Lecture on "Shipbuilding"
by Mr. A. M. Greenlees.
6th October, 1914.

Gentlemen,

It has been extremely difficult for me to determine what I should say to you to-night, because of my want of knowledge of what would interest you. I therefore decided upon a simple talk on Shipbuilding, the evolution of the propulsion of vessels by steam power, and generally to outline the preliminaries necessary to the work of construction and launching of steel ships. The time at my disposal will not permit my entering upon an explanation of the many operations connected with shipbuilding, any one of which will provide material for an evening's discourse. I trust, however, that what I have to say will be of sufficient interest to permit some of you to visit the yard at Williamstown where you will be able to see in the course of construction and completion a number of steamships, not of the liner class perhaps, but of a type suitable enough to demonstrate that not only can steamships be satisfactorily built in Victoria, but that the industry is of greater magnitude than is generally supposed.

The steam engine—that mightiest of factors in the evolution of the ship and its propulsion, as in other matters on land—was an accomplished thing, and fairly familiar, before it began to be applied on any practicable scale to ocean navigation. Suggestions for, and particularly efforts at, employing steam as the motive power were plentiful long before this stage had been reached. The earliest attempt to propel a vessel by steam is claimed to have been made by Giovanni Branca of Loretto, who apparently adopted a device, planned so that a jet of steam blew against the series of vanes arranged on the rim of a wheel.

In 1730 another remarkable proposition was made for marine propulsion. Doctor John Allen thought it possible to move a boat by pumping in water at the bows and pumping it out again at the stern, this scheme being probably the earliest attempt to secure motion by what afterwards became known as the jet propeller system. Like almost all other inventions relating to the propulsion of vessels at that time, his was crude in details, and does not seem to have been put to any practical use.

The next inventor, who turned his attention to the question was Jonathan Hulls, for whom it has been claimed with some justification, that he was the actual inventor of the steamboat. The new vessel was tried on the Avon, but tradition says it was a failure, by reason of the inventor not having provided the proper means to communicate the
power to the paddle, and this so disheartening him that he relinquished the idea. He published a lengthy description of his boat, in which he states that it would not be practicable to place his engine on anything but a tow boat, as it would take up too much room to allow of other goods, besides fuel, being carried on the same vessel, and it could not be used in a storm.

In 1759, a Swiss pastor published at Geneva a proposal to use an oar fitted with a foot which would expand when used for propelling a boat and contract when being moved forward through the water for another stroke. He visited London in 1760 to lay his proposal before the Government. His propellers were to be worked by springs, which in turn were to be compressed by a kind of cannon with a piston. A pamphlet which he issued at the time of his application to the Government contains the interesting statement that he had been informed that a Scotchman had propounded a scheme 30 years earlier for propelling vessels forward by the recoil from the firing over the stern. The gunpowder of the period made up in smoke what it lacked in power, hence, although the vessels of his day were not large, the ingenious Scot found by the experiments made for that purpose that thirty barrels of gunpowder had scarce forwarded the ship a space of ten miles, and it is not surprising that this means of mechanical propulsion shared the fate of all its predecessors.

Scotland owes her pre-eminence in shipbuilding and marine engineering to Patrick Miller, an Edinburgh banker, who, having retired with a large fortune, set himself the task of ascertaining whether some better means of propelling vessels other than with sails or oars could not be obtained. He had exhibited at Leith, on the Firth of Forth, a triple vessel, “having rotatory paddles in the two inter-spaces driven by a crank which was turned by four men.” This he matched to a fast-sailing Customs wherry over a distance of six or seven miles, and was very satisfied with the victory he secured. But his son’s tutor, James Taylor, having taken his turn at the crank, was so convinced by the violence of the exertion that some more reliable power was needed that he urged on Mr. Miller the propriety of employing a steam engine.

Mr. Miller had placed a new double boat on his lake, and Taylor, with his permission, arranged with his friend, William Symington, to fit it with a steam engine. Symington, who was then employed as a mining engineer, constructed a model of a steam carriage in which he had converted the reciprocating motion of the pistons into a rotatory motion. Miller and Taylor were shown this model in December, 1787 (the engine had only four inch brass cylinders), and the trial of Miller’s boat took place on
14th October, 1788, in the presence of several hundreds of people, and was so successful that Miller resolved to repeat the experiment on a larger scale.

A design of a steam vessel by Symington, who had been associated with Miller and Taylor, was brought under the notice of Lord Dundas, who was largely interested in the Forth and Clyde Canal, and suggested to him the advisability of towing barges by steam power. The “Charlotte Dundas” was accordingly built in 1801 under the patronage of Lord Dundas, and made her appearance on the Canal in 1802. The propelling machinery of the vessel was a long way in advance of the time, inasmuch as it consisted of a stern wheel driven by the first horizontal direct-acting engine. The “Charlotte Dundas” was 56 feet long by 18 feet beam and 8 feet deep, and towed two barges a distance of 19½ miles in six hours against a strong wind, but complaints were made that the swell she created damaged the Canal banks, and her proprietors were forced to abandon the enterprise. Thus the “Charlotte Dundas,” though an unquestioned engineering success, was a commercial failure, and on being withdrawn from service was laid up—a monument of the genius of her constructor and the prejudice of those who were too ignorant to recognise the obvious.

Robert Fulton, an American citizen of Irish descent, also had a boat built, and at the trial an immense crowd assembled to mark the first experimental voyage of “Fulton’s Folly,” and jeered Fulton and his steamer unmercifully. But when the vessel moved into midstream under the power of her own engines, the crowd cheered as energetically as only a crowd can when it has been agreeably surprised. Dense volumes of smoke began to pour forth from the smoke stack and the boiler to hiss. At one o’clock the hawser was drawn in, the throttle opened, and to the accompaniment of the loud exhaust, the side wheels began to quiver, then slowly to revolve. Under the charge of Fulton the “Clermont” moved out into the stream, the steam connections hissing at the joints, the crude machinery thumping and groaning, the wheels splashing, and the smoke stack belching like a volcano. It is said that one honest countryman, after beholding the unaccountable object from the shore, ran home and told his wife he had seen the devil on his way to Albany in a saw mill. The paddle wheels were 15 feet in diameter, and being uncovered drenched the passengers. A paddle wheel had to be disconnected when it was desired to turn the vessel round. The “Clermont” sailed a distance of 110 miles in 24 hours against the wind, the average speed being about 4½ miles an hour, and the running time to Albany, a distance of 150 miles, was 32 hours, or nearly 5 miles an hour.
The next experiment of importance in steam navigation was made by Hendry Bell. He had been a house carpenter at Glasgow for many years, but having opened a boarding house at the seaside resort of Helensburgh, on the Clyde, he conceived the idea of inducing more visitors to go thither, and as boats moved by paddles and sails had failed him, he determined upon a steam boat. In this he was probably influenced by a correspondence he had with Fulton. The exact nature of the relations between Fulton and Bell has never been determined.

The "Caledonian Mercury," in 1816, published a letter from Bell stating that Fulton wrote to him about Miller's boats (Patrick Miller, of Edinburgh, of whom I have already spoken), and asked for a drawing and description of the machinery. Bell saw Miller and sent Fulton the required information. Fulton afterwards wrote to Bell saying he had constructed a steamer from the drawings Bell sent him, and from this I can only draw the conclusion that Fulton's "Clermont" was produced from Miller's boat. However, Bell seems to have awakened to the fact that he was sending information to other countries instead of using it himself. He roused himself to design a steam boat, for which he had made various models. The result was the "Comet," built for him by John Wood and Co. She was 40 feet by 10½ feet beam and about 25 tons burden. The boiler was placed at one side of the ship, and the funnel, bent so as to rise from the centre, also had to do duty as a mast.

The "Comet" was designed for passengers only, and Bell's advertisement read something like this: "At much expense, fitted out a handsome vessel to ply upon the River Clyde, between Glasgow and Greenock, to sail by power of wind, air and steam. The vessel was to go down to Helensburgh one day and return the next, thus making three trips each way in the week." Many of the sailing-boat owners regarded the "Comet" with undisguised hatred, and its invention as a device of the evil one, thus one Dugall Jamison, a Clyde skipper, whenever the steamboat passed his slow-going sloop, invariably piped all hands—a man and a boy—on deck and bade them "kneel down and thank the Lord that ye sail wi' the 'Amighty's ain win' and no wi' the deevil's sunfire an' brimstane leke that spluttering thing there."

The "Comet's" engine was of four nominal horse power, with a single upright cylinder of 12½ inches diameter and 16 inches stroke. The vessel was originally propelled by two paddle wheels on each side, driven by spur gear, with the paddles on detached arms, but this arrangement giving trouble, complete wheels were substituted, and subsequently, after the vessel had been lengthened about 20 feet
the number of wheels was reduced to two. The career of the "Comet" was not a long one. In December, 1820, she was wrecked outside Crenan Canal. She parted amidships, and while the stern drifted away, the remainder of the vessel, with Bell, crew and passengers and machinery stuck fast. All scrambled ashore, and the machinery was afterwards recovered. Her engine was put to some strange uses. A Glasgow coachbuilder took it as payment for an account, and used it to drive the machinery in his coachworks. It then went to Greenock, where it was installed in a brewery. Another purchaser brought it back to Glasgow, and it ultimately came into the possession of Messrs. R. Napier & Sons, of Glasgow, shipbuilders, in 1882, who presented it to the South Kensington Museum.

As time went on the application of the steam engine for propelling vessels made great progress.

In 1845 steamship building was carried on with great activity, though the change from wood to iron, and from paddles to screw, was gradual. Many wooden vessels, both steamers and sailers, continued to be built, as the prejudice against iron for ship construction died slowly. The screw propellers were at first simply auxiliary to sail. This was due to three causes—mistrust of the propeller, the cost of continually running it, and the difficulty of carrying sufficient coal. As the adaptability of iron for constructional purposes became more generally recognised, it led to the proposal that steamers should be built on the longitudinal principle instead of transverse, and the use of iron also enabled shipbuilders to increase the safety of the vessels considerably by means of transverse bulkheads, the number of these being increased until even as early as 1838. Several vessels were constructed on modifications of the longitudinal system, the chief among them being the "Great Eastern"—this vessel was designed and built by Brunel and Scott Russel—"Brunel's Great Audacity," as she has been called.

The "Great Eastern" was built with an inner skin from the keel to the water line, the inner and outer skins being of the same thickness, and I would ask your special attention to this in view of the fact that, as a result of the loss of the "Titanic," an inner hull has been added to her sister ship, the "Olympic," and also introduced into the construction of the latest White Star liner. The space between the two hulls of the "Great Eastern" was from 34 to 36 inches, and this was estimated to hold 2,500 tons of water ballast. The transverse iron bulkheads divided the vessel into a number of compartments 60 feet long, and in order to add to the strength of the ship and increase her safety in case of collision, there were no openings in these bulkheads lower than the water level (this I may
say has also been suggested in the press regarding the "Titanic").

The "Great Eastern" ran on the rocks on the American coast, near New York, and tore a hole in the outer skin 80 feet long by 10 feet broad, but proceeded to New York, her passengers being unaware of the damage.

The "Great Eastern" was 680 feet long, 82½ feet broad, 58 feet deep, displacement 27,384 tons, and designed to carry 10,000 troops. The launch was arranged for November, 1857. She moved only a few feet, the cause of this doubletless being attributable to the necessity to launch the vessel sideways, thereby greatly adding to the difficulties of the operation. Another attempt was made a few days later, when an advance of one inch only resulted. On 11th January she was moved a little further, and she was finally launched about the end of the month.

As the Company had not enough money to finish her she was sold for the sum of £160,000. It was necessary to raise £800,000 to finish her, but as difficulties in financing the enterprise occurred, the public were appealed to, and responded to the extent of £50,000, many amongst them from perfectly disinterested motives and quite without any expectation of profits, their sole desire being to see the completion of the great ship, which they looked upon as the pride of England, safely accomplished. The trial took place in September, 1859, and was marred by an explosion which killed six men, wounded several others, and wrecked the saloon. Her first voyage was to New York with only 33 passengers. In 1865 she was engaged in laying the Atlantic Cable, and in 1886 she was acquired by an enterprising drapery and tea firm as a show place and advertisement, and in 1890 was sold to be broken up. Before being demolished I remember her lying in the Clyde, where she was used as a dancing saloon.

The "Great Eastern" was an unlucky ship from start to finish. Almost everyone concerned with her had a share of her misfortune, including the builder, Scott Russel, who was ruined by the undertaking. The one task in which she acquitted herself well was the Atlantic Cable laying.

With the launching of the "Rotomahana," built by Denny Bros., of Dumbarton, on the Clyde, in 1879, for the Union Steamship Co., of New Zealand, the iron age of steamship building may be said to close and the age of steel begun, the New Zealand vessel being among the first steel boats built.

A steel or iron ship is often compared from the point of view of strength to a beam or girder, and in many respects such a comparison may fairly be made. When iron or steel girders are used in the construction of bridges, etc., a very
close approximation can be made of the amount of the stresses which may have to be borne, and thus the necessary strengths can be almost entirely calculated, but with the actual ship girder there are considerable complications which make difficult the determination of the scantlings and disposition of the material in order to insure sufficient strength, which cannot be ascertained purely by calculation.

The sudden stresses experienced by ships in a seaway, and when rolling and pitching, render accurate calculations impossible; however, approximate calculations can be made. Thus throughout the history of iron and steel shipbuilding continual changes have been made in the generally accepted rules as experiences have indicated their necessity.

The purposes for which ships are built are many, and each is built sufficiently strong to satisfactorily perform her work. The strength of ships, therefore, should be regulated by their proportions, provided enough free-board remains to ensure stability and seaworthiness.

A fixed standard of strength has to be arrived at to guarantee that the vessel is strong enough to carry with safety and without injury to herself a load which may not under certain conditions be exceeded. With this aim in view, there exist several societies who, as a result of scientific investigations and long experience, have been able to draw up rules and tables of scantlings suited to all kinds of cargo and passenger steamers.

The best known are:
- Lloyd’s Register.
- The British Corporation.
- The Bureau Veritas.
- The Norske Veritas.
- The German Lloyd’s.

These societies save both shipowners and shipbuilders an immense amount of labour and trouble, at the same time proving general uniformity and strength for the vessels constructed under their rules.

To carry out this system, the committees of these societies employ a considerable number of surveyors, whose training and experience have especially fitted them for this work.

“The quality of the material used in the construction,” “The efficiency of workmanship,” “The carrying out of their society’s rules,” and the requirements and the periodical survey, are their sole responsibility.

The constantly recurring loss of ships and of valuable lives prior to 1890, through overloading, compelled the necessity for interference, and so impressed were the people of Great Britain for the need of reform, that the Government
of the day introduced and passed the Load Line Act, and so placed upon the authorities the responsibility of all vessels leaving British ports. The British Government sanctions—

Lloyd's Register,
The British Corporation, and
Bureau Veritas (French),
to assign load lines to vessels classed by them, but the Board of Trade still retains the supreme authority for such assignment.

Steel and iron ships are built on a combination of two systems of framing—long and transverse.

The "long" system includes all girders, which run all fore and aft.

The "transverse" system embraces girders which cross the long framing.

The strongest structure, therefore, is obtained when these two systems have been intelligently woven together. The strength of the one co-operating with the strength of the other, and when this is accomplished the whole is covered by a skin or shell plating and decks.

The transverse framing is placed at intervals of about 20 inches to 40 inches apart, all fore and aft, and it usually consists of the main frame bar, reverse bar, floor plate, beam and pillar, or stanchion.

The primary, if not the chief, interest in the modern shipyard may be said to centre in the designing department and drawing office, where in the first instance the technical qualities and conditions of design of each vessel are determined. These are according as the vessel may be required, for swift mail and passenger service, for moderately speedy and large cargo carrying service, or possibly for a combination of both functions; of course, each of these divisions embraces a large number of possible craft deviating from the general type in respect of form, structure, and mode of propulsion, according to the place and character of service intended. High speed, river, or canal service, light draught pioneering work in undeveloped parts of the world, and vessels large and small in which sails only, or possibly oil, gas, or electric in place of steam engines, are to be the motive power—all these are possible demands with which the naval architect must deal on occasion. With the general elements of design tentatively determined, the lines on which the vessel must be built are drawn out on a small scale.

Following the general design as determined upon comes the detail, or working drawings. In connection with vessels of very exceptional character, in which possibly questions of unusual form, and of stability, speed, draught, etc., out
of the normal are involved, the preliminary work and responsibility in designing are, of course, much enhanced.

It will doubtless surprise most of you to know that a large liner is very frequently constructed on the most meagre information. Ordinarily, particulars such as the following are all the shipbuilding authorities have to go on:

1. Carrying capacity.
2. Space required for passengers and crew.
3. Speed required.
4. Distance between coaling ports.

And upon this apparently insufficient information the naval architect makes his preliminary calculation, from which the whole of the future designing and building operations of the vessel are arranged.

The procedure followed by the naval architect is to make a rough calculation, based on the data of work already done in the yard, which, with the extensive experience he must of necessity possess, enables him with a fair amount of precision to produce an outline of a boat of approximately the dimensions required.

The capacity of the vessel, which means the volume or cubic feet of space required to carry the cargo, etc., having been supplied to him by the owner, he is therefore provided with a definite basis figure. As the nature of the cargo is, however, a very important factor in his calculation, he would have to satisfy himself whether grain or general merchandise was to be carried, and proceed according to the information obtained. In the case of commodities of a deadweight character, special provision would have to be made, but assuming that the vessel was to be employed in the carriage of general goods, 40 to 50 cubic feet would be allowed for each ton space.

The Board of trade takes care that each passenger and member of the crew is provided with a sufficiency of space, and by regulation compels owners to observe very closely the law in this respect.

There is, of course, a minimum, and while some owners take full advantage of this, it is gratifying, even although the change has been brought about principally by the keenness of competition, to find present-day shipowners vying with each other in the matter of the space and accommodation provided, particularly for second class passengers.

In this connection it may not, perhaps, be out of place to compare the space set apart for passengers and crew in the s.s. "City of Chester," a vessel built in the seventies, and the White Star liner "Olympic," which vessel, although over twice the size of the "City of Chester," provides so liberally for her passengers in the matter of space as to only have accommodation for practically the same number.
Having arrived at the space required for the housing of the crew and accommodation for the passengers and their luggage, the allotment of space for baggage being a fixed quantity, he would next ascertain the distance between the ports of call, so as to provide the space necessary for the carriage of stores, water, and the many other things required for their maintenance, and with the information gleaned up to this point, together with the data available in the yard and the experience he would be able to bring to bear on the subject, the architect would be in possession of sufficient material to form a fairly accurate idea of the class of vessel to fit the customer's requirements.

His next step is to determine the size and weight of the machinery, and here again in this rough and ready figuring he has to rely absolutely on his experience and the data at his disposal, and these, I may say, to the expert are quite sufficient for his purpose.

The next consideration is the speed, and as provision has to be made for fuel space, the distance between coaling ports is an important factor.

The weights of hull, machinery, cargo, fuel, passenger and crew space, having been determined, a totalling of the whole gives him the loaded displacement of the vessel which he has conjured up in his mind.

These figures are then fined down into a form more approximately the actual requirements by which means the length, breadth and depth of the ship, also the determination of her lines are arrived at.

The displacement is the amount of water displaced by any floating body. The fact that a floating body displaced its own weight of water was discovered in a very simple manner. A large glass basin was filled and placed in a tray, the water being level with the rim. The object was placed gently in the water and let down until it floated, the result being that the water overflowed, and was caught in the tray. Upon weighing the water that escaped it was found, after allowing for evaporation, that it represented exactly the same weight as the body which had been immersed. Hence the term displacement, which to this day is calculated on the basis of the above simple, but important, discovery, and when applied to shipbuilding represents the total weight of the vessel.

The displacement, length, breadth and depth having been found, he next proceeds to fix the load draught and trim of the vessel. This may be restricted in two ways—first by the owner, who may wish the vessel built to a draught to suit the ports to be called at. In the event, however, of no stipulation having been made, the builder would arrange for the maximum allowed under the Board of Trade regulations in regard to the Plimsol mark.
He has now arrived at a point where the block coefficient must be ascertained. This is the relation between the shaped vessel and its own rectangular block, which is length, breadth, and draught, and this gives what is known in shipbuilding parlance as the coefficient of fineness.

While on this subject, I would say that it is difficult to explain the importance the figure denoting the block coefficient of a vessel is to the shipbuilder, and the amount of information it conveys. Given the figure and length, breadth and depth, the skilled architect could almost offhand furnish you with weight of a huge liner to within a few hundred tons.

The following is a list of the main calculations to be made from those lines:

- Centre of buoyancy, vertically and longitudinally.
- Centre of gravity, vertically and longitudinally.
- Meta centre, vertically and longitudinally.
- Displacement.
- Tons per inch.
- Wetted surface.
- Co-efficients.

and many others of a minor character.

The centre of buoyancy is the centre of the immersed portion of the vessel. If we could imagine it possible to withdraw a ship from the sea, so as to allow the space which she occupied when floating remaining unfilled, then the centre of the mass representing that space would be the centre of buoyancy.

The centre of gravity is the centre of the completed mass of the vessel, or the centre of its weight. Suppose we place a weight on the upper deck of a vessel, the result would be that the centre of gravity would be raised, the reverse applying if the weight were placed in the bottom; therefore, the centre of gravity is governed by the distribution of weight throughout the structure.

To calculate the centre of gravity entails a tremendous amount of work, as this point must be found before the vessel is launched, so as to ensure safety. At this stage of the designing, I would remark that the centre of gravity can only be found very approximately, for up to the present no plans have been prepared.

Each naval architect has his own idea for finding this centre, but for the purposes of this rough calculation quick methods are adopted to arrive at it approximately, such as by co-efficient. This co-efficient is the relation between the height of centre of gravity and the depth of the vessel.

META CENTRE,

Transverse and longitudinally.

When the vessel is inclined through an angle, although the volume still remains, the form of the volume alters so
that the centre of buoyancy moves in the direction of the inclination. A vertical through the centre of buoyancy will intersect the centre line of the vessel, at the meta centre, and if this centre is above the centre of gravity, a righting arm is formed between the centre of gravity and the vertical through the centre of buoyancy. For the buoyancy, acting up through the centre of buoyancy, and the weight acting down through the centre of gravity, tends to bring the vessel back to the upright.

The tons per inch is the number of tons it would take to sink the vessel one inch.

The wetted surface is the surface of that part of the vessel under water.

**CO-EFFICIENT.**

The co-efficients to be found are:
- Prismatic co-efficient,
- Midship area,
- Water plane, and others.

These calculations have all to be worked out from the rough lines, which, as previously stated, have been prepared, and they all have their uses when fining down the finished design of the vessel.

Stability is now the next point to be investigated. The stability of a vessel is one of the most important points to be considered in the designing and construction of vessels, and I am sorry to say sometimes the least attention is paid to it by shipowners. Of course, a vessel with no stability is utterly hopeless.

There are three kinds of equilibrium:
- Stable equilibrium.
- Neutral equilibrium.
- Unstable equilibrium.

A vessel is said to be in a state of stable equilibrium when the meta centre is above the centre of gravity, and when inclined through an angle returns to the upright position. This is constantly happening at sea on account of the wind and waves.

Again, a vessel is said to be in a state of neutral equilibrium when these two points coincide, and when inclined through an angle does not return to the upright position, but keeps the list until a wave or other external force sends her back to the same angle on the other side.

Unstable equilibrium is when the centre of gravity rises above the meta centre, and the vessel tends to turn over altogether.

The three points which have to be considered in the measurement of stability are: centre of buoyancy, centre of gravity, and meta centre, because the weight acting down
through the centre of gravity, and the buoyancy acting up through the centre of buoyancy, it naturally follows that these two points must be in the same line, otherwise the vessel will not float upright.

The meta centre and the centre of buoyancy are both governed by the shape of the vessel's hull, therefore when designing the lines these centres to a certain extent can be placed in positions to give the desired stability and trim.

The naval architect is now in a position to go on with the actual designing of the vessel.

The approximate figures have provided him with a basis to work upon; his next step would be to amend the vessel built up in his imagination and alter his figures to fit.

When the lines are run out the necessary calculations are made from them and put into the form of curves, and this diagram forms the foundation on which all future calculations of the vessel are made.

At this point I may say it is to the late Dr. Froube, of Torquay, that shipbuilders and designers are indebted for much of their most valuable experimental information regarding the law of speed and resistance. No one, indeed, has done more for the science involved in ship designing than Dr. Froube, and virtually all the present day methods of investigation in the science of ship propulsion are based on his researches and conclusions. The result is that designers are able now to predict beforehand, and with much greater accuracy than formerly, what the speed of any proposed vessel will be or what power is requisite for any assigned speed. The essential feature of Dr. Froube's methods is the observation and comparison of small scale models of vessels towed through a large tank of water. Naval architects are often asked to fulfil so many conditions—and sometimes conflicting conditions in one vessel—that the great preliminary difficulty is to persuade the shipowner that the shipbuilder's art has its limitations; the keeping down of the nett tonnage on which the dues are paid relatively to the carrying capacity of vessels is a problem often presented to the naval architect by keen shipowners. Enormous cargo carrying powers on an almost impossibly light draught of water is another feature demanded, and I do believe shipbuilders would not be surprised if asked to design a vessel which would float on a heavy due.

Copies of plans prepared in the drawing office are passed out to the foremen of the various trades, and the first man to take the vessel in hand after it leaves the office on paper is the mould loftsman.

He is provided with drawings and lists of the dimensions of lines and sections, which he proceeds to reproduce on the mould loft floor to actual size.
The mould loft is a large room with a blackened floor, on which the loftsman runs the lines with chalk by means of battens held in place with long nails driven into the floor sufficiently far to hold the battens in place. When the lines have been fared up he next proceeds to prepare the scrieve board for the workmen who are to manipulate the material for the various parts of the structure.

This scrieve board consists of planks tightly clamped together to form a surface large enough to take in the full size of the section of the vessel. He then transfers from the mould loft the sections representing the shape of the frames on the outside of the frame bar; these lines are scrieved into the board, and he also screws the lines representing the decks, stringers, keelsons, floors, and the edges of the shell plating.

This is not the finish of the loftsman's work. From detailed plan supplied to him from the drawing office he draws the stem, stern post, rudder frame, and a host of other special parts of the vessel to full size, and from these lines moulds are made. In a similar manner moulds are made for the plating of a number of parts of the structure, such as the stern plating, tank plating, beam, camber, etc. It would be impossible, with the time at my disposal, to follow on and describe the actual construction of the vessel. I therefore propose to ask you to assume the work is now well advanced, and when the main portion of the vessel has been constructed and the shell caulked, watertight and tested, the vessel is ready for launching. We may say the most important event in the history of a ship is the launch—important not only because this is her introduction to the element upon which the work of her life will be performed, but because in the transit from land to water, unless the greatest care and caution are exercised, results of a most disastrous nature may arise. Instances are on record when the damage received in launching has distinctly contributed to the loss of the vessel at sea, and many a ship has been so injured as to cost her builders thousands of pounds to repair. The strength of the launching cradle and standing ways, the earth foundation, as well as the declivity, length and camber of the standing ways, are all features in the carrying out of a launch which contribute to the success of this operation. Owing to the vast increase in the size of the vessel in recent years, the whole matter of launching is considered and investigated, and elaborate calculations are carried out to ensure a success.

The first part of the operation of construction is to lay keel blocks of a height of about 5 feet across the berth, and upon these the vessel is erected.

Later the standing ways are added, these being laid parallel with the keel at a distance of about one-eighth of the beam of the vessel on each side of the keel.
Again, at a later period sliding ways are laid on top of the standing ways, the space between the sliding ways and the bottom of the vessel being filled in with blocks and wedges, these forming the cradle for the vessel to rest in.

I would say that the real and important work, without which none of these could be brought into use in large vessels, is done on paper prior to the actual launching, the whole position being ascertained by means of carefully worked out calculations and committed to paper.

We will assume that the vessel is built and standing on the blocks in a launching condition, without engines and boilers, and that a full knowledge of the depth of water into which she is to be launched, has previously been ascertained by soundings, also the contour of the land lying underneath the water.

We may also take it that the vessel has been built to a certain declivity or slope—large vessels ranging from \(\frac{1}{4}\) to \(\frac{3}{8}\) of an inch to the foot, and small vessels up to 1 inch to the foot.

The position of the vessel is depicted on paper exactly as she stands on the keel blocks, the ground line being drawn and followed right through underneath the water of the river or bay into which she is to be launched.

Due regard has to be paid to the weight of the vessel, the speed of launching desired, and the distance she can travel with safety after entering the water. In this connection, I would say the heavier the vessel the less the declivity required, and the distance she can travel would, of course, regulate the speed at which she would be let off.

In the event of the water space for launching purposes being limited, arrangements would have to be made for checking her directly she enters the water. If there were, however, no limitations the check would, of course, be unnecessary, and some little risk would probably be taken by the builder to reduce the declivity, thereby minimising the speed.

Generally speaking, some discretion is allowed in the matter of declivity to guard against a false start, which in the winter months might readily occur as a result of the grease on the ways freezing. This applies more to the colder climates.

For the purpose of setting the declivity of the ways, the naval architect up to this point has nothing definite but his experience of prior launchings to go upon.

In arriving at the declivity, quite a variety of considerations have to be taken into account, such as the length the launching ways can be run into the water, the tides, the weight of the vessel and her shape, also the distance she can run upon leaving the ways. These are all important
factors in deciding the declivity, which is shown on the plan by a line representing the surface upon which the vessel slides when being launched.

The Architect next proceeds to ascertain, by means of drawings, the displacement, centre of buoyancy, and the point at which the vessel will begin to float upon entering the water.

I might explain that the purpose for which the foregoing has to be ascertained is so that the displacement and centre of buoyancy can be set out.

The next matter to be considered is the weight and centre of gravity of the entire structure as it stands ready for launching.

In launching, two great dangers are ever present with the builders.

1st. The tendency of the vessel to tip when the centre of gravity passes over the ends of the ways.

2nd. Excessive buoyancy.

The first named presents the greater danger of the two, for if the increasing buoyancy were insufficient to maintain the ever increasing weight as the vessel passes into the water, the bow portion would be raised off the ways, with the probable result that the extreme pressure of weight on the part of the structure not supported by water being thrown on the end of the ways would cause the ways to part and the vessel to fall into the yard.

In the other case, exactly the opposite would happen, for with an excess of buoyancy the stern would be raised unduly, leaving the extreme forward part of the structure to carry the whole of the unsupported weight, resulting in irreparable damage by straining.

The first danger begins when the centre of gravity passes over the end of the ways and continues to increase, until the stern commences to rise, when the second danger comes into play.

The remedy rests, of course, with the naval architect, whose duty it is to carefully safeguard against these contingencies, and this can only be done by arranging conditions that will carry the unsupported portion of the vessel, and by a sufficiency of buoyancy to cause a gradual rising of the stern, so that no undue pressure likely to cause the calamitous results previously referred to would arise.

To attain perfection in launching, one would require conditions giving an increasing buoyancy equal to an increasing weight, until the vessel floats off the ways. This, however, is an impossibility in the practice of shipbuilding; nevertheless, with care and close attention to the minutest details, approximately the best conditions will be arrived at.
The first step in the nature of a safeguard would be to ascertain the point at which the greatest danger, namely, tipping, would take place, and this would be found somewhere between the point when the centre of gravity is over the after end of the ways and the subsequent rising of the stern.

His next care is to ascertain the point at which the second danger, namely, excess of buoyancy, begins, and to find this he must work from the forward end of the vessel.

There are three ways in which the difficulties in regard to tipping and excess of buoyancy may be overcome.

1st. By moving the centre of gravity forward by means of weights placed between the centre of gravity and the fore end of the vessel.

2nd. By lengthening the ways.

3rd. By cambering or rounding the ways.

With the calculations made, the naval architect has now fixed the conditions of the vessel for safe launching; his next step would be to supply particulars of the standing ways to the carpenter for his attention in the laying of the launching way.

After the sliding ways have been fitted and laid they are tilted up from the outside, and a mixture of tallow and soft soap, of about ¼ inch thick, is laid on top of the standing ways, and the sliding ways put back in position.

The cradle is now formed by filling in the spaces between the sliding ways and the bottom of the vessel with blocks and wedges, all fore and aft except at the bow and stern, where the distances are too great to fill up, and blocks of timber standing vertically are used instead, being bound by chains running underneath the vessel from both sides. These are usually termed the forward and after poppets. When these are fitted and complete, the whole of the wedges are driven up tight, thus forming a bed or cradle for the vessel to rest upon when the keel blocks have been taken away.

The triggers are now fitted. There are usually three placed on each side—one at the fore end of the cradle, another about one-fourth of the length of the cradle from the fore end, and the third a little beyond midships from the fore end.

The ways having been completed, the staging and side shores are removed, and the whole vessel cleared fore and aft, and about two days prior to the launch the naval architect works out the transverse centre of gravity, to enable him to distribute the weights necessary to keep the vessel in an upright position when launched.
Stability being, as I am sure you all know, the most important matter of all in the construction of a vessel, the naval architect has long ere this satisfied himself on the point by a series of calculations, and as some adjustment has probably to be made prior to the launch, he would take the fullest advantage of the miscellaneous collection of material on board by moving it into the hold or placing in such positions over the centre of gravity of the vessel as would ensure the amount of stability desired.

The state of the tide is, of course, an important consideration, but, no matter what hour may be fixed for the launch, the work of preparing for the launch begins about six hours ahead of the time decided upon, and the first duty is to examine and again tighten up the blocks and wedges between the ways and the bottom of the vessel.

The next thing is to proceed with the removal of blocks from under the keel, hand rams worked by eight men, four on each side, being employed for this purpose, a beginning being made at the after end. A few of the blocks are, however, left in at the forward end, so as to relieve part of the weight on the triggers.

To a person viewing the preparations for a launch of a large liner for the first time, and being unaware of what is going on underneath, the booming sounds which echo through the empty vessel, caused by the heavy strokes of the ram, coupled with the unearthly shouts and compliments of our friends the shipwrights to each other, are, to say the least of it, somewhat alarming.

When the blocks have been cleared away, the vessel is resting on the cradle, and held in check by the three triggers on each side.

The after trigger is then released, and when this is proved to be quite clear, the centre one is let go—but the latter is not released until everything is in readiness to let go the forward trigger, which is the strongest and most important of all, and is the only thing remaining to hold the vessel in check.

It is a splendid sight to see a large liner launched, and while the visitors cheer as she leaves the ways, but few give a thought to those responsible for the launch, who stand looking on quivering with excitement and anxiety until she is safely floated. The machinery is afterwards installed, and upon completion the vessel is tried and handed over to its owners.