will not give a cloudy precipitate when tested with a solution of silver nitrate.

If the washed emulsion has increased much in bulk while in the muslin bag, squeeze it as much as possible and allow it to drain in the empty boiler for some hours, with an occasional squeeze. Alcohol may also be used to get rid of the extra water absorbed by the emulsion. By covering with alcohol, it soon decreases in bulk, and a couple of washes in water leave it in a condition to be melted and coated on the plates.

If, in coating the plates, the emulsion does not flow readily, the addition of 5 per cent of its volume of alcohol will overcome the trouble. In the case where alcohol has been used to reduce the volume of the washed emulsion, further addition of alcohol may not be necessary.

It is scarcely necessary to say that all the various steps of making the emulsion and coating the plates must be conducted in the dark room, and even the red light must be kept as faint as possible for fear that the work may be injuriously affected. Care must be taken to have all the vessels and implements employed scrupulously clean, which injunction, of course, applies also to the glass plates on which the emulsion is spread. To render them chemically clean it is recommended to immerse them first in nitric acid, then rub with a strong solution of caustic soda in alcohol and rinse in pure water.

It is necessary in carrying out any process for making the emulsion to use distilled water, as the ordinary article is liable to contain substances which interfere with the reactions which must be brought about. Gelatin is sometimes contaminated with sulphurous acid, which renders it unfit for photographic use.

Some years ago we copied from a photographic journal an emulsion process which involved the formation of silver carbonate; we afterward concluded from a consideration of disastrous explosions of indelible ink in which silver nitrate and an alkaline carbonate were present, that it would be best to avoid the process last referred to; the explosions referred to have not been explained, and it seems within possibility that formation of silver carbonate under certain conditions may lead to its explosive decomposition. The result aimed at can be accomplished without either carbonates or ammonia, as shown above; and it is safest to follow methods in which they are not required.—The Druggists Circular and Chemical Gazette.

RECENT SCIENTIFIC DEVELOPMENTS AND THE FUTURE OF NAVAL WARFARE¹.

By MR. WILLIAM LAIRD CLOWES.

At a time like the present, which is one of extremely rapid scientific progress, it is especially incumbent upon us not to neglect, even for a single unnecessary day, any device which may possibly enable us, either in peace or in war, to defeat our rivals by honorable means. Scientific discovery tends ever more and more to obliterate the significance of those physical and moral differences which anciently rendered one race superior to another; and brain and thought are already more potent factors in the world than mere muscle and animal courage. Moreover, we know from experience that to-day or to-morrow may produce a complete revolution of method in almost any of our processes. We ought, therefore, never to sleep, save, as it were, with our ears and eyes open. Yet, strange to say, the amount of practical attention which we give to new machinery and appliances is often, I am afraid, inversely proportionate to the novelty and ingenuity of the device in question. We are too prone, when examining new inventions, to admire the cleverness displayed in them, and then to reject them, wholly and finally, for one of two reasons, both of which are in reality quite inadequate.

One reason frequently alleged is that the invention has yet to be brought to absolute perfection, and that, pending its complete evolution, we may safely neglect it. The other reason is that the machinery or apparatus is too delicate or complicated for use by the class of workmen who are accustomed to handle the appliances which the new apparatus would supersede. The evils resulting from such an attitude, which is characteristically a national one, are twofold. On the one hand, we snub and starve the inventor, and possibly drive him elsewhere in disgust; on the other, we make the far more dangerous mistake of assuming that the tide of technical education will not rise elsewhere so long as we choose to batten it down in our own little hold. What we ought to do is, surely, in the one case to take up promising inventions, and turning them over for development to the brightest intellects at our command, to enjoy the exclusive profits of them as soon as they shall be practically perfect; and, in the other, to educate our men up to the point of being able to use delicate and complicated appliances, instead of rejecting the appliances because our existing men are incapable of handling them. It is absurd for us to say, as in practice we do, "Don't offer us any unfamiliar novelty that isn't approximately perfected; and, above all, don't offer us any perfected novelty that isn't approximately familiar." While we continue to follow that policy we run the risk of falling out of station with the rest of the world, and of not discovering our error of position until too late.

It is mainly with the object of appealing for readier official interest in certain recent inventions, and for a greater official anxiety to educate the workman up to the level of the tools already available, or about to become available, to his hand, that I venture to address you on "Some Recent Scientific Developments and the Future of Naval Warfare." These developments must inevitably influence naval warfare strategically as well as tactically, and it is hard to say in which direction the effects are likely to be more important.

Within the compass of little more than a lifetime the practice of naval strategy has already been revolutionized by the introduction of steam and the electric telegraph. The principle of strategy, however, has suffered no change. It is very simple, and it may still, as in the days of Nelson, be thus formulated: To have at the right spot, and at the right moment, a fighting force superior in *personnel*, as well as in *matériel*, to the

force of the enemy at the same time and place. But the practice is still changing rapidly, and, under the influence of recent invention, it must change still more. We have not yet realized to the full the strategical value of speed² as a factor in the successful carrying out of the fundamental object of strategy. Speed, in the present, is all that, and more than, the weather gage was in the past; and, if we neglect it, we shall cripple the hands of our admirals, no matter how many ships and men we may place at their disposal. It is the soul of all effective combination for offense; and I am not sure that it is not equally valuable as a means of defense against certain weapons which at present cannot easily be otherwise avoided—to wit, submarines. The submarine, of which more anon, is essentially a slow craft, whether she travel on the surface or below it. A large ship can have no more secure protection against the submarine than the fact that she is in very rapid motion. A submarine must come to the surface to look about her; and if her big enemy be seen to be changing position rapidly, the submarine can gather little information that is likely to be of use to her.

And here I should like to say that our own preparations for attacking submarines with spar torpedoes³, fitted to torpedo boats or destroyers, are exciting the ridicule of those foreign nations which, from experience with them, know what submarines are like. We claim that our specially rigged spar torpedo can reach a submarine at a depth of 10 feet below the surface. Commander W. W. Kimball, U. S. N., says⁴ very justly, "Why a submarine should run at 10 feet instead of 30 feet or 40 feet does not appear; nor does it appear how the destroyer could, when the submarine showed for a few seconds, head for her, and strike her with the spar torpedo before she attained a safe depth. While the battleship, protected by the destroyer, is the proper quarry of the submarine, there seems to be no law against sinking the destroyer in passing, if her presence were inconvenient." The truth seems to be that, if the submarine can be reached at all by the spar torpedo, she can—at least in the vast majority of cases—be reached much more expeditiously and certainly by means of the gun; though it may be desirable to mount guns in a special manner in order to deal with her.

The offensive usefulness of speed has, I believe, been doubled or trebled by recent improvements in wireless telegraphy⁵. It looks as if every ship, large or small, in future naval warfare might be, as it were, the mobile terminus of an unlimited number of aerial cables communicating not only with the base on shore, but also with all friendly ships within a radius of several hundreds of miles.

It is true that last year, when wireless telegraphy was employed by one side during the naval maneuvers the system broke down, for the reason that the rival commander was able to tap the messages, and did not use wireless telegraphy himself. But the breakdown on that occasion was due entirely to the manner in which wireless telegraphy was misused. The defeated commander might either have employed a code for the sending of his messages, or have used some variety of wireless telegraphy which was not tapable. It is merely a question, on the one hand, of a special cipher, or, on the other, of special discharge terminals, coherers, and relays⁶. The possible variety is infinite; and it is hardly conceivable that in war time the cipher of one side should be known to the other, or that both sides should use exactly similar instruments, similarly "attuned."

Given a good and untapable system of wireless telegraphy, utilizable over long distances at sea, naval strategy, barring accidents, must rapidly become almost an exact science. But it is desirable to have in reserve some alternative to the lofty spars which at present seem to be favored by Mr. Marconi. They cannot be carried by any vessel in very heavy weather; and they cannot be carried by a small craft, such as a torpedo boat or a steam launch, in any weather. It ought to be possible to substitute for them, when necessary, kites⁷, such as, I believe, were successfully used by Gen. Baden-Powell at Mafeking. These have much greater radial "command" than can be given to spars on board ship, and they can be flown by craft of all sizes. Electrical kite-flying, and wireless telegraphy by that means, should be part of the ordinary routine of every ship of war. Nor must it be forgotten that there is yet much to be learned with regard to kites, especially kites large enough to carry with them a small motor controllable from below.

We have seen in South Africa that, assuming good intelligence to be at the disposal of a belligerent, the essence of effective practical strategy is extreme mobility—extreme speed, that is. I rejoice, therefore, though it is perhaps hardly even a straw to show which way the wind blows, that the admiralty has decided to continue its experiments with turbine propellers in destroyers, and also to apply the turbine principles to propulsion to one comparatively large vessel, a third-class cruiser. I trust, too, that Whitehall has already devoted its attention to Mr. J. T. Marshall's new valve gear, for there can be no doubt that we must witness, within the next few years, an enormous increase in the speed of large fighting ships; and, then, woe betide the power which lags behind its rivals in the matter of rapid mobility. It will see itself condemned to forego strategy altogether in its naval combinations—in other words, it will find itself confined to the local defensive.

² The Engineer, October 26, 1900; Army and Navy Journal, November 10, 1900; SCIENTIFIC AMERICAN, November 24, 1900; Journal of R. U. S. I., November, 1900; Morskoi Sbornik, May, 1900; Mittheilung, February, 1901; Steamship, March, 1901.

³ Proceedings of United States Naval Institution (Notes), June and December, 1901; The Engineer, May 10, 1901.

⁴ Proceedings of United States Naval Institution, December, 1901.

⁵ Army and Navy Register, March 17, 1900; Electrical Review, March 14, 1900; Iron Age, August 23, 1900; SCIENTIFIC AMERICAN, September 8, 1900; SCIENTIFIC AMERICAN, October 20 and November 10, 1900; Steamship, November, 1900; SCIENTIFIC AMERICAN, March 9 and March 30, 1901; Baltimore American, May 8, 1901; Army and Navy Journal, May 25, 1901; Army and Navy Register, April 20, May 11, and June 1, 1901; Yacht, July 6, 1901.

⁶ Engineering, May 17, 1901.
⁷ Journal of United States Artillery, November and December, 1900; SCIENTIFIC AMERICAN, October 13, 1900.

As regards tactical factors, what I have said as to our habitual attitude to new inventions applies more perhaps to them than to strategical factors. Take, for example, the question of range-finding⁸ in action at sea. I was once in one of his majesty's ships in which a set of range-finding instruments was fitted experimentally. The appliances were rejected without undergoing a really fair trial. They were tried superficially by people who knew next to nothing about them; and they were condemned, not, so far as I could ascertain, because they were ineffective, but because they were complicated, and could not, of course, be worked easily by the untrained intelligence which was available to handle them. Surely it would have been better to adopt the invention, which had been well tried abroad, or some superior one, and to train the necessary intelligence.

In the meantime, how does our navy hope to find the range in action? It depends mainly upon being able to note the drop of tentative shots⁹. Where two single ships are engaged, this method, though slow and unscientific, may possibly work; but when whole fleets are engaged, how can any human eye feel certain whence comes the particular shot the drop of which is noted? At Santiago it was found to be impossible to form any correct conclusions in that way. Now there are many excellent and almost perfect range-finders. I will mention only the Barr and Stroud, which is said to be responsible for the recent excellent shooting of the "Terrible," and the Zeiss stereoscopic¹⁰, each of which reduces the possibility of error to a minimum, though there are others almost equally as good. For years we have been flirting with such inventions; for years we have refrained from taking them to our arms, because of our fear that we do not sufficiently understand them. They ought to have been long ago in all our fighting ships. By this time we should have learned to understand them. Other nations have adopted them. What will happen if we fall into a conflict with one of those other nations?

Naval gunnery will also be greatly improved so soon as two or three comparatively small problems which are now awaiting solution shall have been solved. Their solution ought not to be long delayed, if only the right kind of intellects can be persuaded to turn their attention to them. The great want of the day is, of course, an arrangement whereby it shall be possible to fire a projectile through moderately thick modern armor, and to burst it immediately in rear¹¹. Another great want is some new method of igniting smokeless powders¹². These powders, especially when fired in relatively small guns, are, as their name implies, practically smokeless. But at present the most convenient method of igniting them is found to be through the medium of an ignition charge of black powder of the old smoky kind. In small weapons the ignition charge, and the quantity of smoke produced by it, are insignificant; but in the case of heavy guns the ignition charge alone comprises about as much black powder as formerly would have sufficed for a couple of full charges for the old 64-pounder muzzle-loader; and, the volume of smoke thus produced being very considerable, the advantages of employing smokeless powder are to a large extent neutralized.

A very noteworthy development of recent science, and one that cannot fail greatly to influence the tactics of future naval warfare, is the modern submarine¹³. I am not a submarine enthusiast; but it is impossible not to recognize that the extension of the open field of naval operations from a space of two dimensions only to one of three is too significant to be lightly regarded. The best existing submarine is very slow, very blind, of limited radius of action, and very liable to accident; but it is vain utterly to deny the value—especially the moral value—of a craft which, without leaving your immediate vicinity, can move altogether out of your sphere of activity, and still, perhaps, deal you a fatal injury. It seems to me that the submarine, even if it be carried no further than at present, means the doom of the old-fashioned blockade.

But I am sure that the submarine will be carried very much further than at present, and that already we may see traced out before us the lines along which it is destined to develop.

The weakest points of the best existing submarines are: That they cannot see clearly unless they come to the surface to do so; that they cannot be sure of maintaining a given course under water, even by utilizing the Obry apparatus¹⁴; and that the lives of the crews within them are exposed, especially in war time, to extreme risks.

During the past three or four years numerous ingenious inventors have turned their attention to this subject¹⁵ with a view to producing a vessel which shall be capable of moving at considerable speed beneath the surface of the water; which shall not need a human crew; which shall not want to see whether it is bound; which shall be controllable at every moment of its course; shall not expose those who work it to extra-

⁸ Proceedings United States Naval Institution, December, 1900; SCIENTIFIC AMERICAN, November 17, 1900; Journal Royal United Service Institution, September, 1900; Army and Navy Journal, January 19, 1901; Proceedings United States Naval Institution (Notes), June, 1901; The Engineer, March 29, 1901; Proceedings United States Naval Institution, September, 1901.

⁹ Proceedings United States Naval Institution (Notes), March, 1901.

¹⁰ The Engineer, January 25, 1901; Army and Navy Gazette, June 29, 1901.

¹¹ Notes on Naval Progress, July, 1900.

¹² The Engineer, June 1, June 15, and June 29, 1900, August 2, 1901; SCIENTIFIC AMERICAN, July 21, 1900; Army and Navy Journal, June 23, 1900; Marine Engineering, October, 1900; Mittheilung, March, 1901; Proceedings United States Naval Institution (Notes), June, and (Alger) September, 1901; Engineering, August 9, 1901.

¹³ Army and Navy Register, October 20, 1900; SCIENTIFIC AMERICAN, September 1, 1900; Proceedings United States Naval Institution (Notes), March, 1901; Engineering, May 31, June 7, and July 5, 1901.

¹⁴ Steamship, April and May, 1900; United States Gazette, May 19, 1900; Army and Navy Register, October 13, 1900; Marine Engineering, October, 1900; Army and Navy Journal, January 12 and March 23, 1901; Army and Navy Register, February 9, 1900; The Engineer, January 18 and 25, February 1, March 1, and March 8, 1901; Army and Navy Journal, September 7, 1901.

¹⁵ Engineering, April 12, 1901.

¹⁶ SCIENTIFIC AMERICAN, May 12, 1900.

¹ Institution of Naval Architects.

ordinary risks; and which shall be manageable from a distance without the intervention of wires or other visible connections. It is sought, in a word, to combine the useful features of the existing submarine, of the automobile torpedo, of the electrical countermining launch, and of the Brennan torpedo; dispensing, at the same time, with material ties between the operator and the weapon, and securing a range, which, though less than that of the submarine, shall be far greater than that of the countermining launch, the Whitehead, or the Brennan. Some scores of patents bearing upon these projects have been issued to Messrs. Axel Orling and James Tarbotton Armstrong¹⁷, Arthur A. Govan, Cecil Varicas¹⁸, and Bradley A. Fiske, the last-named being the well-known American naval officer who is famous in connection with more than one range-finder, and with other inventions designed to influence the future of naval warfare.

These gentlemen utilize various forms of energy in various ways; and it is impossible here to go into details of their inventions. It must suffice to say that, although no perfect form of vessel controllable by wireless currents—a form to which I have ventured to give the generic name of "Actonaut"—has yet been produced, more than enough has been accomplished to demonstrate that what it is sought to effect can be effected and will be effected in the near future. Indeed, if it were possible to induce these rival inventors to combine and co-operate, and if it were possible to place at their disposal the knowledge and experience of half a dozen men such as Lord Kelvin, Sir Hiram Maxim, Mr. Brennan, and Mr. Marconi, I verily believe that you might have the perfected engine before you on this day next year. When that perfected engine is produced it cannot fail to work something like a revolution in naval warfare.

All these considerations bring me back again to one of the points from which I started. Our best available tools are rapidly getting beyond the effective control of our best available men, and the real lesson of the situation undoubtedly is that if we would properly utilize all the resources which science has placed, and will presently place, at our disposal for the prosecution of naval warfare, we must greatly improve the scientific standard of the *personnel*.

It is significant that Lord Charles Beresford, without committing himself to any expression of opinion as to the merits of certain types of water-tube boilers, has hinted his belief that many of the breakdowns of those boilers may possibly be attributable, not so much to defects inherent in the boilers, as to the incompetency of the working staff, an incompetency due to lack of training and experience, and perhaps also to short-handedness.

The present Board of Admiralty is admittedly anxious to make the naval service all that it should be; nor does it resent friendly criticism. I would therefore ask their lordships to reflect whether the present methods of dealing with the scientific problems and daily work of the royal navy can possibly produce satisfactory results.

There are two categories of scientific officers in the service—the engineers proper, and the specialist executive officers. The engineers are men with a relatively long, broad, and deep scientific and technical training. They are an expensive class, and at present the navy has confessedly failed to attract and retain the best specimens of the class.

The specialist executive officers are, so Mr. C. M. Johnson, R. N., has irreverently said¹⁹, "Men who dabble in electricity, fiddle about with files and hammers, set up amateur lathes in their cabins, and imagine that they are making engineers of themselves." I do not associate myself with this description of a class of officers who, no matter what else may be said of them, are remarkably keen, and do their work astonishingly well, so far as the conditions permit. But the conditions do not permit much. A torpedo-lieutenant generally gets about seventeen months of technical training in the course of his career. This is, naturally, not enough to make a well-equipped electrical engineer of even the most brilliant of men, still less is it enough to make of him a mechanical and hydraulic engineer as well.

Nevertheless, with a view, I suppose, to economizing expenses, and to restricting the total number of commissioned officers carried, the Admiralty has intrusted a great many purely engineering duties to specialist executives, and in addition, has turned over the entire control of the engineering department in small ships to a warrant officer—an artificer engineer. Not only is this officer of necessity a man of limited education and experience, but also he is now a man less experienced than his fellows formerly were; for a lowering of the standard of qualification has recently been sanctioned.

In the meantime, to assist the specialist executives, a class of ratings known as electrical fitters has been lately called into being. This is composed of men who have very little electrical knowledge at all.

And so we see that whereas at one time all the engineering business of the ship was in the hands of properly qualified engineer officers, much of it is now intrusted to specialist executives, much to warrant officers, and some to people admittedly possessed of hardly any scientific training at all.

While, in short, the *matériel* has been improving yearly, the *personnel* has been assuming more and more the character of a penny-wise-pound-foolish makeshift. This state of affairs must, I think, be remedied if we would profit fully by recent scientific developments. The brightest scientific intelligences ought to be attracted to the navy, and to be retained there when once they have been engaged; and I see no reason why they should not be. We are now paying 5s. a day in South Africa to soldiers—men whose necessary qualifications are little higher than those of unskilled laborers. It can hardly be doubted that a first-rate naval engineer officer, even if you have to pay him a thousand a year, is a much cheaper article than an Imperial

Yeoman at £91 5s. Moreover, while you can pick up the latter at any time, you can secure the former only if you engage and train him at a time when, as at present, you are sorely tempted to do without him, and intrust his work to an amateur.

TORPEDO BOAT DESTROYERS.*

By S. W. BARNABY.

So much attention has been drawn to the destroyer class of the British navy during the past year, that no excuse is needed for a short paper on the subject. It will necessarily be short, because no full treatment of the question is possible, in view of the fact that a committee is now sitting at the Admiralty, and is investigating all the cases in which defects due to weakness of construction are reported to have developed during service at sea. I shall not therefore attempt to discuss these cases, because the facts have not been authoritatively made known. Neither do I wish to express an opinion as to the loss of the "Cobra." I will only say that, although she was an exceptional and experimental vessel, still, if we are to believe that no injury to the bottom preceded the accident, it must be considered surprising that no preliminary straining or laboring of the joints gave warning of danger. We have no experience of mild steel, of the high quality to which we have become accustomed, having failed suddenly, even under repeated applications of stresses well within the elastic limit of the material; but as to what really happened, the evidence, to my mind, is not at all conclusive.

The problem which was originally set the destroyer builders was to produce a small vessel which would be faster than a torpedo boat and would carry a heavier armament. Those were the sole conditions imposed. Messrs. Yarrow and ourselves, who made the first designs, naturally worked on the lines of the torpedo boats which we had been building for years. Speaking for ourselves, we had confidence, from our experience with these boats, that if destroyers were developed on the same lines they would be at least as seaworthy as torpedo boats, if not more so. We had built over 200, some of which had made voyages in all weathers and to all parts of the world, and not one had been lost at sea through insufficient strength. We considered that they must be amply strong to live through any weather in which they might be caught, but that the officers and men might reasonably be asked to submit to the same amount of discomfort at sea as was borne by the crews of torpedo boats, seeing that they were designed for the special purpose of catching these boats.

The torpedo gunboat of 800 or 1,000 tons is probably the smallest vessel in which any degree of comfort for the crew can be secured when it is necessary to remain constantly at sea; but although the torpedo gunboats may be able to overhaul torpedo boats in rough weather because of their size, a class was wanted which would overtake them in any weather, and I think this want has been met by the present destroyers. So far as I know, this condition of discomfort has been cheerfully accepted by the navy, and the important question is, Can these small vessels of high speed be made reasonably safe at sea? I think there is no doubt that they can. The strains coming upon a ship among waves are not exactly, or even approximately, calculable. The effect of the inertia forces produced by the rapid motion of the ends of the vessel as she pitches and scends cannot be estimated, because the velocity of the motion of the parts is not determinable. It is not necessary to enumerate the complex forces produced by the motion in a seaway; it is sufficiently evident that the data for exact calculation are altogether wanting. Then, again, while at one moment the deck of the vessel forms the top of the girder and the keel the bottom, at the next moment the rolling of the vessel may make the corner of the deck take the place of the top, and the opposite bilge that of the bottom of the girder. All that is possible to do is to establish a scale of comparison by which we may judge of the safety of one vessel by comparing her with another which has shown no sign of distress during the time that she has been at sea, and even then it is always possible that exceptional circumstances may occur which may cause us to modify from time to time our standard of comparison.

It is usual to suppose that by considering the vessel first as poised upon the summit of a wave of her own length, and then as lying between the crests of a pair of such waves, and reducing the hull to the form of an equivalent girder, that a method of comparing the stresses to which ships are subjected at sea is possible. The vessel may never be in such a condition, probably never is, and if she were, the stresses would doubtless be different from what they are calculated to be; but in default of a better way of ascertaining if a given ship stands at least as good a chance of safety at sea as some other ship which is proved to be satisfactory, the test is a valuable one. It is usual to assume the height of the wave for vessels of this size as about one-twentieth of the length, and some idea of the severity of the supposed conditions may be obtained when it is stated that it means that a 210 foot destroyer is immersed to the gunwale at the two ends, and that only about 2½ feet of the depth of the hull amidships is in the water when she is lying in the trough; and that when poised on the crest, about 34 feet of each extremity of the ship is out of the water altogether.

It is, of course, of great importance that the deck should not only be sufficiently strong to avoid buckling locally under compressive strains, but that the form of the deck, as a whole, should be rigidly maintained. In the long machinery compartment, where there are no bulkheads, either transverse or longitudinal, great care needs to be taken that the deck beams and longitudinal deck girders are sufficiently strong for the purpose. In some of the latest destroyers built abroad, where the engines are placed between the boilers, the coal bunker bulkheads are continuous through the engine room, and greatly add to the strength amidships, but this arrangement obliges the engines to be placed one in front of the other, since there is not sufficient width for them to be abreast. This so greatly adds to the length of the ship, and consequently to the bend-

ing moment, that it is, to my mind, a doubtful advantage. The longitudinals and deep beams over these spaces will no doubt be reinforced in boats in which any tendency to bending has been observed. I think that they might with advantage be further supported by pillars, in order to strengthen the deck to withstand the compression to which it is subjected under a sagging moment. Our practice has been to make the deck perfectly straight for the greater part of the length of the ship, giving no sheer except at the bow. Any sheer amidships prevents the deck from taking its proper share of the tension coming upon the upper works under hogging moments, and throws undue stress upon the sheer strake.

One of the most important factors determining the strength or weakness of a destroyer—more important, in my opinion, than the thickness of the plating—is the ratio of depth to length. In the "Albatross," which is the longest we have built, there are 15¼ depths in the length; but in some of the class, I believe, the depth is much less in proportion. Two destroyers may have the same scantlings of plates and frames, and be alike in length and displacement, and yet one may be a weak ship and the other a perfectly sound one; and especially may this be true if there is a great disproportion in relative depth.

As regards details, to which we attach great importance, I will only mention one or two. Unless the greatest care is taken in leveling the shell and deck plating by hand upon the slab, parts of the plate will be more severely strained than other parts, and the strength of the whole plate will thereby be reduced; but this is an operation requiring great skill and taking much time. No amount of machine rolling will level these plates as they require to be leveled if the full advantage is to be taken of every pound of the material. Joggling the butts of deck platings is, in my opinion, an undesirable practice, especially when this is of high tensile steel. I think it not only injures the plates to treat them in this way, but it also prevents the full tensile strength of the plate from coming into play. A joggled stringer butt, for instance, is subjected to an unfair pull, which has to straighten the kink in the plate before it can stretch it, and an excessive strain is thrown on the sheer strake.

The riveting is another detail requiring the greatest care, and we never allow this to be done by piecework. The introduction of high tensile steel has made the question of riveting of still greater importance. The value of this material would be much enhanced if rivets of the same strength could be employed; but there are difficulties attending its use, and not much experience has been gained with hard steel rivets up to the present. If rivets, either of mild or hard steel, are riveted cold, they appear to become brittle and treacherous, and our experience has satisfied us that good Lowmoor or charcoal iron rivets are more reliable, and as strong as steel rivets when put in cold. Rivets of small diameter cannot, we believe, be safely put in hot, whether they are iron or steel, because they are liable to waste by scaling in heating, and are cooled so rapidly on being put into the holes that there is not time to properly knock them up before they arrive at a temperature at which hammering is injurious to steel. We therefore prefer iron rivets for sizes up to ¾ inch or 7-16 inch, but those of ½ inch or upward might be of steel, and should be worked hot. It may be possible to use high tensile steel for these, if it is certain that its quality is not affected by the heating, on which point more experiments are desirable. The spacing of these rivets could be greater than with iron rivets, and the plate would be stronger at the joint.

The ratio of weight of structural hull to total displacement in destroyers is not unduly light, and does not compare unfavorably with that found in other classes of warships. For example, Sir William White, in his "Manual of Naval Architecture," gives the weight of material contributing to structural strength in a steel-built first-class battleship of the present day as 18 per cent of the total displacement, and for a typical swift protected cruiser of high speed, large coal supply and heavily armed, as 20½ per cent of the total displacement. This is considerably less than the percentage of weight of material contributing to structural strength in torpedo boats and torpedo-boat destroyers. Although the Thornycroft destroyers are not longer in proportion to depth than the earlier torpedo boats, we have taken more care to preserve the continuity of longitudinal strength than was done in those boats. Continuous keelsons, side stringers, and deck stringers have been introduced which were not fitted in the torpedo boats, and far more attention is now paid to the fitting of doubling plates in way of openings in the deck, such as funnels, fan cowls, hatchways, etc., in order to compensate for the material cut away by these openings, and thus to bring the strength there up to that of a normal section taken through the rivet holes at a frame, which should be the weakest section in the ship. To this question of compensation the Admiralty have very properly attached great importance in all their recent specifications, and there is no doubt that it is much more necessary to pay careful attention to it than it was in torpedo boats, on account of the increase in dimensions.

The longitudinal bending moments for similar ships on similar waves vary as the fourth power of the linear dimensions, so that the stress per square inch of material will increase with increase of dimensions if weight of hull vary as displacement, and as a rule this is found to be the case. Large ships are usually more highly stressed than small ones. M. Normand and others have shown that structural weights should vary as the four-thirds power of the displacement for equal stresses under longitudinal bending in similar vessels. But in dealing with moderate increases of dimensions, as in passing from a torpedo boat to a destroyer, there are a good many of the scantlings, such as plating over propellers, doublings and chafing plates in way of anchors, coal bunker bulkheads and shoveling flats, and other parts which do not count for much in structural strength, but which require to be of a certain minimum thickness for local strength in the smaller vessel, and which do not need to be increased in the same proportion as the rest. The weight thus economized can be utilized in thickening the deck, keel, and sheer

¹⁷ New Liberal Review, June, 1901; Army and Navy Journal, November 16, 1901.

¹⁸ SCIENTIFIC AMERICAN, February 16, 1901.

¹⁹ Discussion on Mr. D. B. Morrison's paper before North-East Coast Institution of Engineers and Shipbuilders, February, 1902.

* Paper read before the Institution of Naval Architects.