of his work entitled, "Thé rie Complette de la Construction et de la Manœuvre des Vaisseaux," that "although forty years have elapsed since mathematicians have labored with some success, yet their discoveries are so much enveloped in profound calculations that mariners have scarce been able to derive any benefit from them." This reproach still attaches, I fear, to many writings upon naval architecture; and in removing the cause for it more may probably be done for the benefit and enlightment of students than in any other way. The great want of the time, in this department of science, is elementary explanations of principles and processes stated in clear and precise language, but freed as much as possible from advanced mathematical methods and terms, and from perplexing technicalities.

The difficulties of war-ship construction had become so overwhelming at the end of the last century owing to the above-named, and other causes that radical measures for remedying them could no longer be delayed. No such difficulties had arisen, however, be it observed, even at a much later date, in connection with the ships of the Mercantile Marine. Several attempts were made to improve the existing state of things in the Royal Navy, and to promote the spread of scientific knowledge of naval architecture in this country. These resulted in the establishment of the first School of Naval Architecture by the Admiralty, at Portsmouth, in the year 1811. Dr. Inman, the principal of the school, said, in an official document, printed by order of the House of Commons in 1833, that at that period "scarcely a single individual in this country knew correctly even the first element of the displacement of one

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* L'art de la Marine. M. Romme.

† Papers upon Naval Architecture and other subjects connected with Naval Science. 1827-1833.

of our numerous ships, either light or load." So far as the Mercantile Marine was concerned this may not then have been of much practical importance, but in the Navy the case was very different.

The first School of Naval Architecture remained in operation during more than twenty years, and trained about forty students. The second School of Naval Architecture was founded at Portsmouth by the Admiralty in 1848, with Dr. Woolley as the Principal. This school had only a brief existence, and was closed in the course of a very few years. The third School of Naval Architecture, which also included marine engineering, was opened at South Kensington in 1864, and is now united with the Royal Naval College at Greenwich. The whole of these schools were instituted and carried on for the special purpose of training up war-ship designers and calculators for the work of the Royal Navy; and many students, highly trained in mathematics, and in the special work of war-ship construction, were educated in them. The members of the first School of Naval Architecture were for a long time the victims of professional jealousies and prejudices, and had to contend against the strong opposition of the old class of officers at the Admiralty and in the Dockyards. They were kept in subordinate positions until late in life; and it became the custom for the First Lord of the Admiralty to state annually, from his place in Parliament, that these "young men" (men between 40 and 50 years of age) "though gentlemen, and men of education, yet want experience, and therefore cannot be promoted." The members of the later schools of naval architecture have not had similar difficulties to contend with to anything like the same extent. Some now occupy the highest positions in Her Majesty's service, and have done much to advance the science of naval architecture, and especially to bring about great and long needed improvements in war-ship design.

The demand for improved scientific knowledge of naval architecture has thus existed in connection with the Royal Navy from a very early period, and was long of a most pressing character. The first attempts to supply it had already been made by the establishment of the first School of Naval Architecture, long before the Mercantile Marine was even affected. No difficulties approaching in any degree to those met with by war-ship designers arose to vex the souls of mercantile shipbuilders till after the modern age of steam shipping was entered upon, and till new types of vessels of enormous sizes and novel proportions were designed, in the construction of which previous shipbuilding experience was an unsafe or an insufficient guide.

It is interesting in this connection to observe that the Admiralty practice and that of the Mercantile Marine appear to have been very similar, even down to the present time, in dealing with small craft of old-fashioned types and proportions, which existed in sufficient numbers to enable the qualities of any one vessel to be inferred from those which others were known by experience to possess. At the court martial held to enquire into the cause of the capsizing of the small wooden frigate *Eurydice* in 1878, Mr. Barnaby, the Director of Naval Construction, said that she was inclined under his direction on the 11th May, 1877, not for the purpose of discovering whether she was a stable ship, but as a matter of scientific interest, because, so far as he knew, no sailing frigate or larger sailing ship had ever been inclined in the history of the Royal Navy. Mr. Barnaby explained that, "The reason for this must be the same as that which rules the present practice in the merchant Navy. There are about 5,000,000 tons of registered sailing ships in Great Britain, and it is not the practice of any owners to incline their ships." At the inquiry into the loss of H.M.S. *Atalanta*, another small wooden frigate, two years later, in 1880, Mr. Barnaby said: "The ship was never inclined so as to have the center of gravity ascertained. Her stability was known only in the sense that she was like, or nearly like, other ships whose behavior is well known." These statements show that the practice of the Admiralty and that of the Mercantile Marine have been very similar throughout in regard to the construction of ships of ordinary type, which do not appear to contain elements of special difficulty or danger. It was the development of peculiar types of ships, possessing uncommon or abnormal features, which first made elaborate scientific treatment necessary in both cases, and to which it has latterly been applied. The exceptional difficulties caused by such development arose much earlier in the Royal Navy than in the Mercantile Marine, and therefore had to be dealt with at an earlier period, and at a time when the science of naval architecture was not nearly so advanced as it now is.

Fifty years ago the use of iron for ship construction and the employment of steam propulsion had only been attempted in a few vessels that were employed in coasting or river trades. As regards iron, few persons imagined that it was the material of the future for shipbuilding purposes. Although its use had, for some time, been advocated by a few able and far-seeing men, and some small craft had been constructed of it, the public and the great body of shipbuilders refused, in 1830, to believe that the wooden walls of old England were to be supplanted by a material that would naturally sink. "Who ever heard," it was derisively asked, "of iron floating?" The chief constructor of one of our Royal Naval Dockyards said to Mr. Scott Russell, with a feeling so strong, and with indignation so natural, that the latter never forgot it, "Don't talk to me about iron ships; it is contrary to nature." Steam propulsion was making progress, but it was not yet considered suitable for over-sea trades. Mr. David Napier had made engines of 200 horse-power; and lines of steamers were plying between Liverpool and the Clyde, and between London and Edinburgh. It was not thought possible, however, to make long voyages by means of steam propulsion. Men of high scientific reputation and position believed, in 1835, that in the then state of the marine engine the project of making a voyage by steam alone directly from New York to Liverpool was perfectly chimerical, and that persons might as well talk of "making a voyage from New York or Liverpool to the moon."

The shipbuilders of the old school held back as long as possible from taking the leap in the dark which was involved by commencing the production of iron steamers. The way was at first led, not by the great shipbuilders of the day, but by eminent engineers, such as Napier, Fairbairn, Brunel, Scott Russell, and others, who investigated and solved the leading structural and other problems involved in this great revolution in shipbuilding. It was at the request of Mr. Brunel, and for his guidance in designing the *Great Eastern*, that his friend Mr. William Froude commenced in 1856 his investigations into the laws of motion of a ship among waves. It was not till after mercantile shipbuilders began to build vessels of far greater sizes than those prevalent fifty years ago that the present demand for improved scientific knowledge began to be felt by them. The fact is that the modern changes in shipbuilding practice which followed upon the substitution of iron for wood as the material of construction, and the use of steam propulsion, not only increased the difficulties of manufacture, but they have gradually brought about a change in the shipbuilder's position with reference to his work, and in the nature of his responsibility for it.

Formerly a shipbuilder was merely the builder of a ship, in reality as well as in name. No better mechanics ever existed, nor men more skilled in the geometry and other practical sciences which bore directly upon their work, than many of the shipbuilders of the past. They were perfect masters of what they undertook to do, and possessed a vast amount of special knowledge and ingenuity. Many of the methods by which irregularly-shaped pieces of timber were prepared to their requisite forms involved geometrical processes of an extremely complicated and difficult kind. Some of the problems that were dealt with in practice by the old school of shipwrights would now puzzle many advanced students of descriptive and solid geometry. Shipbuilding was then a highly-developed mechanical art, much of the knowledge of which is not now required, and is, consequently, fast dying out.

The business of the shipbuilder used to be limited to the production of ships of the dimensions and description required by owners; and to building them of good sound timber, well fitted and fastened together. No elaborate calculations were requisite for determining whether one of these vessels would stand up when light, or be stable when laden with certain cargoes; nor were any but the roughest approximate methods necessary even for estimating the displacement or carrying capacity. Owners and masters, as well as the builders, had ample materials, derived from experience and from the observation of many similar vessels, by which to form their own judgments upon such points. Usually these ships would not stand up, when fully rigged and light, without ballast, and judging from the proportions given to them they must also have required ballast when laden with cargoes which were not composed of heavy dead-weight. In most cases iron kentledge was provided for them.

Few of these vessels would shift without ballast, except such as were of the old collier type, and were specially built for the coal trade. It is notorious, however, that the chief reason why so many of the ships of that day were crank, is to be found in the operation of the old tonnage laws, which took breadth into account in estimating tonnage, and ignored depth. Ships were built of great relative depths in proportion to their breadths, and initial stability was deliberately sacrificed in order to reduce the tonnage measurement. The instability of these ships was of such a character, however, owing to their form and proportions, that it could be dealt with and corrected in a practical manner, by means of the trained judgment and experience of the masters and stevedores. Any deficiency of stability was fully indicated by initial tenderness, and the curing of it was simply a question of putting ballast into the bottom. The sail-carrying power at sea usually furnished a good test of stability; and the experience thus gained was practically utilized in loading and ballasting vessels of all sizes and classes. It is important to observe that the instability which these vessels possessed was not of that dangerous and treacherous quality which exists in many modern steamers, and which renders them liable to capsize without previously giving obvious indications by which those on board may be sufficiently trusted to judge of their danger.

The mercantile shipbuilder of the present day has problems of a very different and much more complex and difficult character to deal with than his predecessors, and that is why the necessity for improved scientific knowledge is now so strongly felt. Many of the details of the mechanical work of construction are really simpler, and do not call for the exercise of the builder's personal skill and ingenuity, so far as the hull of the ship is concerned, to such an extent as formerly. What is now required of him is to predict with great accuracy, the weights of complicated iron and steel structures, of various types and sizes, with all their intricate fittings and machinery; the weight of cargo that such structures will carry at sea; the stability they will possess in different conditions of loading, and the treatment necessary to ensure a safe amount of stability being preserved upon all occasions; the amount of steam-power and the rate of coal consumption required to maintain given speeds at sea; and very frequently, the strength that is possessed by the hull to resist the straining action of waves.

Problems like these may now be put before a shipbuilder any day for solution, or, if he neglects to consider them for himself, when constructing certain types of vessels, he may afterwards be held to blame in the event of some unforeseen failure or casualty occurring. Disasters to ships that were once unhesitatingly, and even reverently, attributed to the "act of God" are now seen to be controllable, in many instances, by man, if such knowledge and foresight as he has the power of acquiring, be applied to the purpose. We now, perhaps, suffer occasionally from a reaction towards the opposite extreme, and too much may sometimes be expected of shipbuilders and shipowners in the way of preventing disasters at sea. It does not always appear to be sufficiently borne in mind that, whatever advances may have been made in the application of scientific knowledge and of practical mechanical skill to the construction of ships, men have not yet acquired the power of absolutely dominating all those vast and indefinable forces which nature frequently brings into play upon the ocean.

It is true that shipbuilders still build many ships, as formerly, to detailed specifications, prepared and furnished by the owners, but, even then, they appear liable to responsibilities which, though at present very unsettled and indeterminate in their scope and character, and often quite unintended or unexpected by anyone, are not the less heavy and real. The time has arrived when it is evident that naval architects and shipbuilders require to possess a thorough knowledge of those natural laws upon which the qualities of ships and their safety at sea depend. Such knowledge is necessary, not only to prevent error or disaster in extreme cases, but for the more ordinary and commonplace, though not unimportant, purpose of enabling the requirements of a specification, or the stringent guarantees that are often contained in contracts, to be fulfilled in the simplest and most economical manner that is consistent with the stipulated degree of efficiency. It would be impossible for me to enumerate at the present time all the questions in which sound scientific principles are of importance to the naval architect of the present day, and with which he should endeavor to become acquainted. It is a knowledge of principles rather than of results that he should mainly aim at acquiring; because his information requires to be of that well-grounded, broad, and general character which is readily and directly applicable to novel and everchanging circumstances; and which may be acted upon with certainty and promptitude in difficult cases. Dr. Woolley stated this with great force and clearness in a paper read before the Institution of Naval Architects in 1864; and though he was then specially addressing the constructors of war-ships, I cannot find any words more applicable to the present requirements of mercantile naval architecture. He said that the only way in which superiority in shipbuilding can be acquired is, "by possessing a class of shipbuilders trained in mathematical science with the powers of their minds invigorated and strengthened by a profound and severe course of study, able to deal with questions to which altered conditions are continually giving rise, not by trial and error—which is most frequently but another name for failure—not with the hesitating and trembling hand of the superficial sciolist—but with the firm grasp and bold readiness of the man profoundly skilled in the scientific principles of all kinds which may be made available to the art of naval construction, who feels himself thoroughly at home in them, and has acquired such power as to enable him to apply his principles readily and exactly, without fear of failure or of overlooking one principle while anxious to give effect to another."

It has sometimes been asked why, if the necessity for improved scientific knowledge has really been felt in the Mercantile Marine, students have not availed themselves of the educational facilities held out by the late Royal School of Naval Architecture, and by the Royal Naval College at Greenwich? The answer to this question is, to my mind, conclusive, and is only one which furnishes just cause for discouragement to ourselves. The Admiralty Schools of Naval Architecture, and the present Royal Naval College, were organized for the express purpose of supplying the special requirements of the Admiralty service. High mathematical attainments have been expected of all students before entering the college; and the training given to those who have entered has been of an advanced mathematical, and, so far as naval architecture is concerned, of too restricted and special a character for the practical purposes of non-Admiralty students. The instructors and lecturers in naval architecture have, without exception, been able and accomplished naval architects, but they have been specialists in Admiralty war-ship design. This, in my opinion, is alone sufficient to account for much of the want of confidence that has been shown by private shipbuilders in the suitability, for their purposes, of the training offered by the naval College.

The reason why the Admiralty Schools have, in the language of official authorities, been "hopeless failures," so far as the Mercantile Marine is concerned, is because they were too exclusively naval in their character and work, and because no adequate attempts were made to adapt them to the requirements of non-Admiralty students. The differences between the processes that are adopted in the Royal Navy and in the Mercantile Marine in the designing of ships are radical, and can only be properly appreciated by those who happen to be intimately acquainted with both. In the Mercantile Marine economy of time and labor is the chief aim of a designer; and short methods of calculation or of temporary approximation, which are but little appreciated in the Admiralty service, are employed for the purpose of enabling the work of construction to be quickly commenced and rapidly proceeded with. Economy of time and of cost of production, and how to secure these advantages, are among the chief subjects which mercantile naval architects require to study, and upon the practice of which their success mainly depends. Long periods are frequently occupied in investigating and arranging the details of war-ship design which cannot be obtained in the Mercantile Marine, and which, if insisted upon, would prove an effectual bar to progress in business.

If we consider the practical work of the shipyard, an accurate and full knowledge of which is invaluable to the naval architect, it will be seen how unsuitable is mere Admiralty teaching to the requirements of the Mercantile Marine by a comparison of the costs of labor in the two cases. The work upon the structural iron or steel portions of the hull of a vessel, which in the ships of the Navy often costs, according to the best information I can obtain, £20 per ton of weight, is carried out upon so much more economical and efficient a system in the Mercantile Marine, both as regards the time and labor expended, that in vessels which are at least equal in strength and durability to those of the Royal Navy, as is proved by the work they do, the cost of labor often amounts to no more than £5 per ton of weight. The time element is an equally important factor in the two classes of work, but this is a point which I cannot now pause to consider. The figures for cost of labor that I have given relate to vessels of as similar construction as possible, with water-tight double bottoms. The difference in cost of production is largely attributable to tedious and costly systems of work that are still cherished in the Royal Navy, but which have been long obsolete in the Mercantile Marine, and been supplanted by improved methods.

It is the two circumstances of the growing necessity felt by mercantile shipbuilders for scientific training in naval architecture, and the failure of the Royal Naval College to furnish such training as they require that have mainly led to the foundation of the John Elder Chair of Naval Architecture. And now the question arises of the method we are going to adopt, and of the kind of training we shall endeavor to give here. This will depend greatly upon the intelligence and energy of the students, and upon the amount of mathematical and general scientific knowledge with which they may be furnished when they come here. The course will be adapted, as far as possible, to their state of knowledge and to their practical necessities. But I cannot undertake to describe its scope in detail, nor to define its limits with precision, without some previous experience of the students. I have not come here with hard-and-fast ideas, nor with a cut-and-dried programme. Had I done so, our progress might thereby have been hampered or wrongly directed—it could hardly have been facilitated. I shall endeavor to help the students, to the best of my ability, to acquire a sound and scientific basis for such knowledge of shipbuilding and engineering as they may already possess—and the more they have the better—and to go forward to a complete study of those scientific principles upon the knowledge of which their success in life will greatly depend. At the same time, while insisting in the most unqualified manner upon the absolute necessity for scientific study, I must warn them against supposing that mere attendance at these classes during one, two, or any number of sessions is going to enable a student to become a competent naval architect or engineer. All that can be given here are intellectual tools with which to work with greatly-increased ease and precision in the practical operations of ship design and construction. Theoretical principles, and the manner in which they can be utilized with advantage in practice, will be taught; but it requires very much more to make a man a naval architect than knowledge that may be acquired within an University, however clever or hard-working a student he may be.

As an example of the training best adapted for producing good naval architects or engineers, and as a pattern which all students of these classes may study, and strive to copy with advantage, I cannot do better than refer to the great engineer after whom this Chair has been named. Mr. John Elder always displayed great talent and application in the study of mathematics, which he diligently pursued in the High School of Glasgow; but he was prevented by a naturally delicate constitution from receiving any University education, except such as was obtained by attendance at the class of Civil Engineering in the old college. He studied privately, however, with great ardor, and acquired a large and varied amount of scientific knowledge, which was also complete and exact, and free from the defects in thoroughness and accuracy which so often beset self-taught scholars. John Elder served an apprenticeship of five years as an engineer in the works of Mr. Robert Napier, working in the pattern-shop, foundry and drawing-office. He afterwards worked as a pattern-maker at Bolton-le-Moors, and as a draughtsman at the great Grimsby Docks. His next situation was that of chief draughtsman under Mr. Napier, which he left three years afterwards to become a partner in the firm of Messrs. Randolph, Elder & Co.

The point to which I now wish particularly to draw your attention is the long and arduous practical training that Mr. Elder went through, It was this combined with his complete scientific knowledge and undoubted natural genius, which enabled him to achieve his great successes in after-life. The highest scientific knowledge attainable is of little use to the naval architect unless it exists in combination with good judgment and practical mechanical skill. Mr. Elder owed both his professional and commercial success to a rare combination of qualities. Prof. Rankine says in the memoir he wrote of him that the different qualifications possessed by Mr. John Elder "are so seldom found united in one man, that the tendency of popular opinion is to regard them as incompatible, and to look especially upon the knowledge, skill, and enterprise which lead an engineer to adopt new or unusual improvements in practice, as being fraught with danger to his success in business, and so no doubt they are, unless regulated by commercial sagacity."

There is, unfortunately, too great a tendency sometimes displayed by enthusiasts in the cause of technical education to elevate mathematical and scientific training above its true position, high as is that to which it is legitimately entitled, and to rely too exclusively upon the results of such training for guidance and power in the performance of large and intricate mechanical operations. It is a *sine qua non* for the modern Naval Architect, although, at the same time, it is by no means sufficient for all his numerous and varied requirements. It is even of little real practical use, unless there underlies it an intimate personal acquaintance with the mechanical operations of the shipyard and engine works, and with the properties and capabilities of the materials there dealt with. Together with this, there must likewise be the faculty, which is more essential than any, and which may be highly cultivated by all open, liberal, and intelligent minds.

"Good sense, which only is the gift of heaven,
And though no science, fairly worth the seven."

I shall not detain you any longer upon the present occasion. We shall commence our regular course of study to-morrow. It will be one which will be adapted, so far as I know how, to your practical needs, and to your present state of knowledge. I hope that the noble profession of naval architecture may one day reckon some of my present students among its chief ornaments; and that the Chair which bears the great and honored name of John Elder may be helpful in training up naval architects and marine engineers to rival him in all that is worthy, good and great.