2½ minutes, giving an average speed of a cloud in thirty seconds.

The foregoing is from *Industries*. The following additional particulars, together with our illustrations, are from *Engineering*:

During the reading of the paper the action of the machine was made very plain to the audience by means of an excellent moving model, constructed thirty-two times the full size, and so arranged that each of the steps forming the stitches could be clearly seen. By means of this model a piece of bell rope, which represented the fine yarn that would actually be used, was woven or knitted into a small piece of fabric. In addition to this large model, Mr. Paget had also prepared for distribution to the members a number of cards having printed on them a section of the portion of the machine at which the stitch is formed, each card, moreover, having mounted on it in proper position specimens of the actual needles, etc., used. These cards were of much service in making the whole matter clear. To the ordinary engineer or mechanic who has no special knowledge of such subjects, there is, perhaps, no more difficult task than the grasping of the design of textile machinery. The details themselves taken individually may be simple, but they are so multitudinous, and so interdependent on each other, that it is difficult to take a comprehensive view of the whole scheme. In Mr. Paget's warp weaver, however, the whole arrangement is so well worked out, and each part performs its function in so perfect a manner, that once the method of working is seen and explained it is not at all difficult to master the whole mechanism. At the conclusion of the reading of the paper some very beautiful examples of the articles made by the machine were shown.

The first speaker was Mr. B. A. Dobson, of Bolton, who said he had examined the machine in great detail, and was full of admiration for the masterly way in which the author had designed it to so perfectly meet the requirements of the case. The machine worked admirably in every way, but beyond all in speed. If he could have found a defect, he should have thought it a fair matter for criticism, and it would have given him material for discussion, but the truly scientific manner in which Mr. Paget had carried out the design left no room for questioning. He had referred to the high speed at which the machine worked, and this was not so much a matter for wonder in itself as the fact that it was associated with such smoothness of running. It was astonishing that there was no vibration. Certainly he had never seen any machine of a similar description with less of this objectionable feature, and it was a valuable lesson to all engaged in the manufacture of that class of machinery. One of the most interesting points was the remarkable celerity with which the changes were made in the character of the materials produced. The mechanism to effect this was described in the paper, and constituted one of the most novel and valuable features in the design. The old type of knitting machines do not possess this device, but still they have been largely employed. They are mostly constructed, Mr. Dobson went on to say, in Germany. They are beautifully made, and everything that can be done has been done to bring them to perfection. They cannot, however, by any possibility, rival the present machine in speed, for it was beyond their nature to do so. Mr. Paget had obtained his high speed by an entirely different principle, and by the small range of movement he had adopted he could always work from six to ten times faster than an ordinary knitting machine. The shaping device was a most beautiful application of mechanism. There were six motions, and many of the actions were not explained by the author; indeed, the speaker considered it would take six papers, each as long as the one read, to describe them all. Mr. Dobson concluded by saying that he considered Mr. Paget's machine one of the most remarkable inventions of modern times.

Professor Alexander B. W. Kennedy was the next speaker. He said he had had an opportunity of carefully examining this machine, and had seen it at work. In fact, he had spent two days in its company, and the conclusion he had come to at the end of that time was that no man could say his mechanical education was complete until he had mastered the details of this machine. He had seen a row of needles, twelve to the inch, the machine being 84 in. wide, first weaving heavy towels. These towels were made side by side, and were finished in 15¼ minutes, which was equal to about twelve towels an hour, or one every five minutes, fully completed and fringed and ready for use, except that they had to be cut apart. The machine stopped by itself when it had made the requisite number of courses. Then, without any changing of the parts, the same machine wove side by side five ladies' clouds. These were 6 ft. 6 in. long, and were finished in three minutes, which was equal to 100 per hour. The toweling was 67 courses to the inch, and the clouds 2¼ courses to the inch, yet the same machine produced these two very fabrics so very unlike in appearance. The stitch was the same, the only difference being in its length, and the change was effected by the attendant simply pulling a lever. The speaker had a piece of material in which the open cloud pattern had been woven on to the toweling, the one appearing as a border to the other. A point that was of the greatest value in this machine was the ease with which the beams were changed. In a machine working so rapidly as that under consideration, the time occupied in changing the beams and rethreading the machine, were these operations done in the ordinary way, would make a very serious reduction in the percentage of work turned out. Mr. Paget had, however, devised an apparatus by means of which the mechanical labor was very much lessened. He had succeeded in reducing the time necessary for rethreading to as many minutes as it formerly took hours. The whole operation of changing the beams, etc., was carried out by the girl who attended the machine, and one young girl besides, with the assistance of a third girl from a neighboring machine for less than a minute. The taking out of the two old beams and the putting in of the two new ones occupied 8½ minutes. The utmost exertion was the very light pull on the rope of a hoisting gear, which forms part of the machine. The putting of the whole 504 threads of one beam into their respective troughs or guides took exactly ten seconds, and the adjusting of the four or five which not quite accurately entered the troughs brought this up to one

minute. From the time when the trapped thread ends were brought to the front of the machine until the whole 1,008 of them had been properly placed, secured by two courses, worked by hand, and the traps cut off, was not more than 3½ minutes. Threads had then to be taken out at intervals to space the machine into five breadths, and new selvedge and mending bobbins had to be put on to suit the new yarn; but with all this and all other delays, including overhauling of the needles, the whole time taken by the change, until the machine started by power on the new work, was exactly 25 minutes. The speaker also wished to call attention to the reservoir beam which gave regular rotation to the main beam. The speed at which the thread was woven varied considerably, but by means of the ingenious device Mr. Paget had employed the rotative action was steady. In conclusion, the speaker remarked that Mr. Paget had said that the machine was absurdly simple; it might be so, but it was to be wished that there were many more engineers who were capable of devising these absurdly simple devices, which were so beautiful in their results.

A speaker here asked if the same machine could be used for fine yarns or threads as well as those of a coarse kind. To this Mr. Paget replied that this was so; in fact, an enthusiastic friend of his had stated his belief that all materials, even as fine as a silk handkerchief, would eventually be made on this machine. Mr. Paget was not sufficiently sanguine to indorse this view, but doubtless a good deal would be done in the manufacture of fine material as experience advanced.

Mr. Daniel Adamson spoke of the excellence of the material produced and the hygienic character of the woven woolen materials when worn as underclothing. He also spoke at some length on the improvement in the mental and moral characteristics that were likely to follow from female attendants having the charge of such a well designed piece of mechanism. With regard to the apparent complexity of the warp weaver at first sight, Mr. Adamson remarked that when he first gave up locomotive engineering in 1849, and settled in Manchester, he was more or less appalled by the apparent complexity of cotton machinery. But, on looking into the matter, he saw that this complexity was due chiefly to the reduplication of movements for a vast number of spindles, and that it disappeared when a single spindle was considered by itself. In the same way, if those who examined Mr. Paget's warp weaver at the exhibition would ignore the fact of its working with 1,008 threads, and make themselves acquainted with the manner in which a single thread did its work, they would find the machine very easy to understand.

Mr. Birckel also spoke of the beauty of design in the machine. He pointed out that the control of motion to one-fiftieth part of an inch was a thing not before effected in any textile machine, and its accomplishment in the case under discussion placed Mr. Paget in the foremost rank of mechanical workers. The spinning mule was a monument of mechanical ingenuity, but even that did not work to such a degree of nicety as this.

The president, Mr. Cochrane, also wished to add his testimony to the extreme ingenuity of the apparatus. A point that struck him was the manner in which the design got rid of the solid metal in the knocking-over bar, while at the same time attaining extreme rigidity. He would be glad if Mr. Paget would say how the needles were manufactured, and especially how the depression provided to receive the turned-over or hooked point, formed by the beard of the needle, was made. He would also like to ask what would be the wear and tear of the machine, that is, how long it would last.

Mr. Paget, in his reply, wished first to thank Mr. Dobson for the kind words of appreciation he had spoken. Warp weaving had been practically dormant in England and France, and almost so in Germany, but now that materials could be shaped so as to take any desired form, to fit the figure, etc., he hoped that it would become an active industry. Mr. Adamson had referred to the education which a girl received in learning to run the machine. With this the speaker agreed, for the intelligence of the operator was developed by the delicacy of the mechanism. He had been told that he ought to be ashamed of himself for inventing such machines as would take the bread out of the mouths of poor girls who earned some money by knitting. This, however, was not his view of the situation. When he first went to Loughborough in 1854 the wages of the best girls engaged in the hosiery industry was 8s. per week. He himself paid 8s. 6d., but that was above the ruling price and there was only one other girl in the town getting such pay. The wages, however, rose in such a proportion that in 1885 and 1886—which he admitted was a time of inflation—the rate was 18s. to 20s. per week. Since then there had been a fall, but although at present times were exceptionally dull, no good hands could be got under 15s. to 16s. per week. Thus by reason of machinery of a type similar to that under discussion, the wages of girls had been raised 100 per cent. even in dull times. Mr. Birckel had made reference to the accuracy to which they had to work, and had mentioned the fiftieth part of an inch as the amount to which the movement had to be controlled. The accuracy of movement, however, had really to be insured within an error of 0.01 in. in either direction, making a total extreme range of 0.02 in. The essence of good working in machines of this class was extreme accuracy in their manufacture, and he had in constant use at his factory, as an ordinary workshop tool, one of Whitworth's measuring machines capable of measuring to 0.0001 in. Moreover, every man and boy in his works had to learn to measure to half this fraction, and he found practically that there was no difficulty in accustoming the workmen to such accuracy of measurement.

He had been asked a question as to the rigidity and mode of support of the knocking-over bar. A former president of the Institution had once informed him that some cylinders he had bored in a vertical position were no longer circular, but became oval when they were laid on their sides. If that was the case with a comparatively rigid section, such as that of a cylinder, how much more so would it be in a long bar, were it only supported at its extreme ends? As accuracy of position was of the very first necessity, the knocking-over bar had to be supported at intervals, and so the connectors—which were thin pieces of steel passing between the threads of the warp—became necessary, for stretching these connectors was a very different matter

to what simply bending the bar would be. A very small force would cause deflection of the latter, while a tensile stress on the former would give no visible result. He could not claim credit for the invention of the hooked needles, as they had been brought before the world some 120 years ago by William Lee, and were now a part of every hosiery machine. They were made entirely by machinery, except the bending over, and the depression to take the point was punched. Up to about twenty-five years ago, this punching had been done by hand, but it was now done by a machine. As to wear and tear or durability, the new machine had only been running for such a short time that it would be obvious he could not speak from actual experience on this point. Nevertheless, he could form a strong opinion inferentially. The first knitting machine he had made in 1862 was still running and doing excellent work. The parts that would be liable to wear in the new machine were similar to those used in the knitting machine, and, therefore, he concluded that one would have as long a life as the other.

The president in moving a vote of thanks to the author—a vote which was heartily accorded—spoke of the advantages of substituting the chains described for the old Jacquard cards.

THE CORROSION AND FOULING OF STEEL AND IRON SHIPS.*

By Prof. V. B. LEWES.

THE difficulty of obtaining adequate experimental data, and the fact that nearly every one who has worked at the subject has had a composition of his own to bring before the public, has so hampered and restrained the free discussion and interchange of ideas on this most important question, that at the present time we have made but scant progress beyond the point reached twenty years ago, and my object in bringing this paper before you is more to excite you to discussion, and to show you the known facts of the case, than to tell you of any very new or startling discoveries.

Corrosion generally precedes fouling on exposed metal surfaces, and it is therefore this portion of the subject that will be considered first, together with the means which have been taken to prevent it and to protect the plates of our vessels from decay.

In a paper which I had the honor to bring before you two years ago, I pointed out that in all processes of rusting, carbonic acid gas and moisture played an important part, the iron uniting with the carbonic acid and oxygen of the water to form ferrous carbonate while the hydrogen was set free, and that the ferrous carbonate then took up oxygen dissolved in the water or present in the atmosphere as the case may be, and was decomposed into ferric oxide (rust) and carbonic acid, which being liberated in actual contact with the moist surface of the iron, carried on the process of "rusting."

This view of the case was confirmed by a paper read by Prof. Crum Brown before the Iron and Steel Institute, at Edinburgh, last autumn, and is generally accepted as the true explanation of the corrosion taking place on iron or steel surfaces exposed to moist air or fresh water; but the rusting of the metal in sea water has by many chemists been ascribed to a more complex action, in which the salt present plays an important part by first forming oxychloride of iron.

This preliminary stage of corrosion in sea water is, I am inclined to think, a myth. When iron filings or turnings are exposed to the action of sea water, hydrogen gas is evolved, and ferrous oxide and carbonate are formed, and this changes, as in air or fresh water, into ferric oxide, by taking up dissolved oxygen present in the water. At no time have I been able to detect the presence of oxychloride, and from the fact that a few drops of alkali added to the sea water stop the corrosion, I am of opinion that the simple rusting of iron in sea water is due to the same cause as in fresh—i. e., the decomposition of the water by the iron in presence of carbonic acid.

The saline constituents of sea water, however, do undoubtedly play an important part in a more active form of corrosion, by helping to excite galvanic action between the iron in the plates and any foreign metal or impurities present, an action which is also materially aided by want of homogeneity in the metal, by particles of rust, by mill scale, by wrought and cast iron or steel in contact with each other; or even by the different amount of work, such as hammering or bending, undergone by different parts of the same plate; and in all of these cases the galvanic action set up causes rapid oxidation of the iron at the expense of the oxygen of the water, hydrogen being evolved.

We may therefore consider that on the skin of a ship two processes of rusting are going on, the simple corrosion on exposed surfaces of the metal, due to the presence of moisture, carbonic acid, and free oxygen, which forms a fairly uniform coating of rust on the metal, and the more local corrosion due to galvanic action, which results in pitting and uneven eating away of the plates.

As I pointed out in a previous paper, rust cones are due to the most local form of galvanic action, caused by the presence of a speck of deposited copper, lead, or other foreign metal, or even a small particle of rust or mill scale left on the surface of the iron, and covered by the compositions used as protectives and anti-foulers; as soon as the sea water penetrates to these, galvanic action is set up, water is decomposed, rust formed, and the escaping hydrogen pushes up the composition, forming a blister, the hydrogen leaks out, the water leaks in, the action becoming more and more rapid, and the blister gradually filling with the result of the action—rust. The blister bursts, but the cone of rust has by this time set fairly hard, and continues to grow from the base, the layers of rust being perfectly visible in a well-formed cone, and when the rust cone is detached, the pitting of the metal at the base of the cone is, as a rule, found to be of considerable depth.

The speak of foreign matter which has caused this destructive action generally clings to the surface of the iron, and, being at the bottom of the pitting, escapes detection and removal, and when the vessel, newly coated with fresh compositions, again goes to sea, the corrosion will again probably be set up in the same spot.

* A paper read at the thirtieth session of the Institution of Naval Architects, by Prof. V. B. Lewes, F.R.S., F.I.C., Royal Naval College Association, on April 12, 1889.

The corrosion of the plates in the interior of a vessel is a subject quite equal in importance to the external action of sea water and dissolved gases on the metal; and from the fact that certain portions of the interior plates, from their position, escape the frequent examination and attention bestowed upon the exterior, it becomes a still greater source of danger.

Corrosion, like all other forms of chemical action, is much accelerated by increase of temperature; and in the bottom of a ship, near the furnace room and boilers, this has a considerable effect in increasing rapidity of rusting. Also in the coal bunkers, the mere contact of moist coal with iron plates sets up galvanic action, carbon being electro-negative to iron, and the coal dust which sifts down into the double bottom lends its aid to the destruction of the plates; while if the coal contains any "pyrites," which is nearly always the case, these double sulphides of iron and copper are gradually oxidized into soluble sulphates of the metals, and these, washing down into the bilge water, would at once cause most serious corrosion, should they come in contact with any bare portion of the plates. Repairs to any portion of the inside plates will loosen rust and mill scale, which, finding its way into the bottom, tends to set up galvanic action; while the

that it would have to be renewed frequently, which, even leaving out the question of cost, is in many cases impossible.

Zinc is practically the only metal which could be used for this purpose, in order to place the plates of the ship in an electro-negative condition, and it is therefore to zinc that inventors have turned from time to time, the chief novelties introduced being the method of attachment. As far back as the year 1835, I believe Mr. Peacock tried zinc plates on the bottom of H. M. S. Medea, and in 1867 Mr. T. B. Daft again brought the subject forward; Sir Nathaniel Barnaby, Mr. McIntyre, and others also suggesting various plans of attachment, while as late as last year Mr. C. F. Henwood read a paper at the United Service Institute strongly advocating zinc sheathing as attached by his system. Where the galvanic contact has been but small, there the sheathing has had a certain life, but has afforded but little protection to the iron, and has gradually decayed away in a very uneven fashion; while in those cases where galvanic contact has been successfully made, the ship has on several occasions returned from her voyage minus a considerable portion of the sheathing.

Another drawback to the use of zinc sheathing is one

would rapidly destroy the hull, should any abrasion of the coating or damage to the insulating material take place.

The non-metallic coatings which are intended to do away with corrosion have been almost endless. At the present moment there are upward of thirty in the market; while the patent list of the last fifty years contains an enormous number which were practically still-born.

They may be divided for convenience into—

- (a) Oil paints.
- (b) Pitch, asphalt, tar, or waxes.
- (c) Varnishes consisting of resins and gums dissolved in volatile solvents.
- (d) Varnishes containing substances to give them body.
- (e) Coatings of cement.

And, before going into these in detail, it is necessary to consider the condition of the surfaces to which they will have to be applied and the effect this will have upon them.

Air has the power of holding water vapor in suspension, the amount so held being regulated by the temperature; the higher the temperature, the more can the air hold as vapor, while any cooling of the air saturated at the particular temperature causes a deposition of the surplus moisture. When a ship is scraped down to the bare iron in the dry dock, we have a huge surface of metal which varies in temperature much more rapidly than the surrounding air, and cools much more rapidly than the stone walls of the dock; as it cools, so it chills the layer of air in immediate contact with it, and causes a deposition of the surplus moisture on its surface—a phenomenon known as the "sweating of iron"—and on to this moist surface the protective composition has to be painted. If now a rapidly drying varnish is put on, the rapid evaporation of the volatile solvent causes again another sudden fall of temperature—evaporation being always accompanied by loss of heat—and this fall of temperature again causes a deposition of moisture, this time on the surface of the protective, so that the coating is sandwiched between two layers of moisture, both of them probably acting deleteriously upon the resin or gum in the varnish, while the moisture on the iron also prevents adherence of the varnish to the metal. If, instead of a quick-drying varnish, the old fashioned red lead and linseed oil protector had been used, the second deposition would not have taken place, but the sweating of the iron would have prevented cohesion, and, when dry, any rubbing of the coating would bring it off in strips.

The condition of the outer skin of a ship, when she is being coated with her protective composition, is one of the prime factors in the discrepancies found in the way in which compositions act. It being a very usual thing for a composition to give most satisfactory results on several occasions, and then, apparently under exactly similar circumstances, to utterly break down, and to refuse even to keep on. Too much stress cannot be laid upon the condition of the plates at the time of coating, and it is absolutely essential either to have a perfectly dry ship or else a composition which is not affected by water.

When an old ship is broken up, you will often see on the backs of the plates the numbers which have been painted on them with white lead and linseed oil before the ship was built, and under the paint, the iron in a perfect state of preservation, the secret being that the paint was put on while the plates were hot and dry.

Boiled linseed oil, mixed with red or white lead, is among the oldest of the protective compositions in use, but of late years has been but little employed, since it was proved by M. Jouvin, of the French navy, and also in this country, that compounds of lead, when exposed by the wasting of the vehicle to the action of sea water, are converted into chloride of lead, and this is rapidly acted on by the iron, depositing metallic lead and forming chloride of iron, the deposited lead carrying on the corrosion of the iron by rapid galvanic action. The drying of boiled linseed oil is due to the fact that it has in it a certain quantity of an organic compound of lead, and the drying properties are given to it by boiling it with litharge (oxide of lead), so that even when red or white lead is not mixed with it, still lead compounds are present, and this action will go on to a lesser extent. When the boiled oil dries, it does so by absorbing oxygen from the air, and becomes converted into a sort of resin, the acid properties of which also have a bad effect upon iron, so that protectives containing boiled oil are open to objection. Within the last two months a good example of the action of sea water on the bottom of an iron ship, coated with red lead, has been afforded by H. M. S. Nile, which, after being painted over with coats of red lead, was allowed to remain for some months in Milford Haven, with the result that her bottom is very seriously corroded, and, on examination of specimens of rust taken from her, the crystals of metallic lead are in many cases easily identified.

If red lead is used, it can only form a groundwork for an anti-fouling composition which has to protect the red lead as well as the iron of the ship from the action of sea water, and when the anti-fouling composition and the vehicle perish, then serious corrosion must ensue.

The second class of protectives, consisting of tar and tar products, such as pitch, black varnish, and also asphalt and mineral waxes, are among the best protectives, the waxes especially not being affected by the sweating of the plates, and forming admirable coatings for the plates. Certain precautions, however, must be taken in the case of tar and tar products, both of which are liable to contain small quantities of acid and of ammonia salts; but if care be taken to eliminate these, and if it could be managed to apply this class of protectives hot to warm plates, the question of protection would be practically solved, bituminous and asphaltic substances forming an enamel on the surface of the iron which is free from the objections to be raised against all other protectives, that is that being microscopically porous they are pervious to sea water.

The third class of protectives consists of varnishes formed by dissolving gums or resins in volatile solvents, such as spirit, turpentine, naphtha, fusel oil, etc., and such varnishes are open to several objections; in the first place, they are acted upon by moisture, which causes a deposition of the resins or gums as a non-coherent powder and destroys tenacity of the varnish. The amount of action which moisture has on such a spirit varnish depends to a considerable extent upon

THE PAGET WARP WEAVER AND KNITTER.

scale of oxide of copper from copper and brass fittings and pipes is another great cause of danger, as the bilge water would gradually convert it into soluble salts, which will deposit their copper upon the iron wherever a crack or abrasion enables them to come into contact with it; and finally, leakages from stores and cargo are in many cases of a character highly injurious to iron.

In addition to all these sources of danger, we must remember that the interior of the vessel is the part most liable to abrasion from shifting and moving of cargo, coals, etc.

The protection of the outsides of the bottoms of our ships from the destructive agencies of sea water and dissolved gases may be said to have been attempted in two ways—by metallic and by non-metallic coatings.

So far, all attempts at metallic coatings have proved failures, and, as far as it is possible to judge, there is but small likelihood of their ever being made to succeed, because if zinc is used in order to protect the iron of the ship there must be galvanic action, and this action must take place evenly all over the surface of the iron plates, which means that the sheathing must be in uniform metallic contact with the iron, in which case the wasting of the sheathing would be so rapid

which was found when it was used to coat wooden ships, and that is that zinc when in sheets, like every other metal, is by no means homogeneous, and that for this reason the action of sea water upon it, leaving out of consideration galvanic action, is very unevenly carried on, the sheathing showing a strong tendency to be eaten away in patches, while the metal itself undergoes some physical change, and rapidly becomes brittle.

Attempts have been made to galvanize the iron before the building of a ship; but Mr. Mallet showed as early as 1843 that this coating was useless when exposed to sea water, as in from two to three months the whole of the zinc was converted into chloride and oxide, and that when, therefore, galvanizing is used, care must be taken to protect the thin coating of zinc. This does not, of course, apply to fresh water, in which galvanized iron would answer very well, the rapid action being due to the salts in the sea water; but even in this case the galvanizing would have to be done after the plates had been riveted together, as any breaking of the surface would set up rapid wasting of the zinc, and it could, therefore, only be used on small craft.

Copper, tin, and lead have been proposed for coating ships, but these metals are electro-negative to iron, and

the proportion of resin or gum to spirit, when the solvent is present in large quantities, and the resin in comparatively small; then the moisture has apparently little action; but it must be remembered that the drying of such protectives means the rapid evaporation of the solvent and concentration of the resin or gum, while the rapid volatilization which is going on cools the hull of the ship, and causes deposition of moisture on the drying varnish, with most disastrous results.

Another point which must be borne in mind is that no such varnish is impervious to gases and liquids. We are apt to think of a coating of varnish as being perfectly homogeneous; but, on examining it through a microscope, it is seen to be full of minute capillary tubes, which become gradually enlarged by the action of water, and finally result in the destruction of the varnish, while moisture and dissolved gases find their way to the metal, and carry on corrosion. The application of several coats of varnish tends to diminish this evil, as in many cases the holes in the first coat will not correspond with the holes in the second, and so each succeeding coat will tend to make the protective more and more impervious. In using such varnishes, they must only be applied in favorable weather, and must be allowed to thoroughly harden before being brought in contact with the water.

In the fourth class we have varnishes of this kind to which body has been given by the addition of foreign constituents, generally mineral oxides; and this class is far preferable to the last, if the solvent used is not too rapid in its evaporation, and if care has been taken to select substances which do not themselves act injuriously upon iron or upon the gums or resins which are to bind them together, and are also free from any impurities which could do so.

At present the favorite substance used to give color and body to such varnishes is the red oxide of iron, the color of which effectually cloaks any rusting which may be going on under it. In using the red oxide for this purpose, care should be taken that it contains no free sulphuric acid or soluble sulphates, as these are common impurities, and are extremely injurious, tending to greatly increase the rate of corrosion. The finest colored oxides are, as a rule, the worst offenders in this respect, as they are made by heating green vitriol (sulphate of iron), and in most cases the whole of the sulphuric acid is not driven off, as the heat necessary impairs the color. This acid is often neutralized by washing the oxide with dilute soda solution, but very little trouble, as a rule, is taken to wash it free from the resulting sulphate of soda, which is left in the oxide.

A sample of exceptionally good color intended for using in protective compositions was sent me a few weeks ago for analysis, and proved to contain no less than 15.3 per cent. of sulphate of soda.

The best form of oxide of iron to use for this purpose is obtained by calcining a good specimen of hematite iron ore at a high temperature. When prepared in this way, it contains no sulphates, but from 8 to 40 per cent. of clay; if the percentage does not, however, exceed 12 to 18 per cent., it is perfectly harmless.

Composition manufacturers can easily test their red oxide for themselves, to see if it contains soluble sulphates, by warming a little of it with pure water, filtering through blotting paper, and adding to the clear solution a few drops of hydrochloric acid and a little solution of chloride of barium (easily obtained at any druggist's). If a white sediment forms in the solution, the sample should be rejected.

In a previous paper* on the corrosion and protection of iron and steel ships, I pointed out that when such a varnish perished, the oxide of iron being left in contact with the iron plates, increased the corrosion going on at the surface of the metal, all oxides being electro-negative to the metals from which they are produced, and on that occasion I advocated the use of finely divided metallic zinc, which can be obtained as an impalpable powder, in place of the oxide of iron, pointing out that such a composition would last as long as any varnish of this class, and that, when the varnish perished, as it must do after long exposure to sea water, then the metallic zinc would, on coming in contact with the iron, set up galvanic action; but that, instead of being electro-negative, as in the case of oxide of iron, and causing corrosion of the plates, it would be electro-positive, and in consequence would protect them, being itself slowly oxidized, and so would give a fresh period of protection.

I hoped at the time that I had made it perfectly clear that the zinc would in no way act until both the anti-fouling and protective varnish had perished, and had become spongy and porous, and that the idea was a prolongation of the period of protection, the great point which has now to be aimed at; but the remarks made afterward in several journals which were kind enough to notice my paper showed me that they had mistaken my intention, and supposed that the zinc was put in to at once create galvanic action, and predicted that if by any chance it did act, the hydrogen generated would blow the composition into blisters, and defeat its own purpose. I need hardly point out that nothing was farther from my intention, as zinc in fine powder will be acted on more rapidly than the dense metal in plates, and I have already pointed out that this is destroyed too rapidly by galvanic action to render it of practical use as a protective *per se*.

As to the hydrogen blowing off the composition, no gas could be generated until both the anti-fouling and the protective coatings had perished and were rendered perfectly porous by the action of the sea water, a condition which would have permitted the free escape of the generated hydrogen, which, it must be remembered, will permeate through openings which other gases cannot pass through.

One of the largest firms of composition manufacturers had enough curiosity to try the effect of zinc *versus* oxide of iron, and painted a patch of it upon a ship coated with their compositions, and after a long voyage she returned with her protectives in perfectly good order, and had it not been for the patch containing zinc having had its position fixed by careful measurements, its whereabouts could not have been discovered. This is exactly what one would have expected; as long as the varnish remains intact, oxide of iron, zinc, or, indeed, any substance which will not damage the varnish, does perfectly well; but had the vessel been allowed to continue until the varnishes had perished, then I ven-

ture to say that the patch containing the zinc would have shown better protection than those parts containing the oxide of iron. My ideas have undergone considerable modification during the past two years, but I still consider the views I put forward in my last paper were perfectly sound, and I am every day more and more convinced that the great object the composition maker has to aim at is the prolongation of the life and effectiveness of compositions, and not the multiplication of short-lived devices, however admirable in their action.

In the fifth class of protectives we have cement coatings; but these, together with such schemes as the covering the hull of the vessels with vitreous glazes, glass, etc., have of late years, as far as I know, entirely been abandoned. The action of cement on iron, however, must later on be discussed in its important bearing on the protection of the interior portions of the hull, for which it is largely employed, its weight and the difficulty of attachment rendering it unfitted for outside work.

In selecting a protective composition for the bottom of a vessel, one of the second or fourth class should be chosen, attention being given to the points I have indicated, which are that in the bituminous and asphaltic compositions all the original acids must be eliminated, and that in the varnishes of the fourth group quickly evaporating solvents should be avoided, and, if possible, zinc substituted for oxide of iron.

The vessel should have her plates as dry as possible during the application of the protective, and, if feasible, days on which the air is fairly dry should be chosen. The protective should not be too thick, as, if it is, it does not readily fill into inequalities in the plates; and, if in this way any air is inclosed, change of temperature will cause it to expand or contract, thus causing a blister to form, which will fill with sea water and set up rapid corrosion. The composition must either be elastic or else have the same rate of expansion and contraction as the iron; for, if not, the change of temperature will cause cracking and tearing of the composition with disastrous results. The vessel, if she has to be scraped down to the bare metal, must be scrubbed free from all traces of rust, and where a well-adhering coating of composition exists, it should be painted over and not disturbed. In the case of a new ship, she must be pickled with dilute acid, to get rid of every trace of mill scale, and then washed down with some slightly alkaline liquid to neutralize every trace of acidity, the alkali in turn being removed by clean water. Under these conditions, and given a composition with good adhering properties, but little apprehension need be felt as to the ravages of corrosion on the metal of a ship's bottom, the chief risk being from abrasion and other mechanical injury to the composition, coupled with improper constituents in the anti-fouling compositions. The protection of the interior portion of the vessels, where the plates are exposed to the corroding action of bilge water, rendered more active by a high temperature, leakage from cargo, acids and sulphates from wet coals, and the presence of such electro-negative factors as coal dust, scale, and rust, is a matter of quite as great importance as the exterior protection; while the great chance of mechanical abrasion during coaling and shifting of cargo, as well as the difficulty of getting at the lower portions of the hold to examine the condition of the plates, renders it a question of the gravest consideration. The corrosion found in the portions underneath the engine seats, the bunkers, and the water-ballast chambers, especially near the engine room, is often very serious, and needs most careful watching, which, from the position of these parts of the vessel, it is very hard to bestow upon it.

It must also be remembered that the bilge water in a vessel is in constant motion, and that the air in these parts of the vessel may be expected to be exceptionally rich in carbonic acid gas, which, as I have before shown, is the most important factor in corrosion. Under these conditions any abraded portion would probably be continually washed over, and then exposed to the foul air, a condition of things most conducive to rapid rusting. There are three main classes of protectives for the interior of a ship:

1. Cements.
2. Bituminous coatings.
3. Paints.

The first of these, the cement coatings, have many good points to recommend them, but they also have many serious drawbacks.

The rigidity, firmness of adherence, and endurance are all of them points of the greatest importance, and there is no doubt but that the silicates present in the cement in time not only bind the cement into a mass of wonderful hardness, but also bind that cement to the iron. A point to which I should like to draw your attention, however, is that a thin coating of Portland cement is highly porous, and that it can be permeated by liquids and gases. Suppose, now, that some copper scale from the interior fittings had fallen into the bottom of the vessel, and had been converted into soluble salts of copper by the saline bilge water, this solution would soak through the capillary orifices in the cement until it came in contact with the iron below, when the copper would be deposited on the iron, and rapid galvanic action set up, the cement being loosened, and to a certain extent lifted, by the formation of rust, while corrosion would gradually extend under the cement, giving on the outside of the coating but little sign of damage taking place below it.

Also the hardness and rigidity of the cement gives it a tendency to crack away from the metal when any strain is thrown upon the plates, or during any expansion or contraction of the metal; while any repairs on the outside of the ship, such as making a boring to test the thickness of plate, replacement of rivets, etc., would undoubtedly cause a loosening of the cement coating within, and wherever a loosening takes place, the space between the cement and the plate will quickly be found to become a starting point for corrosion, which quickly spreads and loosens the cement, and will only be discovered by chance.

It is for this reason that I consider bituminous or asphaltic varnishes, freed from any trace of acid, and applied hot, or sound tough paint, preferable to cement; as, although they are not so hard, yet if serious corrosion should be set up, it is easily discovered and stopped before much damage results, while, being impervious to moisture, deleterious solutions, either from the

coal bunkers or cargo, would be prevented from acting upon the skin of the ship.

In approaching the subject of fouling, one is impressed with the apparent hopelessness of obtaining any reliable information from the successes or failures registered by the bottoms of the vessels in the service or in the mercantile marine. Hundreds of ships may be examined, and their condition and the nature of the compositions used upon them registered, and just as one begins to feel that the key to the mystery is within one's grasp, a whole series of results so abnormal suddenly comes to light that it seems impossible to reconcile them with one's previous experience. A ship may sail half a dozen times to the same waters, coated with the same composition—on four occasions she will come home clean and in good condition, while on the other two voyages she may accumulate an amount of weed and animal life sufficient to knock down her speed from nine knots to five.

Moreover, if the compositions with which she was coated be examined, and scrapings taken from her on her return, no cause will present itself that can in any way explain the great difference in her condition. After several years of close observation, however, certain factors begin to make themselves apparent. Ships at sea from March to August show a worse average than those afloat from August to March; one also begins to realize that the amount of fouling increases enormously if the ship has been long at anchor—ships which have been lying at the mouths of rivers, although quite clean in the brackish water, foul much more rapidly on going to sea than the vessels which have been cruising, or even at anchor for the same time in salt water; and finally, certain ports and certain seas seem to exercise a deleterious effect, both as regards corrosion and fouling, which is not to be found elsewhere.

Turning back to the naval history of the past, we find that fouling is no new trouble born with the advent of our present iron monsters; but that it has been the one trouble that the combined engineering and scientific skill of many centuries has been unable to overcome.

With our wooden ships, metallic copper sheathing, if it were of the best kind, answered the purpose fairly well; but then the copper wasted so fast that inferior kinds and alloys were substituted to prevent the rapid loss, and, with the slowing down of the destruction of the copper, at once the trouble of fouling returned.

When iron ships began to replace the wooden ones, as was only natural, attempts were made to utilize the metal which had before given relief; but it was quickly found that the effect of the galvanic action set up by the copper was fatal to the iron plates of the ship, and attempts were then made to sheathe the ship with copper plates in such a way that they should be insulated from the iron of the vessel, a condition almost impossible to attain and attended with great risk should any accidental injury to the insulation take place. Early in the history of iron shipbuilding the idea was started of using coatings of paint, so prepared as to fulfill the same functions as the copper plates had done; but from 1840, when the first paint of this kind was patented, down to the present day, when there are upward of thirty-two different compositions in the market, very little progress has been made in their manufacture, and the best of their compounds cannot be relied upon for keeping a ship's bottom even fairly free from fouling for periods extending beyond nine months, and I am personally convinced that the reason of this is to be found in the fact that a start was originally made in the wrong direction.

The idea which originally led to the present class of anti-fouling compositions was that the copper salts formed by the action of the sea water on the metallic sheathing owed a considerable portion of their value as anti-foulers to the poisonous action they exerted upon marine animal and vegetable growths; but, when an observer comes to study the natural history of these lower forms of animal life and vegetation, it is gradually forced upon one that it is only in the early stages of their growth—the germ period—that metallic poisons can affect them.

Seaweeds do not take in the constituents they require for their growth by means of their roots, as is, to a certain extent, the case with ordinary plants, but absorb them by means of their pores from the water itself, the root only serving to attach them to the solid they choose for their resting place; it is also well known that when once a marine plant which has passed the first stages of existence is dislodged or torn from its support, it cannot reattach itself to anything else, while most of the mineral poisons have little or no effect upon their life and growth.

In the same way we find that, with the animal life found on a ship's bottom, the under side is used to cling on with only, and not as an extractor of nourishment, and that, therefore, after the seeds and germs have once obtained a foothold on the side of the vessel, no amount of poison which can be put into a composition will have any effect upon them. Metallic poisons undoubtedly do exert an influence upon the germs in their earliest stages; but after that they are perfectly useless as anti-foulers, and only imperil the plates of the vessel.

The germs of both kinds of growth are of necessity more abundant in the surface water near shore than in deep water, and therefore the period when the ship is in port is the time when the germs are most likely to make good their attachment, after which their further development is, unless other methods of getting rid of them are employed, merely a matter of time.

On examining the conditions under which a vessel is placed when coated with a composition which relies for its anti-fouling powers on metallic poisons only, we at once see the reasons which must make such a coating of little or no avail. In the composition we have drastic mineral poisons, probably salts of copper, mercury, or arsenic, which have been worked into a paint by admixture with varnishes of varying composition, and each particle of poison is protected from the action of the sea water by being entirely coated by this vehicle; that this must be so is evident, or the composition would not have sufficient cohesive power to stick on the ship. As a rule, care is taken to select fairly good varnishes, which will resist the action

* Some copper-sheathed vessels still exist, and its revival has been lately warmly advocated in America.

* Transactions of the Institution of Naval Architects, vol. xxviii.

of sea water for, perhaps, two or three months, before they get sufficiently disintegrated to allow the sea water to dissolve any of the poison; while even with the accidental or intentional use of inferior varnishes, three or four weeks will pass before any solution can take place, and any poison be liberated to attack the germs. A ship is dry-docked, cleaned, and, her anti-fouling composition having been put on, she goes probably into the basin to take in cargo. Here she is at rest, and, with no skin friction or other disturbing causes to prevent it, a slimy deposit of dirt from the water takes place, and this, as a rule, is rich in the ova and germs of all kinds of growth, while the poisons in her coating are locked up in their restraining varnish, and are rendered inactive at the only period during which they could be of any use. After a more or less protracted period, the ship puts to sea, and, the perishing of the varnish being aided by the friction of the water, the poisonous salts begin to dissolve or wash out of the composition; but the germs have already got a foothold, and with a vessel sweeping at a rate of, say, 10 to 12 knots through the water, the amount of poison which can come in contact with their breathing and absorbing organs is evidently so infinitesimally minute that it would be impossible to imagine it having any effect whatever upon their growth. If the poison is soluble, it is at once washed away as it dissolves; if it is insoluble, then it is also washed away, but there is just a chance that a grain or two may become entangled in the organs of some of the forms of life, and cause them discomfort. As the surface varnish perishes, the impact of the water during the rapid passage of the vessel through the water quickly dissolves out or washes out the poisonous salts, and leaves a perished and porous but still cohesive coating of resinous matter, which forms an admirable lodgment for anything which can cling to it; and by the time the vessel lays to in foreign waters, teeming with every kind of life, the poison which would now again have been of some use is probably all washed away, and a fresh crop of germs are acquired, to be developed on the homeward voyage, and a "bad ship" is reported by the person who looks after her docking. It is evident that a poison, even if it had the power of killing animal and vegetable life in all stages, could only act with the vessel at rest, unless it were of so actively corrosive a nature as to burn off the roots and attachments of the life rooted to it, and if it did this, what, may I ask, would become of the protective composition and the plates of the vessel? And I think it is also evident that any poison so used must be under conditions in which it is very unlikely to be in a position to act when it might do good.

The lamentable failure of composition after composition of this kind has gradually reduced them in number to some ten or twelve at the present time, and in most cases it is low price alone which keeps them in the market.

The practical proof, given by experience, that poisons alone are unable to secure a clean bottom, soon led many inquirers to the conviction that it was the exfoliation in the case of copper which had acted in giving fairly good results, and in many compositions the attempt has been made to provide a coating which shall slowly wash off, and, by losing its original surface, shall at the same time clear away germs and partly developed growths, and so expose a continually renewed surface, in this way keeping the bottom of the vessel free from life. There is no doubt that, when this is successfully done, a most valuable composition will result, but the practical difficulties which beset this class of anti-foulers must not be overlooked. In order to secure success, the composition must waste at a fairly uniform rate, when the ship is at rest, and also when she is rushing through the water; and this is the more important in the case of service vessels, as in many cases they spend a large percentage of their existence at anchor or in the basins of our big dockyards. If a composition is made to waste so rapidly that it will keep a vessel clean for months in a basin, then you have a good composition for that purpose; but send the vessel to sea, and under conditions where you have a higher temperature, and the enormous friction caused by her passage through the water exerting its influence upon the composition, and you will find that the coating, which did its work well for six months at rest in the basin, will, in the course of one month under these altered conditions, be all washed away, and fouling will be set up. Noting this result, the manufacturer renders his composition more insoluble—less wasting—and so obtains a coating which, when the vessel is in motion, scales just fast enough to prevent fouling, and good results at once follow; the composition is then put on the same or other vessels, and they take a spell of rest in the basin, and, bereft of the aid of the higher temperatures and the friction of the water, the composition ceases to waste fast enough, and bad results at once have to be recorded.

There is no doubt that this is the true explanation of the wide discrepancies which are found between the compositions in the navy and in the mercantile marine; take any of the big lines, their steamers are running at a fairly uniform rate of speed, and the periods of inaction are as short as the desire not to waste the charge on the capital they represent can make them, and under these conditions, by varying the constituents in the varnishes used for anti-fouling purposes, it is fairly easy, giving the necessary data, to so constitute a composition as to secure admirable results; but when you come to apply this same coating to an ironclad running at various speeds, and as often at rest as in motion, then you at once find that the composition you before imagined to be all that could be desired fails just as lamentably as the tribe of anti-foulers which preceded it. It is not so very long ago that I had the honor to serve on an Admiralty committee under the able guidance of Admiral Colomb, and, after inspecting many vessels in the mercantile marine, and watching all the dockings of service vessels over a considerable space of time, we were forced to the conviction that it was only in very rare cases that the condition of the bottoms of her Majesty's ships at all approached the freedom from fouling to be found in the ships belonging to the big companies, with the result that some of the most successful of the compositions in the mercantile marine were brought into use in the navy, and I believe the reports of the dockings since they have been adopted will amply prove the existence of the difficulties I have mentioned.

Another factor which is often overlooked, and which tends to give misleading results, is the action of brack-

ish water, which in many cases seems to exert a special action in keeping the bottom of a vessel clean, the fresh water having a tendency to disagree with certain forms of marine growth, while the salt water is apparently equally unpalatable to the fresh water forms of fouling.

In most of the compositions now in use, attempts are made to combine strongly poisonous substances with exfoliating and wasting coatings, and this is done by either using metallic soaps, the basis of which is, as a rule, copper, or else by charging a perishable and easily washed-off varnish with poisonous salts, consisting, as usual, of compounds of either copper, mercury, or arsenic, and in some cases all three.

As I have before pointed out, I do not think the presence of these substances exerts any deterrent action upon the fouling, save perhaps when the vessel is at rest; but they exert undoubtedly an important influence upon the rate of exfoliation, as when the perishing of the varnish exposes them they dissolve, or are washed out, and in this way tend to disintegrate and clear away the surface more rapidly—an important and decidedly useful function, but one which might be more cheaply performed by substances other than high-priced metallic poisons.

The use of metallic poisons of the character indicated throws an increased burden upon the protective composition, as, should the latter become abraded by friction of chain cables, barges alongside, or any other cause, the iron of the vessel will be attacked by the metallic salts, either present in the soluble form in the anti-fouling composition, or rendered so by the solvent action of the saline constituents of the sea water, the action of the metallic salts being to rapidly dissolve portions of the iron, and to deposit the metal which they contain upon the surface of the plates, and these deposits, exciting energetic galvanic action, cause corrosion and pitting to go on with alarming rapidity.

Both mercury and copper salts are offenders in this way, but copper is by far the most objectionable, from the fact that the salts formed by the action of the sea water upon the compounds used in the compositions are far more soluble than the corresponding salts of mercury, and are therefore liable to be present in much larger quantity, and so exert comparatively a much more injurious action on the plates.

As an illustration of this, two equal portions of sea water were saturated, the one with copper chloride, the other with mercuric chloride, and into each a piece of steel, planed upon one side, and of about equal weight and size, was placed and left for four days. At the end of this period the two plates were removed, and, after being cleaned and dried, were again weighed, when it was found that the one exposed to the copper-saturated sea water had lost 22.2 per cent. in weight, while the plate exposed to the mercurial solution had only lost 3.6 per cent., this being due to the much larger amount of the copper salt soluble in the sea water.

On now placing these plates in clean sea water, corrosion went on in each case with extreme rapidity, and after being exposed for a month, they had both wasted to about the same extent—that is to say, when once deposited on the iron, mercury is practically as injurious as copper.

I am quite aware that this experiment is not at all likely to be carried out in practice, and none can have a greater conviction of the inutility of small laboratory experiments than I have, as they lack all the factors of mass of material and atmospheric influence which play so important a part in a question like the present; but such an experiment gives one a definite and fairly correct idea of the relative rate of action of the two poisons upon the plates.

All the time the ship is in motion, the wash of the sea water will prevent the metallic poisons doing the plates or the marine growths much harm, but there is one phase of this question which I think has been overlooked. I need not point out that in certain ports there is a fashion in compositions, and that most of the homes of the mercantile marine have some pet local composition which is largely used at that particular port. If, now, many ships are lying in a basin, taking in and discharging cargo, and if the prevalent compositions contain copper, it is evident that a certain quantity will go into solution in the water, which often does not undergo frequent or rapid change, and under these conditions every ship in the basin will be exposed to the same danger, and wherever an abrasion has taken place in the protectives, there copper will be deposited on the iron, causing corrosion and destruction of the plates; and it must be remembered that when the vessel is next docked and coated, no amount of scraping will remove the fine particles of copper deposited in the pitted and corroded portions of the plate, and so finely divided as to be invisible to the eye, but that they will remain and carry on the destructive work under the new coatings of the protective.

It is, I think, a well recognized fact that, when a vessel coated with a copper compound has become corroded from failure of her protective, or from abrasion, even an entire change of composition does little or no good in stemming the tide of corrosion until after some considerable period has elapsed, a result which is due to the same cause; and inasmuch as copper compositions are a source of danger, not only to the ships coated with them, but to any others which may be at rest in the same basin, I do strongly urge upon the manufacturers to abandon the use of these deleterious compounds, and to use others equally efficacious and free from the grave objections I have enumerated.

At the present time, fifteen out of thirty-two principal compositions rely upon copper in some form or other as the basis of their anti-fouling composition, and in one which has enjoyed considerable favor finely divided metallic copper itself is used; and should a vessel coated with it, after the varnishes had commenced to disintegrate, be moored alongside an iron ship by a chain cable, or even by a wet hawser, a big galvanic couple would be formed at the expense of serious damage to any exposed iron.

In the history of anti-fouling many attempts have been made to obtain highly glazed and glass-like surfaces which it was hoped would withstand the action of sea water, and afford no lodgment to marine growths; but even glass itself is slowly acted upon by sea water, and when once roughened on the surface, will foul, while the rigidity of such coatings, and the straining and cracking consequent on unequal expan-

sion and contraction of the plates and their coating, offers a serious obstacle to any such scheme.

In concluding this long paper, I wish to point out that in the present phase of the anti-fouling question, and until some new principle for preventing marine growth has been advanced and successfully adopted, satisfactory results can only be insured by an intelligent use of the existing compositions.

The protective composition is the important composition, and care must be taken to obtain the best in the market, as, if the protection is good, the plates remain uninjured even if fouling takes place. The anti-fouling composition to be used with it must either be elastic or have the same rate of contraction and expansion as the protective, and must—at any rate in the navy—be chosen to suit the work to be done, such as contain copper compounds being carefully rejected, while preference should be given to those which rely on exfoliation rather than mineral poisons. If a vessel is to remain at rest for a considerable period, an anti-fouling composition which exfoliates rapidly, and which also contains poisons known to act on germ life, must be used, the amount of such poison depending on the seasons and the waters in which the ship is to be; while if a vessel is to be continually running, then a slowly exfoliating composition must be employed, and a very small percentage of poison is all that is required, as skin friction and the comparative absence of the germs and spores in deep water will do the rest.

Our ships represent an enormous capital, and any trouble or care which will prolong their existence is well worth taking and will be amply repaid, and at the present time a heavily corroded and foul vessel means either ignorance or negligence on the part of those who have the responsibility of deciding on the compositions to be used; and, finally, it must be clearly borne in mind that there is no anti-fouling composition which ever has been made, or probably ever will be made, that will answer for all cases, and that, until this is clearly recognized, the present unsatisfactory condition of the question will exist.

WOODEN PAVEMENTS IN PARIS.

MR. A. C. DANNER, the Mobile, Ala., lumberman, is deeply interested in the improvement of Mobile streets, and is doing a great deal toward making them not only passable, but substantial thoroughfares. In his investigations on the subject of wooden pavements, says the *Timberman*, he has received the following from the prefect of Paris:

PARIS, FRANCE, April 29.

SIR: By a letter dated March 13, 1889, you have asked me for information as to the use of wooden pavements in Paris.

Wooden pavements in Paris have had an incontestable success, due partly because it is better understood and the work better executed than in any other towns. The public appreciates it strongly, and the administration have come to the conclusion that the subject of paving no longer presents any difficulties. That which one appreciates in wooden pavement is its noiselessness to those who live along the public streets, and its evenness, and at the same time its elasticity, which renders the traction much easier, and the many advantages it possesses both for foot passengers as well as for horses and all vehicles.

On the other hand, wooden pavements require great care and assiduous cleansing, constant washing with water (nearly every morning it should be done on the most frequented streets), and sprinkled frequently with clean sand, according to the circumstances of the atmosphere, and unless this care is given to it, wooden pavements will give greater inconveniences than advantages. Asphalt possesses the same qualities as wooden pavement in regard to traffic, and has the advantage of being impermeable, and to require less care as to cleansing, but the public, with some exaggeration, perhaps, consider it more slippery.

The woods used are:

Pitch pine, for certain streets that have a great deal of traffic over them, being very hard, not at all slippery, and excellent wood for the purpose.

French pine, which has given very good results; the "double" or "twin" pine is nearly equivalent to pitch pine.

Swedish pine, which originally was used exclusively on account of its low cost, its homogeneity, and on account of the vast extent of forests permitting the feasibility of obtaining as much as was needed, is now pretty much abandoned in place of the French pine, which affords better surface for walking, and is more resisting.

As a rule, these woods are not put down when the sap is in the tree, but generally in winter, or better still as regards the French pine, after the sap of August. However, some timber growers maintain that resinous wood can be cut down when the sap is in the tree. The question has not been elucidated by experience.

Chestnut has some special advantages. Beech has been used along the line of tramways, and has received very limited use. Larch has not yet been tried.

The durability of wooden pavements, according to the amount of traffic, and for a pavement well laid, will vary between seven to twelve years, but it is necessary at the beginning to be very strict as to the selection of the wood, and to be very careful afterward in the keeping in repair and the proper cleansing of the pavement.

The net first cost of a square meter of wooden pavement of 0.15° in height, including the foundation of concrete of 0.15°, but not including the removal of the old road, varies between 17f. and 19f. The cost of an asphalt road of 0.05° height upon concrete foundation of 0.15° is 19f. 50c. per square meter. The cost of a stone road upon a foundation of sand varies between 18f., 18f. 60c. and 23f. per square meter, and upon concrete between 20f. and 26f. per square meter. Of course it is understood that all these figures apply to Paris.

As to the annual expense connected with the pavement it can be calculated at from 20c. to 40c. for proper repairing, and between 80c. and 1f. 20c. for cleansing.

Receive my salutations, etc. General inspector of bridges, etc.

(Signed)

V. MUES.

SEAMLESS boiler tubes are now made from solid ingots of metal by a process that twists and stretches the fibers, and is said to make a tube much stronger than the ordinary ones.