An Unsinkable Titanic

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AN UNSINKABLE TITANIC

[Illustration: Photo by Brown Bros., New York

STOKE-HOLE OF A TRANSATLANTIC LINER]

AN
UNSINKABLE
TITANIC

EVERY SHIP
ITS OWN LIFEBOAT

BY
J. BERNARD WALKER
Editor of the Scientific American

[Illustration]

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To
THE MEMORY OF THE CHIEF ENGINEER OF THE _TITANIC_,
JOHN BELL,
AND HIS STAFF OF THIRTY-THREE ASSISTANTS,
WHO STOOD AT THEIR POSTS IN THE ENGINE-
AND BOILER-ROOMS TO THE VERY LAST,
AND WENT DOWN WITH THE SHIP,
THIS WORK IS DEDICATED

PREFACE

It is the object of this work to show that, in our eagerness to make the ocean liner fast and luxurious, we have forgotten to make her safe.

The safest ocean liner was the _Great Eastern_; and she was built over fifty years ago. Her designer aimed to make the ship practically unsinkable--and he succeeded; for she passed through a more severe ordeal than the _Titanic_, survived it, and came into port under her own steam.

Since her day, the shipbuilder has eliminated all but one of the safety devices which made the _Great Eastern_ a ship so difficult to sink. Nobody, not even the shipbuilders themselves, seemed to realise what was being done, until, suddenly, the world's finest vessel, in all the pride of her maiden voyage, struck an iceberg and went to the bottom in something over two and a half hours' time!

If we learn the lesson of this tragedy, we shall lose no time in getting back to first principles. We shall reintroduce in all future passenger ships those simple and effective elements of safety--the double skin, the longitudinal bulkhead, and the watertight deck--which were conspicuous in the _Great Eastern_, and which alone can render such a ship as the _Titanic_ unsinkable.

*   *   *   *   *

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J. B. W.

NEW YORK, _June_, 1912.

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CHAPTER I

INTRODUCTORY

Among the many questions which have arisen out of the loss of the _Titanic_ there is one, which, in its importance as affecting the safety of ocean travel, stands out preëminent:

"Why did this ship, the latest, the largest, and supposedly the safest of ocean liners, go to the bottom so soon after collision with an iceberg?"

The question is one to which, as yet, no answer that is perfectly clear to the lay mind has been made. We know that the collision was the result of daring navigation; that the wholesale loss of life was due to the lack of lifeboats and the failure to fill completely the few that were available; and that, had it not been for the amazing indifference or stupidity of the captain of a nearby steamer, who failed to answer the distress signals of the sinking vessel, the whole of the ship's complement might have been saved.

But the ship itself--why did she so quickly go to the bottom after meeting with an accident, which, in spite of its stupendous results, must be reckoned as merely one among the many risks of transatlantic travel?

So far as the loss of the ship itself was concerned, it is certain that the stupefaction with which the news of her sinking was received was due to the belief that her vast size was a guarantee against disaster--that the ever-increasing dimensions of length, breadth, and tonnage had conferred upon the modern ocean liner a certain immunity against the dangers of travel by sea. The fetish of mere size seems, indeed, to have affected even the officers in command of these modern leviathans. Surely it must have thrown its spell over the captain of the ill-fated _Titanic_, who, in spite of an oft-repeated warning that there was a large field of ice ahead, followed the usual practice, if the night is clear, and ran his ship at full speed into the zone of danger, as though, forsooth, he expected the _Titanic_ to brush the ice floes aside, and split asunder any iceberg that might stand in her way.

[Illustration: Courtesy of _Scientific American_

RIVETTING THE OUTER SKIN ON THE FRAMES OF A 65,000-TON OCEAN LINER]

Confidence in the indestructibility of the _Titanic_, moreover, was stimulated by the fact that she was supposed to be the "last word" in first-class steamship construction, the culmination of three-quarters of a century of experience in building safe and stanch vessels. In the official descriptions of the ship, widely distributed at the time of her launching, the safety elements of her construction were freely dwelt upon. This literature rang the changes on stout bulkheads, watertight compartments, automatic, self-closing bulkhead doors, etc.,--and honestly so. There is every reason to believe that the celebrated firm who built the ship, renowned the world over for the high character of their work; the powerful company whose flag she carried; aye, and even her talented designer, who was the first to pronounce the _Titanic_ a doomed vessel and went down with the ship, were united in the belief that the size of the _Titanic_ and her construction were such that she was unsinkable by any of the ordinary accidents to which the transatlantic liner is liable.

How comes it, then, that this noble vessel lies to-day at the bottom of the Atlantic in two thousand fathoms of water?

A review of the progress of those constructive arts which affect the safety of human life seems to show that it needs the spur of great disasters, such as this, to concentrate the attention of the engineer and the architect upon the all-important question of safety. More important than considerations of convenience, economy, speed of construction, or even revenue-earning capacity, are those of the value and sanctity of human life. Too frequently these considerations are the last to receive attention. This is due less to indifference than to inadvertence--a failure to remember that an accident which may be insignificant in its effect on steel and stone, may be fatal to frail flesh and blood. Furthermore, the monumental disasters, and particularly those occurring in this age of great constructive works, are frequently traceable to hidden or unsuspected causes, the existence and potentialities of which are revealed only when the mischief has been done. A faulty method of construction, containing in itself huge possibilities of disaster, may be persisted in for years without revealing its lurking menace. Here and there, now and then, some minor mischance will direct the attention of the few to the peril; but the excitement will be local and passing. It takes a "horror"--a "holocaust" of human life, with all its attendant exploitation in the press and the monthly magazine, to awaken a busy and preoccupied world to the danger and beget those stringent laws and improved constructions which are the earmarks of progress towards an ideal civilisation.

[Illustration: Courtesy of _Scientific American_.

Note how far the _Great Eastern_ was ahead of her time. She was not exceeded until the advent of the _Oceanic_ in 1899.

GROWTH OF THE TRANSATLANTIC STEAMER FROM 1840 TO 1912]

Not many years ago, there was being erected across the St. Lawrence River a huge bridge, with the largest single span in the world, which it was believed would be not only the largest but the strongest and most enduring structure of its kind in existence. It was being built under the supervision of one of the leading bridge engineers of the world; its design was of an approved type, which had long been standard in the Western Hemisphere; and the steelwork was being fabricated in one of the best equipped bridge works in the country. Nevertheless, when one great cantilever was about completed, and before any live load had been placed on it, the structure collapsed under its own weight. One of the principal members--a massive steel column, five feet square and sixty feet long--crumpled up as though it had been a boy's tin whistle, and allowed the whole bridge to fall into the St. Lawrence, carrying eighty men to their death! The disaster was traced to a very insignificant cause--the failure of some small angle-bars, 3½ inches in width, by which the parts of the massive member were held in place. No engineer had suspected that danger lurked in these little angle-bars. Had the accident happened to a bridge of moderate size, the lessons of the failure would have been noted by the engineers and contractors; it would have formed the subject, possibly, of a paper before some engineering society, and the warning would have had results merely local and temporary. But the failure of this monumental structure, with a loss of life so appalling, gave to the disaster a world-wide notoriety. It became the subject of a searching enquiry by a highly expert board; the unsuspected danger which lurked in the existing and generally approved methods of building up massive steel columns was acknowledged; and safer rules of construction were adopted.

It took the Baltimore conflagration to teach us the strong and weak points of our much-vaunted systems of fireproof construction. Only when San Francisco, after repeated warnings, had seen the whole of its business section shaken down and ravaged by fire, did she set about the construction of a city that would be proof against fire and earthquake. It was the spectacle of maimed and dying passengers being slowly burned to death in the wreckage of colliding wooden cars, that led to the abolition of the heating stove and the oil lamp; and it was the risk of fire, coupled with the shocking injuries due to splintering of wooden cars, that brought in the era of the electrically lighted, strong, and incombustible steel car.

The conditions attending the loss of the _Titanic_ were so heartrending, and its appeal has been so world-wide, as to lead us to expect that the tragedy will be preëminently fruitful in those reforms which, as we have shown, usually follow a disaster of this magnitude. Had the ship been less notable and the toll of human life less terrible, the disaster might have failed to awaken that sense of distrust in present methods which is at the root of all thorough-going reform. The measure of the one compensation which can be recovered from this awful loss of life and treasure, will depend upon the care with which its lessons are learned and the fidelity with which they are carried out.

Unquestionably, public faith in the security of ocean travel has been rudely shaken. The defects, however, which are directly answerable for the sinking of this ship are fortunately of such a character that they can be easily corrected; and if certain necessary and really very simple changes in construction are made (and they can be made without any burdensome increase in the cost) we do not hesitate to say that future passenger travel on a first-class ocean-going steamship will be rendered absolutely safe.

[Illustration: Small dial indicates whether signals come from port or starboard.

RECEIVING SUBMARINE SIGNALS ON THE BRIDGE]

The duty of a passenger steamer, such as the _Titanic_, may be regarded as threefold: She must stay afloat; she must provide a comfortable home for a small townful of people; and she must carry them to their destination with as much speed as is compatible with safety and comfort. Evidently the first condition, as to safety, should be paramount. When it has been determined to build a ship of a certain size and weight (in the case of the _Titanic_ the weight was 60,000 tons, loaded) the designer should be permitted to appropriate to the safety elements of her construction every pound of steel that he may wish to employ. In a vessel like the _Titanic_, which is to be entrusted with the care of three or four thousand souls, he should be permitted to double-skin the ship, and divide and subdivide the hull with bulkheads, until he is satisfied that the vessel is unsinkable by any of the ordinary accidents of the sea. When these demands have been met, he may pile deck upon deck and crowd as big a boiler- and engine-plant into this unsinkable hull as the balance of the weights at his disposal will allow.

Unfortunately the Board of Trade requirements under which the _Titanic_ was built--and very conscientiously built--proceed along no such common-sense lines. Instead, the Board many years ago framed a set of rules in which the safety requirements were cut down to such a low limit, that the question of a ship's surviving a serious collision was reduced to a mere gamble with Fate. The Board of Trade ship may fill _two_ adjoining compartments, and then _with the top of her bulkheads practically level with the sea_, in the opinion of the Board, she will have a fighting chance to live _in smooth water_!

The _Titanic_ filled at least five adjoining compartments, and hence,--thanks to these altogether inadequate and obsolete requirements, she is now at the bottom of the Atlantic; and, thanks again to the requirements of the Board as to lifeboat accommodations, over fifteen hundred of her passengers and crew went down with the ship!

[Illustration: Water is hauled up in the canvas bucket and its temperature taken by thermometer.

TAKING THE TEMPERATURE OF THE WATER]

CHAPTER II

THE EVER-PRESENT DANGERS OF THE SEA

Boswell, that faithful, if over-appreciative chronicler, tells us that Dr. Johnson once described an ocean voyage as "going to jail with a chance of being drowned." Had some one quoted the grim witticism of the doctor in the spacious dining-room of the _Titanic_ on the night of April the fourteenth, it would have provoked a smile of derisive incredulity. Going to sea in the cramped quarters of the frail sailing packet of Johnson's day was one thing; crossing the Atlantic at railroad speed in the spacious luxury of a 60,000-ton liner was quite another. Yet, five hours later, when the vast bulk of that noble ship was slanting to its final plunge, the pitiless truth was brought home to that awe-stricken crowd that, even to-day, travel by sea involves the "chance of being drowned."

The remarkable immunity of the high-speed Atlantic liners from such accidents as befell the _Titanic_ has been due in part to careful seamanship and in part to an amazing run of good luck. Of this there can be no doubt whatever. On a recent occasion the subject was brought up for discussion in the officers' quarters of one of the fastest liners. In answer to the writer's question as to whether the dangers of running at high speed through fog or ice-infested regions were not enormous, one of the officers frankly admitted that, not only were the risks most serious, but the immunity from such disasters as that which befell the _Titanic_ was to be explained on the ground of sheer good fortune. "I well remember," said he, "that the first time I found myself in charge of the bridge on a ship that was running through fog at a speed of over 20 knots, I fairly shivered with a sense of the possibilities of disaster that were involved. To-day--well--familiarity, you know----"

[Illustration: Stewards are closing door in fire-protection bulkhead.

FIRE-DRILL ON A GERMAN LINER]

Let it not be supposed, from the heading of this chapter, that it is the writer's purpose to draw any lurid picture of the dangers of ocean travel. These are no greater to-day than they were before the _Titanic_ went down. Icebergs have swept down from the Arctic seas from time immemorial, and year by year they will continue to throw the shadow of their awful menace across the lines of steamship travel. Fog, with its ever-present dangers of collision, will continue to infest the ocean highways; and always, the half-submerged derelict, a peril scarcely less than that of the iceberg, will continue to sail its uncharted course over the high seas.

The strength of the impulse to build unsinkable ships will be exactly in proportion to our realisation of the dangers which beset ocean travel. The toll of human life exacted in the recent disaster will lose its one possible compensation, if it fails to impress deeply the very serious lesson that since the sea is not man's natural element, he can hold his way safely across its surface only at the cost of most careful preparation and eternal vigilance.

Protracted and amazing immunity from disasters of portentous magnitude has bred in us something of that very contempt for the dangers of the sea above referred to. We have piled deck upon deck until the "floating palace" of the sea towers twice as far above the water-line as it extends below it. So rapidly have we added weight to weight and horsepower to horsepower, that both the mass and the power have been quadrupled. The giant steamship of to-day, as she rushes through the black night and the all-obscuring fog, represents a potential engine of destruction, for which no parallel can be found in the whole field of human activity.

Do you doubt it? Then learn that on that fatal night when the _Titanic_ bore headlong into the icefield, she embodied in her onrushing mass an energy equal to that of the combined broadsides of our two most powerful battleships, the _Florida_ and the _Utah_. Which is to say that, if the two dreadnoughts had discharged their twenty twelve-inch guns, at point-blank range, against the iceberg which sank this ship, they would have struck a combined blow of less energy than that delivered by the _Titanic_. And every one of these guns, be it remembered, delivers its shell with an energy of 50,000 foot-tons--sufficient to lift either of these battleships nearly two and a half feet into the air.

[Illustration: Hose from bellows supplies fresh air to man with smoke helmet.

FIRE-DRILL ON A GERMAN LINER]

Of the serious risk to a ship of collision with an iceberg, it is superfluous to say anything here. The swift sinking of the world's greatest steamship has driven that lesson home, surely, for all time to come. But there are two other forms of accident on the high seas--collision with another ship and the running down of a derelict--whose possibilities of disaster are scarcely less. For if the huge steamships of our day, moving at high speed, are such potential engines of destruction, it follows that the damaging effects of collisions are proportionately increased.

If a 60,000-ton ship, such as the _Titanic_, while running at high speed, were struck on the beam by a vessel of large size, it is quite conceivable that the outside plating of three of her compartments (not merely the "two adjoining" of standard shipbuilding practice) might be broken in, or the seams and butts started, before the energy of the colliding ship was absorbed and the two vessels swung clear of each other. The average length of the compartments of the _Titanic_ was about 53 feet. At 21 knots she would move forward about 35 feet in one second. Hence, in a few seconds' time (even allowing for her slowing down due to the drag of the other ship), her enormous energy of over 1,000,000 foot-tons would cause her to grind along past the broken bow, surely more than the 100 feet or so which would suffice to involve three compartments. If three compartments amidships were opened to the sea, it would mean the admission of some 12,000 to 15,000 tons of water.

Even more insidious is the menace of the abandoned and water-logged ship--the justly dreaded derelict--which, floating low in the water, and without a light to reveal its position, may lie directly in the path of the high-speed ocean liner. So slightly does the derelict project above the surface, that it is almost impossible of detection by night from the lofty position of the lookout on a modern steamship.

[Illustration: Test of fire mains is made every time the ship is in port.

FIRE-DRILL ON A GERMAN LINER]

Another risk of the sea, which, because of long immunity from disaster, is in danger of being overlooked or underrated, is that of fire. The structural portions of a ship and its engine- and boiler-plant, being of metal, are proof against fire; but the stateroom partitions, the wooden floors and ceilings, the wainscoting, and the hundreds of tons of material used in decoration and general embellishment, to say nothing of the highly inflammable paint-work and varnish, constitute a mass of material, which, in the event of a serious fire, might turn the whole interior of a large passenger ship into one vast cauldron of flame. Fortunately, the bulkhead is as effective in confining a fire as it is in localising an inflow of water in the event of collision. Therefore, some of the bulkheads of the under-water portion of all passenger ships should be continued (of lighter construction) right through the decks reserved for passenger accommodations, to the topmost deck of the ship.

But, perhaps, after all said and done, the greatest perils of high-speed ocean travel are to be found in that spirit of nautical _sangfroid_, or indifference to danger, which, as this disaster has proved, may in time begin to characterise the attitude even of so experienced a navigator as the late captain of the _Titanic_.

Protection against the dangers of the sea may be sought in two directions: First, the enforcement of rules for more careful navigation; second, the embodiment of non-sinkable construction in the ship.

The protection afforded by the one is limited by the fallibility of human nature.

The protection afforded by the other is exact, absolutely sure, and will last as long as the ship itself.

If we would make ocean travel safe we must make the ship, as far as possible, unsinkable. In other words, the naval architect must adopt that principle of construction, common in other lines of mechanical work, which has been aptly designated as "fool-proof." In the building of folly-proof ships, then (the term is here used in a modified sense and with not the least reflection upon that fine body of professional men whose duties lie on the bridge of our ocean liners), is to be found the one sure protection against the perils of the sea.

We are well aware that the merchant ship, like the warship, is a compromise, and that the ingenuity of the naval architect is sorely taxed to meet the many demands for speed, coal capacity, freight capacity, and luxurious accommodations for passengers. All this is admitted. But the object of these chapters is to show that in designing the ship, the architect has given too little attention to the elements of safety--that, in the compromise, luxurious accommodations, let us say, have been favoured at the expense of certain protective structural arrangements, which might readily be introduced without any great addition to the cost of the ship, or any serious sacrifice of comfort or speed.

Under the sobering effect of this calamity, caution and moderation are the watchwords of the hour. Steamships are leaving port crowded with lifeboats of every size and shape. Steamship routes have been moved far to the south of the accustomed lines of travel. The time occupied in passage is longer, distances are greater, and the coal bill runs into larger figures.

But competition is keen, dividends must be earned, and amid all the fret and fever of our modern life, memories, even of stupendous happenings, have but a brief life. Steamship routes, under the strong pressure of competition, will tend to edge northward on to the older and shorter sailing lines. Immunity from disaster will beget the old _sangfroid_; and with the near approach of the age of motor-driven ships, we may look for an increase in speed such as the old Atlantic has never witnessed, even in the years of fiercest contest for the blue ribbon of the seas.

Let it be so--provided, always provided that, made wise by the lessons of the hour, we write it in our laws and grave it deep in the hearts of our shipbuilders, that the one sure safeguard against the eternal hazards of the sea is the fireproof and unsinkable ship!

CHAPTER III

EVERY SHIP ITS OWN LIFEBOAT

Say what we will, it cannot be denied that the lifeboat is a makeshift. The long white line of boats, conspicuous on each side of the upper deck of a large passenger ship, is, in a certain sense, a confession of failure--an admission on the part of the shipbuilder that, in spite of all that he has done in making travel by sea fast and comfortable, he has not yet succeeded in making it safe.

Progress in shipbuilding and especially in the construction of fast and luxuriously appointed ships has been simply phenomenal, particularly during the past two decades. There is no art in the whole field of engineering that has made such rapid and astonishing strides; and it is not stretching the point too far to assert that man's mastery of the ocean is the greatest engineering triumph of all time.

The fury of the elements, as shown in a heavy storm at sea, has always been regarded as one of the most majestic and terrifying exhibitions of the forces of nature. When the sailing packet was struck by the full fury of a gale, the skipper lay to, thankful if he could survive the racket, without carrying away boats, bulwarks, and deck gear. Frequently, with canvas blown out of the bolt ropes, he was obliged to run under bare poles, at the imminent risk of being swamped under the weight of some following sea. For many a decade, even in the era of the steamship, it was necessary, when heading into a heavy sea, to slow down the engines, maintaining only sufficient speed to give steerage way. To-day, so great are the weight and engine power that the giant steamship, if the captain is willing to risk some minor mishaps to her upper works, may be driven resistlessly along the appointed lines of travel regardless of wind and sea. So far as the loss of the ship from heavy weather is concerned, man has obtained complete mastery of the ocean.

[Illustration: This ship, with 34 compartments below a water-tight steel deck, would serve as its own lifeboat in the event of collision.

THE 44,000-TON, 25½-KNOT LUSITANIA]

The writer well remembers a trip to the westward on one of the subsidised mail steamers, built to naval requirements, which was made at a time when the ship was striving to accomplish the average speed of 24½ knots for the round trip from England to America, which was necessary before she could claim the government subsidy. In the run to the eastward, the ship had averaged for the whole passage 25 knots; therefore to win the coveted prize, it was necessary, on the return passage to New York, to maintain an average of 24 knots. As it happened, two hours out from Queenstown it began to blow hard from the southwest, and for the next four days the wind, veering from southwest to northwest, never fell below the strength of half a gale. On the fourth day out the wind rose to full cyclonic force, and against the most tempestuous weather that the North Atlantic can show, the ship was driven for twenty-four hours into what the captain's log-book designated as "enormous head seas." She averaged a speed of 23 knots for the whole four days of heavy weather, and came through the ordeal without starting a single rivet, or showing any signs of undue strain in her roughly-handled hull.

The large and powerful passenger steamer of to-day is proof against fatal damage due to wind and sea. True it is that these ships occasionally reach New York after a stormy passage, with porthole glasses broken, windows smashed, and rails and other light fittings carried away; but these are minor damages which in no way affect the integrity of the ship as a whole.

If, then, the shipbuilder has made such wonderful strides in the strength of his construction and in the development of engine power, is it not a strange anomaly that he should have so far failed in his attempt to provide against sinking through collision, as to be under the necessity of advertising the fact, by crowding the topmost deck with appliances for saving the lives of the passengers when the ship goes down?

But it will be objected that, even if the ship were made so far unsinkable that she might act as her own lifeboat, there would yet remain the risk of her destruction by fire, and that, if a fierce conflagration occurred, the passengers would have to abandon ship and take to the boats. The objection is well made, and if it be possible to introduce structural features which will render ships both fireproof and unsinkable, the thing should be done.

It is sincerely to be hoped that one outcome of the present world-wide interest in the subject of safety at sea, will be a searching investigation of the whole question of fire protection. In some of the first-class passenger ships, notably those of the leading German companies, the subject has been given the attention which it merits; but there is no doubt that a large majority of the vessels engaged in the passenger-carrying trade contain no fire protection of a structural nature; that is to say, the spaces reserved for passenger accommodations are not laid out with any view to limiting the ravages of fire. On most of these ships a fire which once obtained strong headway might sweep through the decks devoted to passenger accommodations, without meeting with any fireproof wall to stay its progress.

Now the most effective protection against a conflagration on board ship is to apply the same method of localisation which is used to such good effect in limiting the inflow of water resulting from collision. The steel bulkhead and the steel deck, acting as fire screens, may be made as effective in limiting the area of a fire as they are in limiting the area of flooding.

The passenger decks should be intersected at frequent intervals by steel bulkheads, extending from side to side of the ship and carried up to include the topmost tier of staterooms. Where the alleyways intersect the bulkheads, fireproof doors would afford all the necessary means of communication. The provision of many such bulkheads, coupled with the installation of an ample fire-main service and the faithful practice of fire-drills, would render the loss of a ship by fire practically impossible.

The pathetic reluctance of her passengers to leave the _Titanic_ for the lifeboats was justified, surely, by the seeming security of the one and frailty of the other. Perfectly natural was their belief that the mighty ship would survive, at least until the rescuing steamers should reach her vicinity and render the transfer of passengers a safe operation. Did not the _Republic_ remain afloat for many hours after a collision scarcely less terrible than this, and was not the _Titanic_ twice her size and, therefore, good as a lifeboat for many an hour to come?

[Illustration: PROVISIONING THE BOATS DURING A BOAT DRILL]

[Illustration: Courtesy of _Scientific American_

LOADING AND LOWERING BOATS, STOWED ATHWARTSHIPS]

In considering the excellent service rendered by the lifeboats of the _Republic_ and the _Titanic_, it should be borne in mind that the weather conditions happened to be very favourable. The launching of lifeboats in rough weather is a difficult and perilous operation. Frequently the sinking ship will have a heavy list; if she lists to starboard, the boats on that side can be launched well clear of the ship, but the boats on the port or higher side cannot be so launched. As they are lowered, they will come in contact with the side of the ship and be damaged or capsized. Furthermore, should the ship be rolling, the boats are liable to be swung violently against the vessel and their sides may be crushed in or heavily strained, rendering them unseaworthy. Had a heavy sea, nay, even a moderate sea, been running at the time of the _Titanic_ disaster, how long would her heavily loaded boats have survived in water that was infested with ice floes? Their helplessness will be more evident when we remember that they weighed between one and two tons, and that when they were loaded down with sixty-five people, the total weight must have been about six tons. Now a craft of six tons' displacement requires considerable handling, and the two or three sailors allotted to each boat, jammed in, as they were, among crowded passengers, would have been powerless in heavy weather to keep the boat from broaching broadside to the sea and capsizing.

The demand, then, for unsinkable ships is justified by the fact that the lifeboat is at best but a poor makeshift--that to put several thousand people adrift in mid-ocean is to expose them to the risk of ultimate death by starvation or drowning.

[Illustration: Courtesy of _Scientific American_

BOAT DECK OF TITANIC, SHOWING, IN BLACK, PLAN FOR STOWING EXTRA BOATS, TO BRING TOTAL ACCOMMODATIONS UP TO 3,100 PERSONS]

However, in view of the fact that ninety-five passenger ships out of every hundred are built with the single skin, low bulkheads, and non-watertight decks, which characterised the _Titanic_, it is certain that the cry: "A lifeboat seat for every passenger" is fully justified.

The problem of housing the large number that would be required presents
no insuperable difficulties, and there are several alternative plans on
which the boats might be disposed. On page 45 will be found a proposed
arrangement, reproduced by the courtesy of the "Scientific American,"
which shows in white the twenty boats actually carried by the _Titanic_,
and in black the additional boats which would be necessary to increase
the total accommodation to about 3,100 people. This plan would
necessitate the sacrifice of some of the deck-house structures. Between
each pair of smoke-stacks two lines of four boats each are stowed
athwartships. The boat chocks are provided with gunmetal wheels, which
run in transverse tracks sunk in the deck. Along each side of the
boat-deck there is a continuous line of boats.

[Illustration: Courtesy of _Scientific American_

THE ELABORATE INSTALLATION OF TELEGRAPHS, TELEPHONES, VOICE-TUBES, ETC.,
ON THE BRIDGE OF AN OCEAN LINER]

Another plan would be to take advantage of the full capacity of the
Welin davit with which the _Titanic_ was equipped, which is capable of
handling two or even three boats stowed abreast. Three lines of boats
carried on each side of the long boat-deck of a modern liner would
provide ample accommodation for every person on board.

But we repeat--and the point cannot be too strongly urged--that
however complete the lifeboat accommodation may be, it is at the best a
makeshift.

The demand that every ship that is launched in the future shall be
so far unsinkable as to serve as its own lifeboat in case of serious
disaster is perfectly reasonable; for there are certain first-class
transatlantic liners in service to-day--notably in certain leading
English and German lines--which fulfil this condition. Considerations
both of humanity and self-interest should lead to the adoption of
similar principles of construction by every passenger steamship company.
It is possible that the time will come, and it may indeed be very close
at hand, when the most attractive page in the illustrated steamship
pamphlet will be one containing plans of the ships, in which the
safeguards against sinking--such as side bunkers, high bulkheads, and
watertight decks--are clearly delineated.

CHAPTER IV

SAFETY LIES IN SUBDIVISION

Other things being equal, the protection of a ship against sinking is exactly proportionate to the number of separate watertight compartments into which the interior of her hull is subdivided. If she contains no watertight partitions whatsoever, her sinking, due to damage below the water-line, is a mere matter of time. If the inflow exceeds the capacity of the pumps, water will flow into the ship until all buoyancy is lost. Protection against sinking is obtained by dividing the interior of the hull into a number of compartments by means of strong, watertight partitions, or bulkheads. Usually, these are placed transversely to the ship, extending from side to side and from the bottom to a height of one or two decks above the water-line. They are built of steel plates, stiffened by vertical I-beams, angle-bars, or other suitable members. The bulkheads are strongly riveted to the bottom, sides, and decks of the ship, and the joints are carefully caulked, so as to secure a perfectly tight connection. In the standard construction for merchant ships, as used in the _Titanic_, the bulkheads are placed transversely to the length of the ship, and the number of separate compartments is just one more than the number of bulkheads, ten such bulkheads giving eleven compartments, fifteen, as in the _Titanic_, giving sixteen compartments, and so on. In the case of a few high-class merchant steamers, built to meet special requirements as to safety, bulkheads are run lengthwise through the ship. These longitudinal bulkheads, intersecting the transverse bulkheads, greatly increase the factor of safety due to subdivision; for it is evident that one such, running the full length of the ship, would double, two would treble, and three would quadruple the number of separate compartments.

[Illustration: HYDRAULICALLY-OPERATED, WATERTIGHT DOOR IN AN ENGINE-ROOM BULKHEAD]

The bulkhead subdivision above described is all done in vertical planes. Its object is to restrict the water to such compartments as (through collision or grounding) may have been opened to the sea. As the water enters, the ship, because of the loss of buoyancy, will sink until the buoyancy of the undamaged compartments restores equilibrium and the ship assumes a new position, with the water in the damaged compartments at the same level as the sea outside. This position is shown in Fig. 2, page 57. It must be carefully noted, however, that this condition can exist only if the bulkheads are carried high enough to prevent the water in the damaged compartments from rising above them and flowing over the tops of the bulkheads into adjoining compartments.

In addition to lateral and longitudinal subdivision by means of vertical bulkheads, the hull may be further subdivided by means of horizontal partitions in the form of watertight decks--a system which is universally adopted in the navies of the world. For it is evident that if the ship shown in Fig. 2, page 57, were provided with a watertight deck, say at the level of the water-line, as shown in Fig. 1, page 57, the water could rise only to the height of that deck, where it would be arrested. The amount of water entering the vessel would be, say, only one-half to two-thirds of that received in the case of the vessel shown in Fig. 2.

If ships that are damaged below the water-line always settled in the water on an even keel, that is to say without any change of trim, the loss through collisions would be greatly reduced. But for obvious reasons, the damage usually occurs in the forward part of the ship, and the flooding of compartments leads to a change of trim, setting the ship down by the head, as shown in Figs. 3 and 4. If the transverse bulkheads are of limited height, and extend only to about 10 feet above the normal water-line, the settling of the bow may soon bring the bulkhead deck (the deck against which the bulkheads terminate) below the water. If, as is too often the case, this deck is not watertight--that is to say, if it is pierced by hatch openings, stair or ladder-ways, ventilator shafts, etc., which are not provided with watertight casings or hatch covers, the water will flow aft along the deck, and find its way through these openings into successive compartments, gradually destroying the reserve buoyancy of the ship until she goes down. The vessels shown in Figs. 3 and 4 are similar as to their subdivision, each containing thirteen compartments; but in Fig. 3 the bulkheads are shown carried only to the upper deck, say 10 feet above the water, whereas in Fig. 4 they extend to the saloon deck, one deck higher, or, say, 19 feet above the same point. Now, if both ships received the same injury, involving, say, the three forward compartments, a loss of buoyancy which would bring the tops of bulkheads in Fig. 3 below the surface, would leave the bulkheads in Fig. 4, which end at a watertight deck, with a safe margin, and any further settling of the ship would be arrested.

[Illustration:

FIG. 1 WATERTIGHT DECK AT WATERLINE LIMITS INFLOW OF WATER

FIG. 2 HIGH BULKHEADS, WITHOUT WATERTIGHT DECK WOULD SAVE THE SHIP BUT PERMIT DEEP SUBMERSION

FIG. 3 SINKING BY THE HEAD; WATER FLOWING ALONG LOW BULKHEAD DECK AND ENTERING COMPARTMENTS THROUGH DOORS OR HATCHWAYS

FIG. 4 DOWN BY THE HEAD, BUT SAVED BY HIGHER BULKHEADS AND WATERTIGHT BULKHEAD DECK

FIG. 5 RELATIVE AREA OF FLOODING FROM SAME DAMAGE IN SHIPS,

"A" WITH DOUBLE SKIN; "B" WITH SIDE BUNKERS; "C" WITH A SINGLE SKIN.
TRANSVERSE BULKHEADS ON EACH SHIP

DIAGRAMS SHOWING PROTECTIVE VALUE OF TRANSVERSE AND LONGITUDINAL BULKHEADS, WATERTIGHT DECKS, AND INNER SKIN]

Ordinarily, it would suffice to carry the first two bulkheads at the bow and the last two at the stern to the shelter deck, terminating the intermediate bulkheads one deck lower. But whatever the deck to which the bulkheads are carried, care should be taken to make it absolutely watertight. Otherwise, as already made clear, the so-called watertight subdivision of the ship may, in time of stress, prove to be a delusion and a snare.

Although the longitudinal bulkhead, which is employed below the water-line, and chiefly in the holds and machinery spaces, is the least used, it is one of the most effective means of subdivision that can be employed. A certain amount of prejudice exists against it, on the ground that it confines the inflowing water to one side of the ship, causing it to list, if not ultimately to capsize. But this objection merely points the moral that all things must be used with discretion. A single longitudinal bulkhead, built through the exact centre of a ship, would invite a speedy capsize in the event of extensive injury below the water-line. The loss of the British battleship _Victoria_ emphasised that truth many years ago. But longitudinal bulkheads, carried through the engine and boiler spaces, at the sides of the ship, are a most effective protection. Not only is each of the large compartments in the wider central body of the ship divided into three, but along each side is provided a row of comparatively small compartments, several of which could be flooded without causing a serious loss of buoyancy.

These bulkheads, built some 15 to 18 feet in from the side of the ship, not only form an inner skin for the ship, but they serve as the inner wall of the coal bunkers. They extend from the inner bottom to the under side of the lower deck, to both of which they are securely riveted, the joints being carefully caulked, to render them watertight. The space between the ship's side and the bulkhead is subdivided by transverse watertight partitions (see plan of _Mauretania_, Fig. 3, page 129), placed centrally between the main transverse bulkheads of the ship.
A further and most effective means for protecting the buoyancy is to construct the ship with a double skin up to and preferably a few feet above the water-line. The inner skin should extend from the first bulkhead abaft the engine-room to the first or collision bulkhead, forward. This construction merely involves carrying the inner floor plating of the double bottom up the sides of the ship to the under side of the lower deck. As all merchant ships are built with a double bottom (see page 107), the cost of thus providing a double skin below the

water-line is small in proportion to the security against flooding which it affords.

The description of the _Titanic_, published at the time of her launch, stated that any two of her adjoining compartments could be flooded without endangering the safety of the ship, and the question must frequently have occurred to the lay mind as to why the ability of the ship to sustain flooding of her interior was confined to two, and not extended to include three or even more compartments.

The ability to stand the flooding of two compartments only is not peculiar to the _Titanic_. It represents the standard practice which is followed in all passenger ships, the spacing and height of whose bulkheads is determined in accordance with certain stipulations of the British Board of Trade. These stipulations, as given by Prof. J. H. Biles of Glasgow University, in his book "Design and Construction of Ships," are as follows:

> "A vessel is considered to be safe, even in the event of serious damage, if she is able to keep afloat with two adjoining compartments in free communication with the sea. The vessel must therefore have efficient transverse watertight bulkheads so spaced that when any two adjoining compartments are open to the sea, the uppermost deck to which all the bulkheads extend is not brought nearer to the surface of the water than a certain prescribed margin.
>
> "The watertight deck referred to is called the bulkhead deck. The line past which the vessel may not sink is called the margin of safety line.
>
> "The margin of safety line, as defined in the above report, is a line drawn round the side at a distance amidships of three-one-hundredths of the depth at side at that place below the bulkhead deck, and gradually approaching it toward the aft end, where it may be three-two-hundredths of the same depth below it."

By referring to the diagrams on page 66 showing the disposition of bulkheads on certain notable ships, it will be seen that, in the case of the _Titanic_, the application of the Board of Trade rule called for the extension of the bulkheads amidships only to the upper deck, which, at the loaded draft of 34 feet, was only 10 feet above the water-line! Compare this with the safe construction adopted by Brunel and Scott Russell over fifty-four years ago, who, in constructing the _Great Eastern_, extended all the bulkheads (see page 83) to the topmost deck, fully 30 feet above the water-line.

[Illustration: CLOSING, FROM THE BRIDGE, ALL WATERTIGHT DOORS THROUGHOUT

THE SHIP BY PULLING A LEVER]

Before leaving the question of bulkheads, the writer would enter a strong protest against the present practice of placing watertight doors in the main bulkheads below the water-line. They are put there generally for the convenience of the engine- and boiler-room forces, whose duties render it necessary for them to pass from compartment to compartment. As at present constructed, these doors are of the sliding type, and they can be closed simultaneously from the bridge, or separately, by hand. The safer plan is to permit no bulkhead doors below the water-line, and provide in their place elevators or ladders, enclosed in watertight trunks. Access from compartment to compartment must then be had by way of the bulkhead deck.

The advantage of lofty bulkheads was admirably illustrated in the case of the _City of Paris_ and the _City of New York_, designed by Mr. Biles in 1888. Although these were small ships compared with the _Titanic_, their fourteen bulkheads were carried one deck higher. Biles laid down the rule that no doors were to be cut through the bulkheads, and in spite of strenuous objections on the grounds of passenger accommodation and general convenience in the operation of the ship, he carried his point.

[Illustration: COURTESY OF ENGINEERING

OLYMPIC AND TITANIC 1912

LUSITANIA 1906

GREAT EASTERN 1858

CAMPANIA 1893

PARIS 1868

A COMPARISON OF BULKHEAD PROTECTION IN SOME NOTABLE SHIPS]

The wisdom of this construction was demonstrated years later, when, as a result of an accident to her engines, the two largest adjoining compartments of the _City of Paris_ were flooded, at a time when the ship was 150 miles off the coast of Ireland. There was no wireless in those days to send out its call for help, and for three days the ship drifted in a helpless condition. Thanks to her lofty bulkheads, the good ship stood the ordeal and was finally brought into port without the loss of a single passenger.

BULKHEAD SPACING ON NOTABLE SHIPS

NAME	Date of Building	Registered Length, Feet [1]	No. of Main W. T. Bulkheads	Average Length of Compartments	Per cent. of Length
Titanic	1911	852.5	15	53	6.2
Lusitania	1907	762.0	16	45	5.9
George Washington	1908	699.0	13	50	7.1
Great Eastern	1854-59	680.0	9	68	10.0
Carmania	1905	650.0	15	50	7.8
Campania	1893	601.0	8	67	11.1
New York	1888	517.0	14	37	6.7
Alma	1894	270.7	11	23	8.3

[1] Figures in this column represent the length between perpendiculars.

An interesting study of bulkhead practice in some notable ships is afforded by the table and diagrams which are herewith reproduced by the courtesy of "Engineering." In the matter of height of bulkheads above the water-line, the _Great Eastern_ stands first, followed by the _Paris_, the _Lusitania_, the _Campania_, and the _Titanic_.

CHAPTER V

THE UNSINKABLE _GREAT EASTERN_ OF 1858

The term "unsinkable," as applied to ships, is used throughout the present work in an accommodated sense. There never was but one unsinkable craft, and for that we must go back to the age of primitive man, who doubtless paddled himself across the rivers and lakes upon a roughly fashioned log of wood.

In the modern sense, an unsinkable ship is one which cannot be sunk by any of the ordinary accidents of the open sea, such as those due to stress of weather, or to collision with icebergs, derelicts, or some other ship.

Can such a ship be built?

Not only is it feasible to construct vessels of this type to-day; but, as far back as the year 1858, there was launched a magnificent ship, the _Great Eastern_, in which the provisions against foundering were so admirably worked out that probably she would have survived even the terrific collision which proved the undoing of the _Titanic_.

The _Great Eastern_ represented the joint labours of the two most distinguished engineers of the middle period of the nineteenth century, I. K. Brunel and John Scott Russell. The former was responsible for the original idea of the ship, and it was he who suggested that it should be built upon the principles adopted in the rectangular, tubular bridge that had recently been built across the Menai Straits. To Scott Russell, as naval architect, were due the lines and dimensions of the ship and the elaborate system of transverse and longitudinal bulkheads.

Those were the days when the engineer was supreme. He worked with a free hand; and these two men set out to build a ship which should be not only the largest and strongest, but also the safest and most unsinkable vessel afloat. How they succeeded is shown by the fact, that on one of her voyages to New York, the _Great Eastern_ ran over some submerged rocks off Montauk Point, Long Island, and tore two great rents in her outer skin, whose aggregate area was equivalent to a rupture 10 feet wide and 80 feet long. In spite of this damage, which was probably greater in total area than that suffered by the _Titanic_, the ship came safely to New York under her own steam.

[Illustration: Courtesy of Holmes' "Ancient and Modern Ships"

GREAT EASTERN, 1858; THE MOST COMPLETELY PROTECTED PASSENGER SHIP EVER BUILT]

There can be no doubt that in undertaking to build a ship of the then unprecedented length of 692 feet, the designers were as much concerned with the question of her strength as with that of her ability to keep afloat in case of under-water damage. But it so happens that the very forms of construction which conduce to strength are favourable also to flotation--a fact which renders all the more reasonable the demand that, in all future passenger-carrying steamships, a return shall be made to the non-sinkable construction of this remarkable ship of over fifty years ago.

Let it not be supposed, however, that Brunel and Russell were insensible to the risks of foundering through under-water damage, or that the fully protected buoyancy of this vessel was accidental rather than the result of careful planning. For in the technical descriptions of the ship, it is stated that the inner skin was carried forward right up to the bow, as a protection against "collision with an iceberg," and it is further stated that the combination of longitudinal and transverse bulkheads afforded such complete subdivision, that "several compartments might be opened to the sea without endangering the ship."

So remarkable in every respect was the _Great Eastern_, so admirable a model is she of safe construction, even for the naval architect of to-day, that a somewhat extended description of the construction of the vessel will doubtless be welcome.

It was at the close of the year 1851 that Brunel made a study of the problem of building a vessel of sufficient size to carry enough coal to make a round voyage to Australia and back, and at the same time afford comfortable accommodations for an unusually large number of passengers and carry a large amount of freight. With the thoroughness and frank open-mindedness which distinguished the man, he sought for information and advice from every promising quarter. Sir William White is of the opinion that all the leading features of the design, such as the structure, the arrangement of the propelling machinery, and the determination of dimensions, originated with Brunel, who said at the time: "I never embarked on any one thing to which I have so entirely devoted myself and to which I have devoted so much time, thought, and labour; on the success of which I have staked so much reputation, and to which I have so largely committed myself and those who were supposed to place faith in me." Sir William states that, after going carefully through Brunel's notes and reports, his admiration for the remarkable grasp and foresight therein displayed has been greatly increased. "In regard to the provision of ample structural strength with a minimum of weight, the increase of safety by watertight subdivision and cellular double-bottom, the design of propelling machinery and boilers, with a view to economy of coal and great endurance for long-distance steaming; the selection of forms and dimensions likely to minimise resistance and favour good behaviour at sea, Brunel displayed a knowledge of principles such as no other ship designer of that time seems to have possessed." The value of this tribute will be understood when it is borne in mind that Sir William White is the most widely known architect of the day.

The principal dimensions of the _Great Eastern_ were as follows:

PARTICULARS OF THE _GREAT EASTERN_

Length between perpendiculars	680 feet
Length on upper deck	692 "
Extreme breadth of hull	83 "
Width over paddle-boxes	120 "
Depth from upper deck to keel	58 "
Draught of water (laden)	28 "
Weight of iron used in construction	10,000 tons

The ship was propelled by two separate engines, driving respectively paddle-wheels and a single propeller. The engines for the paddle-wheels were of the oscillating type. The cylinders were four in number, 74 inches in diameter, by 14-feet stroke, and each one in the finished condition weighed 28 tons. The paddle-wheels were 56 feet in diameter. Steam for these engines was supplied by four, double-ended, tubular boilers, each 17 feet 9 inches long, 17 feet 6 inches wide, and 13 feet 9 inches high, and weighing, with water, 95 tons. Each boiler contained 10 furnaces. The screw engines, which were placed in the aftermost compartment of the machinery spaces, were of the horizontal, opposed type; there were four cylinders, 84 inches in diameter, by 4-feet stroke, and each one, in the finished condition, weighed 39 tons. The propeller shafting, 150 feet in length, weighed 60 tons. The four-bladed propeller was 24 feet in diameter. Steam was supplied to these engines by six tubular boilers of about the same dimensions as those for the paddle-wheel engines. The working pressure was 25 pounds per square inch.

[Illustration: Length, 692 feet; beam, 83 feet; depth, 58 feet. Subdivision: Double hull; nine main bulkheads, 53 feet high, extending to upper deck, and six sub-bulkheads 35 feet high, extending to lower deck. Two longitudinal bulkheads through machinery spaces.

LONGITUDINAL SECTION AND PLAN OF THE GREAT EASTERN, 1858]

The estimated speed of the _Great Eastern_ was 15 knots; her best actual performance on an extended voyage was an average speed of 14 knots, which was realised on one of her trips to New York. She was designed to carry 4,000 passengers, namely 800 first, 2,000 second, and 1,200 third class, besides a crew of 400. She had a capacity of 5,000 tons of cargo, and 12,000 tons of coal. When fitted up for the accommodation of troops she could carry 10,000. Fully laden with passengers, cargo, and coal, she displaced, on a draft of 30 feet, about 27,000 tons;--her actual draft was from 26 to 28 feet. The accommodations for passengers would have done credit to one of our modern liners. There were five saloons on the upper, and another five on the lower deck. The uppermost deck afforded two unbroken and spacious promenades, one on each side of the ship, each of which was 20 feet wide and over 600 feet in length.

Because of the great length of the ship it was decided to launch her sideways,--a disastrous experiment which cost the company dear. The launching ways yielded under the great weight, the ship jammed on the ways, and she had to be laboriously forced into the River Thames, inch by inch, by the aid of powerful hydraulic jacks. The great cost of the launching, which occupied two and a half months' time, caused the failure of the original company, and the ship was sold for $900,000 to a new company, who completed her in 1859. She made several voyages to America; and although in this service she was unprofitable, the great ship proved that she was staunch, eminently seaworthy, and fast for a passenger ship of that period. Although the _Great Eastern_ was never employed on the Australian service, for which she was designed, she was usefully employed in 1865 in laying two of the Atlantic telegraph cables, and, subsequently, in similar service in other parts of the world--a work for which her great strength and size rendered her peculiarly adapted. After serving an inglorious career in the hands of the showman, the _Great Eastern_ was sold for the value of her metal and was broken up in the autumn of 1888.

The financial failure of this ship was not due to any excessive first cost, resulting from the very thorough character of her construction, but rather to certain economic conditions of her time. Traffic across the Atlantic, both freight and passenger, was as yet in its infancy; and even if full cargoes had been available, the loading facilities of those days were so inadequate, that the ship would have been delayed in port for an unconscionable length of time. Furthermore, fuel consumption, in that early stage of development of the steam engine, was excessive, the coal consumed per horsepower per hour being about three and one-half to four pounds, as compared with a modern consumption of from one and a quarter to one and a half pounds per horsepower.

A careful study of the construction of this remarkable vessel establishes the fact that over fifty years ago Brunel and Scott Russell produced in the _Great Eastern_ a ship which stands as a model for all time. Realising, in the first place, how vulnerable is an iron vessel which carries only a single skin, they decided to provide a double skin and construct the ship with two separate hulls, placed one within the other and firmly tied together by a system of continuous longitudinal and lateral web-plates or frames. By reference to the cross-section, published on page 83, it will be seen that the double-skin construction extended entirely around the hull, and was carried up to a continuous plate-iron lower deck, which was from 8 to 10 feet above the water-line, the distance varying with the draft of the ship. The two skins were placed 2 feet 10 inches apart and they were tied together by 34 longitudinal web-members, which ran the entire length of the double hull, and divided the space between the two skins into separate watertight compartments. These were themselves further subdivided by a series of transverse webs which intersected the longitudinal webs. The cellular construction thus provided extended from the aftermost bulkhead right through to the bow, to which it was carried for the purpose of protecting the forward part of the ship against the effect of collision with icebergs, which at that early day were recognised as constituting a serious menace to navigation. The inner skin was not continued aft of the aftermost bulkhead, for the reason that at the stern it would have been unnecessary and somewhat inconvenient.

[Illustration:

TITANIC   BUILT 1912

MAURETANIA   BUILT 1906

GREAT EASTERN BUILT 1858

TWO EXTREMES IN PROTECTION, AND A COMPROMISE]

The double hull was closed in by a watertight iron deck (the lower deck), which served to entirely separate the boiler- and engine-rooms and the holds from the passenger quarters. Above the lower deck the hull was built with a single skin, which terminated at a flush, continuous, cellular steel deck, corresponding to the shelter deck of modern steamships, which extended unbroken from stem to stern. This deck was an unusually rigid structure. Its upper and lower surfaces were each one inch in thickness, and each consisted of two layers of half-inch plating riveted together. The double deck thus formed was two feet in depth, and the intervening space was intersected by longitudinal girders, the whole construction forming an unusually stiff and strong watertight deck, which was admirably suited to meet the heavy tensional and compressive stresses, to which a ship of the length of the _Great Eastern_ is subjected when driving through head seas.

The watertight subdivision of the _Great Eastern_ was more complete than that of any ship that was ever constructed for the merchant service, more thorough even than that of recent passenger ships which have been designed for use as auxiliary cruisers in time of war. In addition to the great protection afforded by her double hull, she was subdivided by nine transverse bulkheads, which extended from the bottom clear through to the upper deck, or to a height of 30 feet above the water-line. Compare this with the practice followed in the _Titanic_ and in all but a very few of the merchant ships of the present day, whose bulkheads are carried up only from one-third to one-half of that height, and too often terminate at a deck which is not, in the proper sense of the term, watertight.

In addition to these main bulkheads, the _Great Eastern_ contained six additional transverse bulkheads, which extended to the iron lower deck. Five of these were contained in the machinery spaces and one was placed aft of the aftermost main bulkhead. The submerged portion of the hull, or rather all that portion of it lying below the lower deck, was thus divided by 15 transverse bulkheads into 16 separate watertight compartments.

[Illustration: From an old photograph, taken in 1860

GREAT EASTERN, LYING AT FOOT OF CANAL STREET, NORTH RIVER, NEW YORK]

Not content with this, however, Brunel ran throughout the whole of the machinery and engine spaces two longitudinal bulkheads, which extended from the bottom of the ship to the top deck. A further subdivision consisted of a curved steel roof which separated the boiler-rooms from the coal-bunkers above them. Altogether the hull of the _Great Eastern_ was divided up into between 40 and 50 separate watertight compartments. An excellent structural feature, from which later practice has made a wide departure, was the fact that no doors were cut through the bulkheads below the lower deck.

Such was the _Great Eastern_, a marvel in her time and an object lesson, even to-day, in safe and unsinkable construction. That her valuable qualities were not obtained at the cost of extravagance in the use of material is one of the most meritorious features of her design and construction. On this point we cannot do better than quote from the address of Sir William White, delivered when he was President of the Institution of Civil Engineers: "I have most thoroughly investigated the question of the weight absorbed in the structure of the _Great Eastern_, and my conclusion is that it is considerably less than that of steel-built ships of approximately the same dimensions and of the most recent construction. Of course these vessels are much faster, have more powerful engines, and have superstructures for passenger accommodation towering above the upper deck. These and other features involve additional weight; and the _Great Eastern_ has the advantage of being deeper in relation to her length than the modern ships. After making full allowance for these differences, my conclusion is that the _Great Eastern_ was a relatively lighter structure, although at the time she was built only iron plates of very moderate size were available."

CHAPTER VI

THE SINKABLE _TITANIC_

In all the long record of disasters involving the loss of human life there is none which appeals so strongly to the imagination as those which have occurred upon the high seas, and among these the loss of the _Titanic_ stands out preëminent as the most stupendous and heartrending tragedy of them all. The ship itself was not only the latest and largest of those magnificent ocean liners which, because of their size and speed and luxurious appointments, have taken such a strong hold upon the public imagination, but it was popularly believed that because of her huge proportions, and the special precautions which had been taken to render her unsinkable, the _Titanic_ was so far proof against the ordinary accidents of the sea as to survive the severest disaster and bring her passengers safely into port.

The belief that the _Titanic_ stood for the "last word" in naval architecture certainly seemed to be justified by the facts. She was not a contract-built ship in the commonly accepted sense of that term. On the contrary, she was built under a system which conduces to high-class workmanship and eliminates the temptations to cheap work, which must always exist when a contract is secured in the face of keen competition.

The famous White Star Company have pointed with pride to the fact that the excellence of their ships was due largely to the fact that they had been built in the same shipbuilding yard and under an arrangement which encouraged the builders to embody in the ships the most careful design and workmanship. Under this arrangement, Messrs. Harland & Wolff, of Belfast, build the White Star vessels without entering into any hard and fast agreement as to the price: the only stipulation of this character being that, when the ship is accepted, they shall be paid for the cost of the ship, plus a certain profit, which is commonly believed to be ten per cent.

[Illustration:

GREAT EASTERN 1858
FOUR WATERTIGHT COMPARTMENTS

TITANIC 1912
ONE WATERTIGHT COMPARTMENT

Titanic shows omission of inner skin, longitudinal bulkheads, and watertight decks. Transverse bulkheads are lower by 20 feet.

FIFTY YEARS' DECLINE IN SAFETY CONSTRUCTION]

Of the strength of the _Titanic_ and the general high character of her construction there can be no doubt whatever. Not only was she built to the requirements of the Board of Trade and the insurance companies, but, as we have noted, she was constructed by the leading shipbuilding company of the world, under conditions which would inspire them to put into the world's greatest steamship the very best that the long experience and ample facilities of the yard could produce.

The principal dimensions of the _Titanic_, as furnished by her owners, were as follows:

PARTICULARS OF THE _TITANIC_

	Ft.	Ins.
Length over all	882	9
Length between perpendiculars	850	0
Breadth extreme	92	6
Depth moulded to shelter deck	64	3
Depth moulded to bridge deck	73	3
Total height from keel to navigating bridge	104	0
Load draft	34	6
Gross tonnage	45,000	
Displacement in tons	60,000	
Indicated horsepower of reciprocating engines	38,000	
Shaft horsepower of turbine engine	22,000	

In this connection the following table, giving the dimensions of the most notable steamships, from the _Great Eastern_ of 1858 to the _Imperator_ of 1913, will be of interest. How rapidly the weight (displacement) increases with the length of these large ships, is shown by the fact that, although in length the _Titanic_ is only about 27 per cent. greater than the _Great Eastern_, in displacement she exceeds her by considerably over 100 per cent.

PARTICULARS OF NOTED TRANSATLANTIC LINERS

NAME	Date	Length between Perpendiculars	Beam	Plated Depth	Displacement	Horse-power	Speed
		Feet	Feet Ins.	Feet Ins.	Tons		Knots
Great Eastern	1858	680	83.0	58.0	27,000	7,650	14.0
City of Paris	1888	528	63.0	41.9	13,000	20,700	21.8
Teutonic	1890	565	57.6	42.2	12,000	19,500	21.0
Campania	1893	600	65.0	41.6	18,000	30,000	22.01
St. Paul	1895	536	63.0	42.0	16,000	18,000	21.08
K. Wilhelm der Grosse	1897	625	66.0	43.0	20,890	30,000	22.5
Oceanic	1899	685	68.5	49.0	28,500	27,000	20.7

Deutschland	1900	663	67.0	44.0	23,600	36,000	23.5
Kaiser Wilhelm II	1903	678	72.0	52.6	26,000	38,000	23.5
Adriatic	1907	709	75.6	56.9	40,800	16,000	17.0
Mauretania	1907	760	88.0	60.6	44,640	70,000	26.01
La France	1912	685	75.5	52.10	27,000	45,000	23.5
Titanic	1912	850	92.6	64.3	60,000	60,000	22.5
Imperator	1913	880	96.0	62.0	65,000	70,000	23.0

The general structure of the _Titanic_ is shown by the midship section, page 83, and the side elevation, page 129. For about 550 feet amidships she contained 8 steel decks, the boat deck, promenade deck, bridge deck, shelter deck, saloon deck, upper deck, middle deck, and lower deck. The highest steel deck that extended continuously throughout the full length of the ship was the shelter deck. For 550 feet amidships the sideplating of the ship was carried up one deck higher to the bridge deck. The moulded or plated depth of the ship to the shelter deck was 64 feet 3 inches and to the bridge deck 73 feet 3 inches. This great depth of over 73 feet, in conjunction with specially heavy steel decks on the bridge and shelter decks, and the doubling of the plating at the bilges, (where the bottom rounds up into the side,) conjoined with the deep and heavy double bottom, served to give the _Titanic_ the necessary strength to resist the bending stresses to which her long hull was subjected, when steaming across the heavy seas of the Atlantic. The doubling of the plating on the bridge and shelter decks served the same purpose as the cellular steel construction which, as mentioned in the previous chapter, was adopted for the upper deck of the _Great Eastern_.

[Illustration: Courtesy of the _Scientific American_

OLYMPIC, SISTER TO TITANIC, REACHING NEW YORK ON MAIDEN VOYAGE]

The dimensions of the frames and plating of the hull were determined by the builder's long experience in the construction of large vessels. The cellular double bottom, which extended the full width of the ship, was of unusual depth and strength. Throughout the ship, its depth was 5 feet 3 inches; but in the reciprocating engine-room, it was increased to 6 feet 3 inches. The keel consisted of a single thickness of plating, 1½ inches thick, and a heavy, flat bar, 3 inches in thickness and 19½ inches wide. Generally speaking, the shell plates were 6 feet wide, 30 feet long, and 2½ to 3 tons in weight. The largest of these plates was 36 feet long and weighed 4¼ tons.

Amidships, the framing, which consisted of channel sections 10 inches in depth, was spaced 3 feet apart. Throughout the boiler-room spaces, additional frames, 2½ feet deep, were fitted 9 feet apart, and in the engine- and turbine-rooms, similar deep frames were fitted on every second frame, 6 feet apart. These heavy web-frames extended up to the middle deck, a few feet above the water-line, and added greatly to the strength and stiffness of the hull.

Had the inside plating of the double bottom been carried up the sides and riveted on the inner flanges of these frames, as shown in the sketch on page 107, it would have served the purpose of an inner skin; and when the outer skin of her forward boiler-rooms was ruptured by the iceberg, it would have served to prevent the inflow of water to these two large compartments. Mr. Ismay, the President of the International Mercantile Marine Company, in his testimony at the Senate Investigation, stated that among the improvements, which would be made in the _Gigantic_, now under construction for the company, would be the addition of an inner skin. Doubtless he had in mind the construction above suggested.

The 10-inch channel frames extended from the double bottom to the bridge deck, and some of these bars were 66 feet in length and weighed nearly 1 ton apiece. The frames were tied together along the full length of each deck by the deck beams of channel section, which, throughout the middle portion of the ship, were 10 inches deep and weighed as high as 1¼ tons apiece. The transverse stiffness of the framing was assured by stout bracket knees, riveted to the frames and deck beams at each point of connection, and by the 15 watertight bulkheads, which were riveted strongly to the bottom and sides of the ship, and also by 11 non-watertight bulkheads, which formed the inner walls of the coal bunkers on each side of the main bulkheads.

The bridge, shelter, saloon, and upper decks were supported and stiffened by four lines of heavy longitudinal girders, worked in between the beams, which were themselves carried by solid round pillars placed at every third deck beam. In the boiler-rooms, below the middle deck, the load of the superincumbent decks was carried down to the double bottom by means of heavy round pillars.

Such was the construction of the _Titanic_; and it will be agreed that, so far as the strength and integrity of the hull were concerned, it was admirably adapted to meet the heavy stresses which are involved in driving so great and heavy a ship through the tempestuous weather of the North Atlantic.

The first sight of such a gigantic vessel as the _Titanic_ produces an impression of solidity and invulnerability, which is not altogether justified by the facts. For, to tell the truth, the modern steamship is a curious compound of strength and fragility. Her strength, as must be evident from the foregoing description of the framing of the _Titanic_, is enormous, and ample for safety. Her fragility and vulnerability lie in the fact that her framework is overlaid with a relatively thin skin of plating, an inch or so in thickness, which, while amply strong to resist the inward pressure of the water, the impact of the seas, and the tensile and compressive stresses due to the motion of the ship in a seaway, etc., is readily fractured by the blow of a collision.

[Illustration: THE FRAMING AND SOME OF THE DECK BEAMS OF THE IMPERATOR, AS SEEN FROM INSIDE THE BOW, BEFORE THE OUTSIDE PLATING WAS RIVETTED ON]

In a previous chapter it was shown that when the _Titanic_ is being driven at a speed of 21 knots, she represents an energy of over 1,000,000 foot-tons. If this enormous energy is arrested, or sought to be arrested, by some rigid obstruction, whether another ship, a rock, or an iceberg, the delicate outside skin will be torn like a sheet of paper.

It was shown in Chapter IV that protection against flooding of a ship through damage below the water-line is obtained by subdividing the hull into separate watertight compartments, and that, roughly speaking, the degree of protection is proportionate to the extent to which this subdivision is carried. Applying this to the _Titanic_, we find that she was divided by 15 transverse bulkheads into 16 separate compartments. But, in this connection it must be noted that these bulkheads did not extend through the whole height of the ship to the shelter deck, as they did in the case of the _Great Eastern_, and therefore it cannot be said that the whole of the interior space of the hull received the benefit of subdivision. As a matter of fact, only about two-thirds of the total cubical space contained below the shelter deck was protected by subdivision. Water, finding its way into the ship above the level of the decks to which the bulkheads were carried, was free to flow the whole length of her from stem to stern. Furthermore, the value of the subdivision below the bulkhead deck depends largely upon the degree to which this deck is made watertight. If the deck is pierced by hatchways, stairways, and other openings, which are not provided with watertight casings and hatch covers, the integrity of the deck is destroyed, and the bulkhead subdivision below loses its value.

It was largely this most serious defect--the existence of many unprotected openings in the bulkhead deck of the _Titanic_--that caused her to go down so soon after the collision.

[Illustration: THIS DRAWING SHOWS HOW THE PLATING OF THE INNER BOTTOM OF SUCH A SHIP AS THE TITANIC MAY BE CARRIED UP THE SIDE FRAMES TO FORM AN INNER SKIN]

Referring now to the side elevation of the Titanic on page 129, it will be noted that the only bulkhead which was carried up to the shelter deck was the first, or collision bulkhead. The second bulkhead extended to the saloon deck, and on the after side of this and immediately against it was a spiral stairway for the accommodation of the crew, which led from their quarters down to the floor of the ship. Here the stairway terminated in a fireman's passage, which led aft through the third and fourth bulkheads, and gave access through a watertight door to the foremost boiler-room. The seven bulkheads, from No. 3 to No. 9, extended only to the upper deck, which, at load draft, was only about 10 feet above the water-line. Bulkhead No. 10 was carried up one deck higher to the saloon deck, as were also bulkheads 11, 12, 13, and 14. Bulkhead No. 15 terminated at the upper deck.

Now, it will be asked: what was the factor in the calculations which determined the height of these bulkheads? The answer is to be found in the Board of Trade stipulations, to which reference was made in Chapter IV, page 62. These stipulations establish an imaginary safety line, below which a ship may not sink without danger of foundering. The safety line represents the depth to which a ship will sink when any two adjoining compartments are opened to the sea and therefore flooded. If the two forward compartments are flooded, for instance, the bow may sink with safety, until the water is only three one-hundredths of the depth of the ship, at the side, from the bulkhead deck. If two central compartments are flooded, the ship is supposed to settle with safety until the bulkhead deck at that point is only three one-hundredths of the depth of the side, at that place, above the water.

The raising of the height of the bulkheads, by one deck, at the engine-room, is due to the operation of this rule; for here the two adjoining compartments, those containing the reciprocating engines and the turbine, are the largest in the ship, and their flooding would sink the ship proportionately lower in the water.

Now it takes but a glance at the diagrams on page 66 to show that the application of the Board of Trade rule brought the bulkhead line of the _Titanic_ down to a lower level than that of any of the other notable ships shown in comparison with her. It was the low bulkheads, acting in connection with the non-watertight construction of the bulkhead deck, that was largely answerable for the loss of this otherwise very fine ship.

[Illustration: Courtesy of _Scientific American_

TWENTY OF THE TWENTY-NINE BOILERS OF THE TITANIC ASSEMBLED, READY FOR PLACING IN THE SHIP]

Another grave defect in the _Titanic_ was the great size of the individual compartments, coupled with the fact that the only protection against their being flooded was the one-inch plating of the outside skin. If this plating were ruptured or the rivets started along the seams, there was nothing to prevent the flooding of the whole compartment and the entry, at least throughout the middle portion of the ship, of from 4,000 to 6,000 tons of water--this last being the approximate capacity of the huge compartment which contained the two reciprocating engines. Now, if safety lies in minute subdivision, it is evident that in this ship safety was sacrificed to some other considerations. The motive for the plan adopted was the desire to place the coal-bunkers in the most convenient position with regard to the boilers. By reference to the hold plan of the _Titanic_, page 129, it will be seen that her 29 boilers were arranged transversely to the ship. With the exception of the five in the aftermost compartment, they were "double-ended," with the furnaces facing fore and aft. To facilitate shovelling the coal into the furnaces, the coal-bunkers were placed one on each side of each transverse watertight bulkhead. The coal supply was thus placed immediately back of the firemen, and the work of getting the coal from the bunkers to the furnaces was greatly facilitated. Now, while this was an admirable arrangement for convenience of firing, it was the worst possible plan as far as the safety of the _Titanic_ was concerned; since any damage to the hull admitted water across the whole width of the ship. The alternative plan, which should be made compulsory on all large ocean-going passenger steamers, is the one adopted for the _Mauretania_, _Kaiser Wilhelm II_, _Imperator_, and a few other first-class ships, in which the coal-bunkers are placed at the sides of the ship, where they serve to prevent the flooding of the main boiler-room compartments. It is probable that any one of the ships named would have survived even the terrific collision which sank the _Titanic_.

The objection has been raised against longitudinal coal-bunkers, that they are not so conveniently placed for the firemen. A large force of "coal passers" has to be employed in wheeling the coal from the bunkers to the front of the furnaces. This, of course, entails an increased expense of operation.

The use of transverse coal-bunkers must be regarded as one among many instances, in which the safety of passenger ships is sacrificed to considerations of economy and convenience of operation.

CHAPTER VII

HOW THE GREAT SHIP WENT DOWN

The _Titanic_, fresh from the builder's hands, sailed from Southampton, Wednesday, April 10, 1912. She reached Cherbourg on the afternoon of the same day, and Queenstown, Ireland, at noon on Thursday. After embarking the mails and passengers, she left for New York, having on board 1,324 passengers and a ship's complement of officers and crew of 899 persons. The passenger list showed that there were 329 first-class, 285 second-class, and 710 third-class passengers.

The weather throughout the voyage was clear and the sea calm. At noon on the third day out, a wireless message was received from the _Baltic_, dated Sunday, April 14, which read: "Greek steamship _Athinai_ reports passing icebergs and large quantity of field ice to-day in latitude 41.51 north, longitude 49.52 west." At about 7 P.M. a second warning was received by the _Titanic_, this time from the _Californian_, which reported ice about 19 miles to the northward of the track on which the _Titanic_ was steaming. The message read: "Latitude 42.3 north, longitude 49.9 west. Three large bergs five miles to southward of us." Later there was a third message: "_Amerika_ passed two large icebergs in 41.27 north, 50.8 west on the 14th of April." A fourth message, sent by the _Californian_, reached the ship about an hour before the accident occurred, or about 10.40 o'clock, which said: "We are stopped and surrounded by ice."

[Illustration: Copyright by Underwood & Underwood, N. Y.

THE LAST PHOTOGRAPH OF THE TITANIC, TAKEN AS SHE WAS LEAVING SOUTHAMPTON ON HER MAIDEN VOYAGE]

These wireless warnings prove that the captain of the _Titanic_ knew there was ice to the north, to the south, and immediately ahead of the southerly steamship route on which he was steaming. The evidence shows that Captain Smith remarked to the officer doing duty on the bridge, "If it is in a slight degree hazy we shall have to go very slowly." The officer of the watch instructed the lookouts to "keep a sharp lookout for ice." The night was starlit and the weather exceptionally clear.

After leaving Queenstown the speed of the _Titanic_ had been gradually increased. The run for the first day was 464 miles, for the second 519 miles, and for the third day, ending at noon Sunday, it was 546 miles. Testimony given before the Court of Inquiry under Lord Mersey, showed that the Chief Engineer had arranged to drive the vessel at full speed for a few hours either on Monday or Tuesday. Twenty-one of the twenty-nine boilers were in use until Sunday night, when three more were "lighted." It is evident that the engines were being gradually speeded up to their maximum revolutions. Both on the bridge and in the engine-room there was a manifest reluctance to allow anything to interfere with the full-speed run of the following day. This is the only possible explanation of the amazing fact that, in spite of successive warnings that a large icefield with bergs of great size was drifting right across the course of the _Titanic_, fire was put under additional boilers and the speed of the ship increased.

It was shown in a previous chapter on "The Dangers of the Sea," that one of the greatest risks of high-speed travel across the North Atlantic is a certain spirit of _sangfroid_ which is liable to be begotten of constant familiarity with danger and a continual run of good luck. If familiarity ever bred contempt, surely it must have done so among the captain and officers of the _Titanic_ on that fatal night. One looks in vain for evidence that the situation was regarded as highly critical and calling for the most careful navigation;--calling, surely, for something more than the mere keeping of a good lookout--an imperative duty at all times, whether by day or night. Yet the fate of that ship and her precious freight of human life hung upon the mere chance of sighting an obstruction in time to avoid collision by a quick turn of the helm. The question of hitting or missing was one not of minutes but of seconds. A ship like this, nigh upon a thousand feet in length, makes a wide sweep in turning, even with the helm hard over. At 21 knots the _Titanic_ covered over a third of a mile in a minute's time. Even with her engines reversed she would have surged ahead for a half mile or so before coming to a stop. Should she strike an obstruction at full speed, the blow delivered would equal that of the combined broadsides of two modern dreadnoughts.

[Illustration: Photograph by Underwood & Underwood, N. Y.

The elimination of swimming pools, squash courts and summer gardens would cover the cost of additional bulkheads and inner skins.

SWIMMING POOL ON THE TITANIC]

And so the majestic ship swept swiftly to her doom--a concrete expression of man's age-long struggle to subdue the resistless forces of nature--a pathetic picture both of his power and his impotence. As she sped on under the dim light of the stars, not a soul on board dreamed to what a death-grapple she was coming with the relentless powers of the sea. Latest product of the shipbuilder's art, she was about to brush elbows with another giant of the sea, launched by nature from the frozen shipyards of the north, and she was to reel from the contact stricken to the death like the fragile thing she was!

At 11.46 P.M. the sharp warning came from the lookout: "Iceberg right ahead." Instantly the engines were reversed and the helm was put hard a-starboard. A few seconds earlier and she might have cleared. As it was, she struck an underwater, projecting shelf of the iceberg, and ripped open 200 feet of her plating, from forward of the collision bulkhead to a few feet aft of the bulkhead separating boiler-rooms numbers 5 and 6. It was a death wound! How deeply the iceberg cut into the fabric of the ship will never be known. Probably the first incision was deep and wide, the damage, as the shelf of ice was ground down by contact with the framing and plating of the ship becoming less in area as successive compartments were ruptured.

[Illustration: Courtesy of _Scientific American_

THE TITANIC STRUCK A GLANCING BLOW AGAINST AN UNDER-WATER SHELF OF THE ICEBERG, OPENING UP FIVE COMPARTMENTS. HAD SHE BEEN PROVIDED WITH A WATERTIGHT DECK AT OR NEAR THE WATER LINE, THE WATER WHICH ENTERED THE SHIP WOULD HAVE BEEN CONFINED BELOW THAT DECK, AND THE BUOYANCY OF THAT PORTION OF THE SHIP ABOVE WATER WOULD HAVE KEPT HER AFLOAT. AS IT WAS, THE WATER ROSE THROUGH OPENINGS IN THE DECKS AND DESTROYED THE RESERVE BUOYANCY]

Whatever may have been the depth of the injury, it is certain from the evidence that the six forward compartments were opened to the sea. Immediately after the collision the whistling of air, as it issued from the escape pipe of the forepeak tank, indicated that the tank was being filled by an inrush of water. The three following compartments, in which were located the baggage-room and mail-room, were quickly flooded. Leading fireman Barrett, who was in the forward boiler-room, felt the shock of the collision. Immediately afterwards he saw the outer skin of the ship ripped open about two feet above the floor, and a large volume of water came rushing into the ship. He was quick enough to jump through the open door in the bulkhead separating boiler-rooms 6 and 5, before it was released from the bridge. The damage just abaft of this bulkhead admitted water to the forward coal-bunker of room No. 5, which held for a while, but being of non-watertight and rather light construction, must have soon given way; for the same witness testified to a sudden rush of water coming across the floor-plates between the boilers.

In spite of the frightful extent of the damage, the _Titanic_, because of the great height to which her plated structure extended above the water-line, and the consequent large amount of reserve buoyancy which she possessed, would probably have remained afloat a great many hours longer than she did, had the deck to which her bulkheads extended been thoroughly watertight. As it was, this deck (upper deck E) was pierced by hatchways and stairways which, as the bow settled deeper and deeper, permitted the water to flow up over the deck and pass aft over the tops of the after bulkheads and so-called watertight compartments. See page 129.

Now, it so happened that for the full length of the boiler-rooms there had been constructed on upper deck E what was known as the "working-crew alleyway." On the inboard side of this passage six non-watertight doors opened on to as many iron ladders leading down to the boiler-rooms. Not only were these doors non-watertight, but they consisted of a mere open frame or grating, this construction having been adopted, doubtless, for purposes of ventilation. Unfortunately, although there was a watertight door at the after end of this alleyway, there was none at its forward end. The water which boiled up from the forward flooded compartments, as it flowed aft, poured successively through the open grating of the alleyway doors, flooding the compartments below, one after the other.

[Illustration:

TITANIC 1912

MAURETANIA 1906

Titanic: Single skin, 16 compartments; _Mauretania_: double skin, 34 compartments.

COMPARISON OF SUBDIVISION IN TWO FAMOUS SHIPS]

It does not take a technically instructed mind to understand from this that the safety elements of the construction of the _Titanic_ were as faulty above the water-line as they were below it. The absence of an inner skin and the presence of these many openings in her bulkhead deck combined to sink this huge ship, whose reserve buoyancy must have amounted to at least 80,000 tons, in the brief space of two and one-half hours.

Not until the designer, Mr. Andrews, had made known to the captain that the ship was doomed was the order given to man the lifeboats. The lifeboats, forsooth! Twenty of them in all with a maximum accommodation, if every one were loaded to its full capacity, of something over one thousand, for a ship's company that numbered 2,223 in all. Just here, in this very fatal discrepancy, is to be found proof of the widespread belief that a great ship like the _Titanic_ was practically unsinkable, and therefore in times of dire stress such as this, was well able to act as its own lifeboat until rescuing ships, summoned by wireless, should come to her aid.

The manner of the stricken ship's final plunge to the bottom may be readily gathered from the stories told by the survivors. As compartment after compartment was filled by overflow from the decks above, her bow sank deeper and her stern lifted high in the air, until the ship, buoyed up by her after compartments, swung almost vertically in the water like a gigantic spar buoy. In this unaccustomed position, her engines and boilers, standing out from the floor like brackets from a wall, tore loose from their foundations and crashed down into the forward part of the ship. Probably it was the muffled roar of this falling machinery that caused some of the survivors to imagine that they witnessed the bursting of boilers and the breaking apart of the hull. As a matter of fact, the shell of the _Titanic_ went to the bottom practically intact. One by one the after compartments gave way, until the ship, weighted at her forward end with the wreckage of engine- and boiler-rooms, sank, straight as an arrow, to bury herself deep in the ooze of the Atlantic bottom two miles below. There, for aught we know, with several hundred feet of her hull rising sheer above the ocean floor, she may now be standing, a sublime memorial shaft to the fifteen hundred souls who perished in this unspeakable tragedy!

[Illustration: Photograph by Underwood & Underwood, N. Y.

Smaller rooms would admit of higher bulkheads and better fire-protection.

THE VAST DINING-ROOM OF THE TITANIC]

CHAPTER VIII

WARSHIP PROTECTION AGAINST RAM, MINE, AND TORPEDO

The most perfect example of protection by subdivision of the hull into separate compartments is to be found in the warship. It is safe to say that there is no feature of the design to which more careful thought is given by the naval constructor than this. Loss of stability in a naval engagement means the end of the fight so far as the damaged ship is concerned. Nay, even a partial loss of stability, causing the ship to take a heavy list, may throw a ship's batteries entirely out of action, the guns on the high side being so greatly elevated and those on the low side so much depressed, that neither can be effectively trained upon the enemy. Furthermore, deep submergence following the entrance of large quantities of water, will cut down the ship's speed; with the result, either that she must fall out of line or the speed of the whole fleet must be reduced.

In the battle of the Sea of Japan it was the bursting of heavy 12-inch shells at or just below the water-line of the leading ship of the Russian line that sent her to the bottom before she had received any serious damage to her main batteries. Later in the fight, several other Russian battleships capsized from the same cause, assisted by the weight of extra supplies of coal which the Russians had stowed on the upper decks above the water-line.

[Illustration: Courtesy of _U. S. Navy Department_

Below the water line this ship is divided into 500 water-tight compartments.

THE UNITED STATES BATTLESHIP KANSAS]

In the matter of subdivision as a protection against sinking, there is this important difference between the merchant ship and the warship, that, whereas the merchant ship is sunk through accident, the warship is sunk by deliberate intention. The amount of damage done to the former ship will be great or small according to the accidental conditions of the time; but the damage to the warship is the result of a deliberately planned attack, and is wrought by powerful agencies, designed to execute the maximum amount of destruction with every blow delivered.

A large proportion of the time and money which have been expended in the development of the instruments of naval warfare has been devoted to the design and construction of weapons, whose object is to sink the enemy by destroying the integrity of the submerged portion of the hull. Chief among these weapons are the ram, the torpedo, and the mine. There can be no question that the damage inflicted by the ram of a warship would be far greater, other things being equal, than that inflicted by the bow of a merchant ship. The ram is built especially for its purpose. Not only is it an exceedingly stiff and strong construction; but it is so framed and tied into the bow of the warship, that it will tear open a long, gaping wound in the hull of the enemy before it is broken off or twisted out of place. The bow of the merchant vessel is a relatively frail structure, and many a ship that has been rammed has owed its salvation to the fact that immediately upon contact, the bow of the ramming ship is crumpled up or bent aside, and the depth of penetration into the vessel that is rammed is greatly limited. Furthermore, because of its underwater projection, the ram develops the whole force of the blow beneath the water-line, where the injury will be most fatal. Even more potent than the ram is the torpedo, which of late years has been developed to a point of efficiency in range, speed, and destructive power which has rendered it perhaps the most dreaded of all the weapons of naval warfare. The modern torpedo carries in its head a charge of over 200 pounds of guncotton and has a range of 10,000 yards. Ordinarily, it is set to run at a depth of 10 to 12 feet below the water; and should it get home against the side of a ship, it will strike her well below the armour belt and upon the relatively thin plating of the hull.

Most destructive of all weapons for underwater attack, however, is the mine, which sent to the bottom many a good ship during the Russo-Japanese war. The more deadly effects of the mine, as compared with the torpedo, are due to its heavy charge of high explosive, which sometimes reaches as high as 500 pounds. Contact, even with a mine, is not necessarily fatal; indeed the notable instances in which warships have gone to the bottom immediately upon striking a mine have been due to the fact that the mine exploded immediately under, or in close proximity to the ship's magazines, which, being set off by the shock, tore the ship apart and caused her to go down within a few minutes' time. This was what happened to our own battleship _Maine_ in Havana harbour, and to the Russian battleship _Petropavlovsk_ and the Japanese battleship _Hatsuse_ at Port Arthur.

Enough has been said to prove that when the naval architect undertakes to build a hull that will be proof against the blow, not merely of one but of several of these terrific weapons, he has set himself a task that may well try his ingenuity to the utmost. Protection by heavy armour is out of the question. The weight would be prohibitive and, indeed, all the side armour that he can put upon the ship is needed at the water-line and above it, as a protection against the armour-piercing, high-explosive shells of the enemy.

Heavy armour, then, being out of the question, he has to fall back upon the one method of defense left at his disposal,--minute subdivision into watertight compartments. Associated with this is the placing at the water-line of a heavy steel deck, known as the protective deck, which extends over the whole length and breadth of the hull and is made thoroughly watertight.

[Illustration: Courtesy of Robinson's "Naval Construction"

HOLD PLAN.

INBOARD PROFILE.

These drawings show the minute subdivision of a battleship. Below the protective deck (shown by heavy line) the hull contains 500 water-tight compartments.

PLAN AND LONGITUDINAL SECTION OF THE BATTLESHIP CONNECTICUT]

The double-skin construction, which was used to such good effect in the _Great Eastern_, is found in every large warship; and in a battleship of the first class, the two skins are spaced widely apart, a spacing of three or more feet being not unusual. The double-hull construction, with its exceedingly strong framing, is carried up to about water-line level, where it is covered in by the protective deck above referred to. Below the protective deck the interior is subdivided into a number of small compartments by transverse bulkheads, which extend from the inner bottom to the protective deck, and from side to side of the ship. The transverse compartments thus formed are made as small as possible, the largest being those which contain the boilers and engines. Forward and aft of the boiler- and engine-room compartments the transverse bulkheads are spaced much closer together, the uses to which these portions of the ship are put admitting of more minute subdivision.

By the courtesy of Naval Constructor R. H. M. Robinson, U.S.N., we reproduce on page 143 from his work "Naval Construction" a hold plan and an inboard profile of a typical battleship,--the _Connecticut_,--which give a clear impression of the completeness with which the interior is bulkheaded. Although the ship shown is less than one-half as long as the _Titanic_, she has 27 transverse bulkheads as against the 15 on the larger ship; and all but nine of these are carried clear across the ship from side to side.

Equally complete is the system of longitudinal bulkheads. Most important of these is a central bulkhead, placed on the line of the keel, and running from stem to stern. On each side of this and extending the full length of the machinery spaces, is another bulkhead, which forms the inner wall of the coal-bunkers. Forward and aft of the machinery spaces are other longitudinal bulkheads, which form the fore-and-aft walls of the handling-rooms and ammunition-rooms.

To appreciate the completeness of the subdivision, we must look at the inboard profile and note that the spaces forward and aft of the engine- and boiler-rooms are further subdivided, in horizontal planes, by several steel, watertight decks or "flats," as they are called.
Including the compartments enclosed between the walls of the double hull, the whole interior of the battleship _Connecticut_, below the protective deck, is divided up into as many as 500 separate and perfectly watertight compartments.

Moreover, in some of the latest battleships of the dreadnought type the practice has been followed of permitting no doors of any description to be cut through the bulkheads below the water-line. Access from one compartment to another can be had only by way of the decks above. Furthermore, all the openings through the protective deck are provided with strong watertight hatches or, as in the case of the openings for the smoke stacks, ammunition-hoists, and ventilators, they are enclosed by watertight steel casings, extending to the upper decks, far above the water-line.

In the later warships, further protection is afforded by constructing the first deck above the protective deck of heavy steel plating and making it thoroughly watertight, every opening in this deck, such as those for stairways, being provided with watertight steel hatches. This deck, also, is thoroughly subdivided by bulkheads and provided with watertight doors.

It sounds like a truism to say that a watertight bulkhead must be watertight; yet it is a fact that only in the navy are the proper precautions taken to test the bulkheads and make sure that they will not leak when they are subjected to heavy water pressure. Before a ship is accepted by the government, every compartment is tested by filling it with water and placing it under the maximum pressure to which it would be subjected if the ship were deeply submerged. If any leaks are observed in the bulkheads, decks, etc., they are carefully caulked up, and the test is repeated until the bulkhead is absolutely tight.

Now, here is a practice which should be made compulsory in the construction of all passenger-carrying steamships. Only by filling a compartment with water is it possible to determine whether that compartment is watertight. To send an important ship to sea without testing her bulkheads is an invitation to disaster. The amount of water that may find its way through a newly-constructed bulkhead is something astonishing; for although the leakage along any particular joint or seam of the plating may be relatively small, the aggregate amount will be surprisingly large.

[Illustration: Between the boiler rooms and the sea are four, separate, watertight walls of steel. The whole is covered in by a 3-inch watertight steel deck.

MIDSHIP SECTION OF A BATTLESHIP]

Let us now pass on to consider the actual efficiency of the watertight subdivision as thus so carefully worked out in the modern warship. Thanks to the Russo-Japanese war, which afforded a supreme test of the underwater protection of ships, the value of the present methods of construction has been proved to an absolute demonstration.

The following facts, which, were given to the writer by Captain (now Admiral) von Essen of the Russian Navy, at the close of the Russo-Japanese war, and were published in the "Scientific American," serve to show what great powers of resistance are conferred on a warship by the system of subdivision above described. The story of the repeated damage inflicted and the method of extemporised repairs adopted, is so full of interest that it is given in full:

"Immediately after the disaster of the night of February 8th," when the Japanese, in a surprise attack, torpedoed several of the Russian ships, "the cruiser _Pallada_ was floated into drydock, and the battleships _Czarevitch_ and _Retvizan_ were taken into the inner harbour, and repairs executed by means of caissons of timber, built around the gaping holes which had been blown into their hulls by torpedoes. The repairs to the _Pallada_ were completed early in April, and about the 20th of June the _Czarevitch_ and _Retvizan_ were also in condition to take the sea. On the 13th of April, during the sortie in which the _Petropavlovsk_ was sunk with Admiral Makaroff on board, the battleship _Pobieda_, in returning to the harbour, struck a contact mine, and was heavily damaged. Similar repairs were executed, and this ship was able to take her station in the line in the great sortie of August 10.

"On June 23 Captain von Essen's ship, the _Sevastopol_, was sent outside the harbour to drive off several Japanese cruisers that were shelling the line of fortifications to the east of Port Arthur. This she accomplished; but in returning she struck a Japanese mine, which blew in about 400 square feet on the starboard side, abaft the foremast, at a depth of about 7 feet below the water-line. The rent was from 7 to 10 feet in depth and 35 to 40 feet in length. The frames, ten in all, were bent inward, or torn entirely apart, and the plating was blown bodily into the ship. She was taken into the inner harbour, where the injured portion of the hull was enclosed by a timber caisson in the manner shown in the engravings on page 155. The caisson--a rectangular, three-sided chamber--was built of 9-in. by 9-in. timbers, tongued and grooved and carefully dovetailed. The floor of the caisson abutted against the bilge keel. The outer wall, which was at a distance of about 10 feet from the hull, had a total depth of about 34 feet, the total length of the caisson being about 75 feet. Knee-bracing of heavy timbers was worked in between the floor and the walls, and the construction was stiffened by heavy, diagonal bolts, which passed through from floor to outside wall, as shown in the drawing. Watertight contact between the edge of the caisson and the hull of the ship was secured by the use of hemp packing covered with canvas. The whole of the outside of the caisson was covered with canvas, and upon this was laid a heavy coating of hot tar. The caisson was then floated into position and drawn up snugly against the side of the ship by means of cables, some of which passed underneath the ship and were drawn tight on the port side, while others were attached to the top edge of the caisson and led across to steam winches on deck. After the water had been pumped out, the hydraulic pressure served to hold the caisson snugly against the hull. The damaged plating and broken frames were then cut away; new frames were built into the ship, the plating was riveted on, and the vessel was restored to first-class condition without entering drydock.

[Illustration: The battleship _Sevastopol_ was twice struck by a mine; but she remained afloat and was repaired by the use of caissons without entering dry dock.

SAFETY LIES IN SUBDIVISION]

"On September the 20th, during operations outside the harbour, the _Sevastopol_ again struck a mine, and by a curious coincidence she was damaged in the exact spot where she received her first injury. This time, however, the mine was much larger and it was estimated to have contained fully 400 pounds of high explosive. The shock was terrific and the area of the injury was fully 700 square feet. The ship immediately took a heavy list to starboard, which was corrected by admitting water to compartments on the port side. She was brought back into the harbour, and a repair caisson was again applied. The repairing of this damage was, of course, a longer job. Moreover, it was done at a time when the Japanese 11-inch mortar batteries were getting the range and making frequent hits. One 11-inch shell struck the bridge just above the caisson and, when it burst, a shower of heavy fragments tore through the outer wall of the caisson, letting in the water and necessitating extensive repairs. Nevertheless, the _Sevastopol_ was again put in seaworthy condition, this time the repairs taking about two and one-half months' time. During the eleven months of the siege of Port Arthur five big repair jobs of the magnitude above described were completed, and over one dozen perforations of the hull below water, due to heavy projectiles, were repaired, either in drydock or by the caisson method."

Now, when it is remembered that the _Sevastopol_ was not a new ship, and that her internal subdivision was not nearly so complete as that which is found in the most modern battleships, it will be realised how effective are properly built bulkheads and thoroughly watertight compartments against even the most extensive injury to the outer shell of a ship. It is claimed for the latest battleships of the dreadnought type, built for the United States Navy, that they would remain afloat, even after having been struck by three or four torpedoes.

Now, it is inexpedient to build merchant ships with such an elaborate system of watertight compartments as that described in this chapter. Considerations of cost and convenience of operation render this impossible; but it is entirely possible to incorporate in the large passenger steamers a sufficient degree of protection of this character to render them proof against sinking by the accidents of collision, whether with another ship, a derelict, or even with the dreaded iceberg.

The manner in which the problem has been worked out in several of the most noted passenger steamers of the present day is reserved for discussion in the following chapter.

[Illustration: This ship has twenty-four compartments below the water line. Fire-bulkheads protect passenger decks.

THE 65,000-TON, 23-KNOT IMPERATOR--LARGEST SHIP AFLOAT]

CHAPTER IX

WARSHIP PROTECTION AS APPLIED TO SOME OCEAN LINERS

It was shown in the previous chapter that the most completely protected vessel, so far as its flotation is concerned, is the warship, and plans were given of a battleship whose hull below the water-line was subdivided into no less than five hundred separate watertight compartments. Facts were cited from the naval operations in and around the harbour of Port Arthur, which prove that the battleship is capable of sustaining an enormous amount of injury below the water-line without going to the bottom.

Now, if it were possible to apply subdivision to the large ocean liners on the liberal scale on which it is worked out in ships of war, it would not be going too far to say that they would be absolutely unsinkable by any of the usual accidents of collision. The 60,000-ton _Titanic_, were she subdivided as minutely as the warship shown on page 143, would contain at least 1,500 separate compartments below her lower deck, and under these conditions even the long rent which was torn in her plating would have done no more than set her down slightly by the head. Her pumps would have taken care of the leakage of water through the bulkheads, and the ship would have come into New York harbour under her own steam.

But a warship and a passenger ship are two very different propositions. The one, being designed to resist the attack of an implacable enemy, who is using every weapon that the ingenuity of man can devise to effect its destruction, is built with little if any regard to the cost. The other, built as a commercial proposition for the purpose of earning reasonable dividends for its owners, and exposed only to such risks of damage as are incidental to ocean transportation, is constructed as economically as reasonable considerations of strength and safety may permit.

Another important limitation which renders it impossible to give a passenger ship the elaborate subdivision of a warship, is the necessity of providing large cargo spaces and wide hatchways for the convenient handling and stowage of the freight, upon which a large proportion of the passenger-carrying vessels chiefly depend for their revenue.

[Illustration: Courtesy of _Scientific American_

Longitudinal bulkheads form an inner skin through machinery spaces. Transverse bulkheads extend two decks (20 feet) above water line, the height increasing towards the ends.

LONGITUDINAL SECTION AND PLAN OF THE IMPERATOR]

On the other hand, the main features of warship protection may be so applied to the large merchant ship as to render her as proof against collision with icebergs, derelicts, or with other vessels, as the warship is against the blow of the ram, the mine, or the torpedo. And the merchant ship of the size of our largest ocean liners has the great advantage over the warship (provided that the average size of her compartments be not too greatly increased) that her great size is in itself a safeguard against sinking.

By way of showing what can be done in applying warship principles of subdivision to merchant vessels, we shall consider in some detail three notable ships, the _Mauretania_, the _Kronprinzessin Cecilie_, and the recently launched _Imperator_.

The _Mauretania_ and her sister, the _Lusitania_, were built under an agreement with the British Government, who stipulated that they would provide a sum sufficient to pay for the new vessels not to exceed $13,000,000, secured on debentures at 2¾ per cent. interest. The two ships were to be of large size and capable of maintaining a minimum average ocean speed of 24½ knots in moderate weather. The government also agreed that if the ships fulfilled these conditions, the Cunard Company was to be paid annually $750,000.00. In return for this extremely liberal assistance, the Cunard Company agreed to employ them in the British mail-carrying service; to so construct them that they would be available for use as auxiliary cruisers; and to hold them at the instant service of the government in case of war. In addition to holding the ships at the service of the government, it was agreed that all the officers and three-fourths of the crew should be British subjects, and that a large proportion should belong to the Royal Naval Reserve. The ships were thus to be utilised as a training school for officers and seamen, and with this point in view a record of the personnel was to be made each month.

The particulars of these two ships as finally constructed are as follows: Length over all 790 feet; beam, 88 feet; displacement, 46,000 tons; and horsepower, 70,000. Both vessels greatly exceeded the contract speed of 24½ knots, the _Lusitania_ having maintained over 25½ knots and the _Mauretania_ 26 knots for the whole run across the Atlantic.

[Illustration: THE ROTOR, OR ROTATING ELEMENT, OF ONE OF THE LOW-PRESSURE TURBINES OF THE IMPERATOR. DIAMETER OVER TIPS OF BLADES IS 18 FEET]

The purpose of the present chapter is to show how successfully the methods of underwater protection employed in naval ships may be applied to passenger ships of the first class; and the _Mauretania_ is given first consideration, for the reason that she is the best example afloat to-day of a merchant ship fully protected against sinking by collision. The protective elements may be summed up as consisting of multiple subdivision, associated with a complete inner skin and a watertight steel deck, answering to the heavy protective deck at the water-line of the warship. By reference to the hold plan on page 129 it will be noticed that she is subdivided by 22 transverse bulkheads, 12 of which extend entirely across the ship and 10 from the side inboard to the longitudinal bulkheads. The space devoted to the turbine engines is subdivided by two lines of longitudinal bulkheading, and the compartment aft of the engine-room spaces is divided by a longitudinal bulkhead placed upon the axis of the ship. Altogether there are 34 separate watertight compartments below the water-line. The most important feature of the subdivision is the two lines of longitudinal bulkheads, which extend each side of the boiler-rooms and serve the double purpose of providing watertight bunker compartments and protecting the large boiler-room compartments from being flooded, in the event of damage to the outer skin of the ship. The main engine-room, containing the low-pressure turbines, is similarly protected against flooding.

Now, all of these bulkheads are carried up to a watertight connection with the upper deck, which, amidships, is over two decks, or say about 20 feet above the water-line, the exception being the first or collision bulkhead, which extends to the shelter deck. A most important feature of the protection, borrowed from warship practice, is that the lower deck, which, amidships, is located at about the water-line, is built of extra heavy plating, and is furnished with strong watertight hatches. It thus serves the purpose of a protective deck, and water, which flooded any compartment lying below the water-line, would be restrained by this deck from finding its way through to the decks above. The _Mauretania_, therefore, could sustain an enormous amount of damage below the water-line without foundering. It is our belief that she would have survived the disaster which sank the _Titanic_. The first three compartments would have been flooded, it is true, but the water would have been restrained from her large forward boiler-compartment by the "inner skin" of the starboard bunkers. Furthermore, the watertight hatches of her lower, or protective, deck would have prevented that upward flow of water on to the decks above, which proved so fatal to the _Titanic_.

[Illustration: In addition to transverse and longitudinal bulkheads, this ship has fire bulkheads in the passenger spaces.

THE 26,000-TON, 23½-KNOT KRONPRINZESSIN CECILIE, A THOROUGHLY PROTECTED SHIP]

In dealing with the question of safety, the German shipbuilders have shown that thorough study of the problem which characterises the German people in all their industrial work. Although German ships of the first class, such as the _Kronprinzessin Cecilie_ and the _Imperator_ are not built to naval requirements, they embody many of the same protective features as are to be found in the _Mauretania_ and _Lusitania_, and, indeed, in some safety features, and particularly in those built in the ship as a protection against fire, they excel them.

The existence of side bunkers, small compartments, and bulkheads carried well up above the water-line, is due to the close supervision and strict requirements of the German Lloyd and the immigration authorities, and it takes but a glance at the hold plan of the _Kronprinzessin Cecilie_ to show how admirably this ship and her sister are protected against collision. There are 21 transverse bulkheads, 18 of which are shown in the hold plan, the other three being sub-bulkheads, worked in the after part of the ship abaft of the machinery spaces. The four engines are contained in four separate compartments, and the boiler-rooms are entirely surrounded by coal-bunkers. These, the largest compartments, are protected throughout their entire length by the inner skin of the coal-bunker bulkheads. The engine-rooms are further protected by extending the inner floor of the double bottom up the sides as shown on page 176. Altogether, the hold plan shows 33 separate, watertight compartments. The collision bulkhead is carried up to the shelter deck, and the other bulkheads terminate at the main deck, which is about 19 feet above the normal water-line.

[Illustration: This well-protected ship has side coal bunkers, and inner skin in engine-rooms. There are thirty-three compartments below the water-line.

HOLD PLAN OF KRONPRINZESSIN CECILIE]

It is greatly to the credit of the Germans that they have given such careful attention to the question of fire protection. We have shown in a previous chapter that the long stretch of staterooms, with alleyways several hundred feet in length running through them, offer dangerous facilities for the rapid spread of a fire, should it once obtain a strong hold on the inflammable material of which the stateroom partitions and furnishings are composed. On the _Kaiser Wilhelm II_ and _Cecilie_ the passenger accommodations on the main deck are protected against the spread of fire by four steel bulkheads, which extend from side to side of the ship. Where the alleyways intersect these bulkheads, fire-doors are provided which are closed by hand and secured by strong clamps.

[Illustration: Courtesy of _Engineering_

SECTION THROUGH ENGINE-ROOM OF THE KAISER WILHELM II, SHOWING INNER BOTTOM CARRIED UP SIDES OF SHIP, TO FORM DOUBLE SKIN]

The fire protection also includes both an outside and an inside line of fire-mains. Fire-drill, with full pressure on the mains, is carried on every time the ship is in port, the outside lines of fire-mains being used. Once every three months there is a fire-drill with the inside line of mains. Every time the ship reaches her home port, both fire-drills and lifeboat drills are carried out under the close inspection of German Government officials.

Now, the provision of fire bulkheads is such an excellent protection that it should be made compulsory upon every steamship of large carrying capacity. Moreover, they should be extended throughout the full tier of decks reserved for passenger accommodation. The bulkheads need not be of heavy construction, and they can be placed in the natural line of division of the staterooms, where they will cause no inconvenience.

Special interest attaches to the _Imperator_ of the Hamburg-American Line, just now, because she is the latest and largest of those huge ocean liners, of which the _Olympic_ and _Titanic_ were the forerunners. This truly enormous vessel, 900 feet long and 96 feet broad, will displace, when fully loaded, 65,000 tons, or 5,000 tons more than the _Titanic_. A study of her hold plan and inboard profile, shown on page 163, proves that it is possible to provide for an even larger boiler and machinery plant than that of the _Titanic_, without making any of that sacrifice of safety, which is so evident in the arrangement of compartments and bulkheads on the _Titanic_. Not only are the bulkheads throughout the machinery and boiler compartments carried to the second deck above the water-line, but the same spaces, throughout their whole length, are protected by an inner skin in the form of the longitudinal bulkheads of the side bunkers. The large forward engine-room is also protected by two longitudinal bulkheads at the sides of the ship and the after engine-room is divided by a central longitudinal bulkhead.

Protection against the spread of fire is assured by several bulkheads worked across the decks which are devoted to passenger accommodation.

CHAPTER X

CONCLUSIONS

I. The fact that the _Titanic_ sank in two hours and thirty minutes after a collision demonstrates that the margin of safety against foundering in this ship was dangerously narrow.

II. It is not to the point to say that the collision was of an unusual character and may never occur again. Collision with an iceberg is one of the permanent risks of ocean travel, and this stupendous calamity has shown how disastrous its results may be. We cannot afford to gamble with chance in a hazard whose issue involves the life or death of a whole townful of people.

III. If it be structurally possible, and the cost is not prohibitive, passenger ships should be so designed, that they cannot be sunk by any of the accidents of the sea,--not even by such a disaster as befell the _Titanic_.

IV. That such design and construction are possible is proved by the fact that the first of the large ocean liners, the _Great Eastern_, built over half a century ago, so far fulfilled these conditions, that, after receiving injuries to her hull more extensive than those which sank the _Titanic_, she came safely to port.

V. It is not to the point to attribute the financial failure of the _Great Eastern_ to the costly character of her construction. She failed because, commercially, she was ahead of her time, passenger and freight traffic being yet in their infancy when the ship was launched. Cheap steel and modern shipyard facilities have made it possible to build a ship of the size and unsinkable characteristics of the _Great Eastern_, with a reduction in the cost of twenty to thirty per cent.

VI. The principles of unsinkable construction, as formulated by Brunel and worked out in this remarkable ship, have been adopted in their entirety by naval constructors, and are to be found embodied in every modern warship. These elements--the double skin, transverse and longitudinal bulkheads, and watertight decks--are the _sine qua non_ of warship construction; and in the designing of warships, they receive the first consideration, all other questions of speed, armour-protection, and gun-power being made subordinate.

VII. In the building of merchant ships, unsinkable construction has been sacrificed to considerations of speed, convenience of operation, and the provision of luxurious accommodations for the travelling public. The inner skin, the longitudinal bulkhead, and the watertight deck have been abandoned. Although the transverse bulkhead has been retained, its efficiency has been greatly impaired; for, whereas these bulkheads in the _Great Eastern_ extended thirty feet above the water-line; in the _Titanic_, they were carried only ten feet above the same point.

VIII. The portentous significance of this decline in the art of unsinkable construction will be realised, when it is borne in mind that the _Titanic_ was built to the highest requirements of the Board of Trade and the insurance companies. She was the latest example of current and approved practice in the construction of high-class passenger ships of the first magnitude; and, judged on the score of safety against sinking, she was as safe a ship as ninety-five out of every hundred merchant vessels afloat to-day.

IX. That the narrowing of the margin of safety in merchant ships during the past fifty years has not been due to urgent considerations of economy, is proved by the fact that shipowners have not hesitated to incur the enormous expense involved in providing the costly machinery to secure high speed, or the equally heavy outlay involved in providing the sumptuous accommodations which characterise the modern liner.

X. If, then, by making moderate concessions in the direction of speed and luxury, it would be possible, without adding to the cost, to reintroduce those structural features which are necessary to render a ship unsinkable, considerations of humanity demand that it should be done.

XI. Should the stupendous disaster of April the 14th lead us back to the sane construction of fifty years ago, and teach us so to construct the future passenger ship that she shall be not merely fast and comfortable, but practically unsinkable, the hapless multitude who went down to their death in that unspeakable calamity will not have died in vain.

XII. In conclusion, let us note what changes would render such a ship as the _Titanic_ unsinkable:

(a) The inner floor of the double bottom should be extended up the sides to a watertight connection with the middle deck. This inner skin should extend from bulkhead No. 1 at the bow to bulkhead No. 14, the second bulkhead from the stern.

(b) The lower deck should be made absolutely watertight from stem to stern, so as to form practically a second inner bottom; and it should be strengthened to withstand a water pressure equal to that to which the outer bottom of the ship is subjected at normal draft.

(c) All openings through this deck, such as those for hatches and ladders and for the boiler uptakes, should be enclosed by strong watertight casings, carried up to the shelter deck, and free from any doors or openings leading to the intervening decks,--the construction being such that the water, rising within these casings from the flooded spaces below the lower deck, could not find its way out to the decks above.

(d) The second bulkhead from the bow and the second from the stern should be carried up to the shelter deck. All the intermediate bulkheads should be extended one deck higher to the saloon deck, D.

(e) The cargo spaces in compartments 3 and 4, lying below the middle deck, should be divided by a central longitudinal bulkhead, and the hatches, leading up from these holds, should be enclosed in watertight casings extending, without any openings, to the shelter deck, where they should be closed by watertight hatch covers. The huge reciprocating-engine-room should be divided by a similar, central, longitudinal bulkhead.

(f) Finally, the passenger spaces on decks A, B, C, and D, should be protected against fire by the construction, at suitable intervals, of transverse bulkheads of light construction, provided with fire-doors where they intersect the alleyways.

*   *   *   *   *

A _Titanic_, as thus modified, might reasonably be pronounced unsinkable. To such a ship we could confidently apply the verdict of Brunel, as recorded in his notes on the strength and safety of the _Great Eastern_: "No combination of circumstances, within the ordinary range of probability, can cause such damage as to sink her."

[Transcriber's Note

All words printed in small capitals have been converted to uppercase characters.

Some illustrations contain explanatory text; the keywords have been
added to the captions.

The following modifications have been made,

Page 10:
"3 1-2 inches" changed to "3½ inches"
(some small angle-bars, 3½ inches in width)

Page 36:
"24 1-2 knots" changed to "24½ knots"
(to accomplish the average speed of 24½ knots)

Page 96:
"TRANSLANTIC" changed to "TRANSATLANTIC"
(PARTICULARS OF NOTED TRANSATLANTIC LINERS)

Page 145:
"U. S. N." changed to "U.S.N."
(courtesy of Naval Constructor R. H. M. Robinson, U.S.N.)

Not modified but retained as printed:

Inconsistent spelling of "underwater" / "under-water"

Inconsistent spelling of "watertight" / "water-tight"]

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