is worth in Shanghai about one dollar per kilogramme. Kaga wax is obtained from *Cinnamomum pedunculatum*, and is softer than Japan wax, but is not exported, nor is the fine white Ibot wax obtained from *Ligustrum Ibotu*. Japan wax is obtained from the kernels of the fruit of *Rhus succedanea*, *verniciifera*, and *sylvestris*. Its preparation is one of the principal industries of Kinsin, the best kind coming from the province of Hizan.

SIBLEY COLLEGE LECTURES.—1892-93.

BY THE CORNELL UNIVERSITY NON-RESIDENT LECTURERS IN MECHANICAL ENGINEERING.

THE GENESIS AND EXODUS OF STEAM.

By GEORGE H. BABCOCK, of New York.

In the beginning, before time was born, when creative energy first began to be exerted, there emanated from Deity himself—because there was nothing else from which to create it—a primal form of matter, the first created thing. What it was we have not been told, but if we suppose that the Creator has followed from the first the plan of evolving the complex from the simple, it is probable that it was that thing which is most elemental in its composition and characteristics. From this point of view it is not improbable that the first thing made was hydrogen, the least ponderable of all substances, believed to be the simplest in its atomic construction, for which reason it has been chosen by scientists as the unit of the chemical scale, and looked upon by many as the basal element from which all others have been made. But, whether it be the primal creation or the basal element, it is a fact that hydrogen conserves in a greater degree than anything else known to us that energy which, itself a divine essence, is manifest to us under different forms which we call light, heat, electricity and force.

Among the earliest created things must also have been oxygen, for it forms a very large part of most substances found in nature. This element is remarkable in many ways, but mostly in that it possesses an affinity for every other known element. Is it therefore too much to say that it symbolizes another great attribute of its Creator—infinite, universal love?

It was these two elements which the All-wise chose to unite, to form that which was to become the greatest physical blessing to the being whom he purposed to create in his own image and place upon the earth in the then future ages.

And so oxygen and hydrogen were married, and in their union brought forth steam in its highest state of energy, ready for its mission in the world, and when, in fulfilling that mission, it had imparted very much of its energy to the things around it, it condensed and became water, and when this had further given of its heat to things colder than itself, it became ice, and so in its triune forms of steam, water and ice, this mineral has gone on from that day to this performing some of the most important and stupendous works in the preparing of this earth for the abode of man. As steam it has shaken and riven the earth, opened and erupted volcanoes, dissolved many other minerals, and deposited them in form or place where they can be made of use, besides having a large share in pushing forward the early vegetation which went to form our coal fields. As water it has fertilized the earth, denuded the surface in many places, and deposited its spoils on others as beds of clay and other alluvial matters; served as a medium for stratifying and even forming many of our rocks, and supported hordes of aquatic animals, whose remains are to-day a prominent part of the earth on which we live. As ice it has had no less part in shaping the face of the earth, digging down mountains, plowing out valleys and transporting rocks to places far distant from their original homes, building up hills and plains innumerable with glacial drift, and disintegrating many of the softer rocks to form the soil in which vegetation thrives. And, since the advent of man upon the earth, this earliest of the compounds has proved itself to be his most obedient and useful servant, as well as his constant friend.

Perhaps you are startled to hear steam classed as a mineral, but if we accept the evidence of science that hydrogen is a metal, then steam and water are a metallic oxide, and as truly mineral as are oxide of iron in iron ore, or oxide of alumina in the ruby and emerald.

We imitate this original genesis of steam in a small way in the oxy-hydrogen flame, and in fact in all our gas lights, for a part of our illuminating gas is hydrogen. The same process is also taking place on a prodigious scale in nature, particularly in the sun, for the telescope and the spectroscope have revealed to us enormous flames of hydrogen, frequently shooting thousands of miles beyond the photosphere of the sun, which cannot be caught else than the festive dance at the nuptials of these two parents of steam.

If to produce one pound of steam or water we mingle $\frac{1}{2}$ of a pound of hydrogen with $\frac{1}{2}$ of a pound of oxygen, and ignite them by a spark of electricity or otherwise, a great expansion takes place with a violent explosion, and enough heat is liberated to have melted 20 pounds of steel, or 70 pounds of gold, or 350 pounds of lead, if it could all have been imparted thereto; and enough, if it were turned into dynamic energy, to have lifted 2,600 tons one foot high, or to have exerted two and one-half horse power for an hour. The temperature produced, if we suppose the steam to retain its specific heat and the whole quantity to be burned at once, would be 12,000° F., or about that wished for by the exasperated Nebuchadnezzar when he ordered the furnace for the reception of his recalcitrant subjects to be heated seven times hotter than it was wont to be heated. It is believed, however, to be impossible ever to attain that excessive temperature by combustion, because long before it is reached, the action of dissociation takes place, and the gases refuse to burn further until some of the heat has been radiated or otherwise disposed of. Nevertheless the oxy-hydrogen flame is still the hottest thing known to us except the electric spark, and is capable of fusing many of the most refractory substances. When it is caused to heat lime or magnesia to incandescence it gives us the well-known calcium light, the most powerful artificial light known—except that of the electric arc.

But to return to our pound of steam. We found it at its birth endowed with an almost inconceivable en-

ergy, more than that developed by the combination of the same quantity of any other elements. This energy or heat it readily imparts to surrounding objects, and it is therefore employed by man to melt, solder, sublimate, heat, or otherwise perform work for him. When it has given off enough heat to have raised 37 pounds of water from the freezing to the boiling point, it will itself become water, and if we still go on reducing its temperature by absorbing its heat, until it has given off enough more to heat 320 other pounds of water one degree, or have melted $2\frac{1}{4}$ pounds of ice, it will have become solid ice itself; but even then it will have retained a quantity of heat, so much so that an amount equal to $\frac{3}{4}$ of that given off since it first became water would have to be extracted before it could arrive at the condition of absolute cold.

But we are more interested as a matter of practice in the regenerating of steam for our use, for even if we found it in sufficient abundance in nature, as in geysers and hot springs, it would scarcely be capable of being harnessed for our service like that which is made in boilers. Water is the most abundant thing in nature. Hence we have no lack of material, and all that is necessary is to restore to it so much of the heat energy it gave up in becoming water as is necessary to turn it again into steam, and bring it to the condition in which it can best work in the harness which we have prepared for it.

And for this purpose we find another bountiful provision of kind nature, in the vast accumulations of stored energy, which we call fuel. How much of this energy thus stored for our use is that which was given off by the primal steam when it became water, we may not know, but that many of our coal fields were laid down while the infant earth was enjoying its steam bath in those ages of hot humidity which preceded the advent of life upon the globe, is doubtless true. However, we mine these stores of coal and put a part of their energy into a portion of water, and so transform it, and say we are making steam, as though it were an original creation.

Let us watch the process. We have say one pound of water, the same quantity that we have just seen made by original synthesis, and we put it in the bottom of a vessel in which we have fitted a perfectly tight and frictionless piston. To the bottom of this vessel we apply our heat, assuming that the vessel itself has neither specific heat nor power of radiation, whereby we are enabled to apply our heat to the water without interference or losses. We start with the water at the temperature of melting ice, 32° F., and occupying a certain cubic space, which for our purpose we may consider as a unit. As heat is added its temperature rises at the rate of one degree for each thermal unit, but for a time this produces no expansion. By a special provision of the beneficent Creator, water does not follow the almost universal law of expansion by heat, until it arrives at about 8° above the freezing point, so that when our great bodies of water, in cooling off during the winter months, have arrived at that point, the cold water no longer sinks, but remains on top to freeze and form a crust of ice, which preserves from extinction the animal life within the depths beneath. At about 40° the water is at its greatest density, and from that time on it will be found to expand gradually as it increases in temperature, until it has arrived at 212°, by the addition of 180½ thermal units, when, if our piston be supposed to be without weight, and to be held down only by the pressure of the atmosphere at the level of the sea, it will have come to what is known as the "boiling point." This boiling point varies with every variation of pressure. Its characteristic is that, when at this point, the water is incapable of becoming any hotter, and every addition of heat thereafter, however small it may be, converts a portion into steam; in other words, the water has all the heat it can hold—as water—at that pressure. Our French friends have therefore named this the "point of saturation," and water in this condition they call "saturated." It is a good term, and deserves to be adopted by us.

Our pound of water, now at 212°, has increased slightly in bulk, so that it occupies about 4 per cent. more space than before, and it has therefore forced up the piston to that extent, and performed an amount of work equal to the distance into the pressure, or, say, the equivalent of one pound raised seventeen inches, and heat energy to that value has disappeared. The heat we have put into our pound of water up to this point has been employed in three ways—first, doing mechanical work in raising the piston; second, overcoming the internal resistance of the water to the separation of the molecules causing expansion; and third, in setting up a more rapid oscillation among the atoms, which we call raising the temperature. The first is so small as to be scarcely appreciable, being less than one one-hundred-thousandth. The second is considerable, and has been estimated to be about 60 per cent. of the whole, while the third is the remaining portion, say 40 per cent., or 72 thermal units.

Now, however, at the point of saturation, an entirely new law comes into force, and the addition of more heat, so long as any water remains, does not raise the temperature any higher, but every unit of heat so added converts a small portion of the water—a little over one one-thousandth part—into steam, having a bulk 1,622 times greater than the water from which it is made, but the same temperature. Here one unit of heat has raised the piston 7,800 times more than the same quantity of heat had done before, and of course accomplished that much more mechanical work, or about the equivalent of 60 pounds raised one foot high. But, as a unit of heat, when all converted into mechanical work, is equal to 778 pounds raised one foot high, only about 8 per cent. of our heat unit has been used up in overcoming external resistance, and the balance has been employed in separating the molecules, overcoming their attraction for each other while assuming their new relations. We may in this way add 966 heat units to our pound of water, each one accomplishing the result just described, when it will be found that every particle of the pound of water has become steam at atmospheric pressure. But the whole of these 966 units have produced no effect whatever upon the thermometer, whence this heat has been termed "latent," which means that it has been devoted to other departments in the business of raising steam. It is not lost, however, any more than the force you exert in raising a

weight or in winding up a spring is lost. It is simply stored ready for use. That portion which was spent in raising the piston against atmospheric pressure is given back when the piston is allowed to fall, and that used in the internal work of expansion is given back either as heat or work when the molecules again come nearer each other to form water, just the same as the watch spring gives back the force you exerted in winding it up.

The action we have thus described is that which takes place every time you boil water in a tea kettle or other open vessel, the atmospheric air taking the place of the piston; but the action in a steam boiler is somewhat different.

If we had placed our pound of water in a close vessel of infinite resistance to rupture, and just large enough to hold it, we could have heated it to any extent without making steam. If we suppose the envelope to have the same coefficient of expansion as the water, and the water to retain the same specific heat as at low temperatures, it will be found that when there has been added the same quantity of heat as was required before to make it all into steam, instead of indicating 212 deg. in the thermometer as before, it will now show nearly 1,200 deg., or be red hot, at which high temperature it would exert a pressure of about 20,000 pounds per square inch, and if permitted to expand against atmospheric pressure only, it will all become steam at 212 deg. as before.

But what we call a steam boiler, though it does not boil steam, but rather generates steam by boiling water, is a close vessel of sufficient strength to stand the pressure we desire to carry, and somewhat larger than the water we put into it. Let us suppose we have such a vessel of one cubic foot capacity, and put into it one pound of water, as before, at 32 deg. As we add heat up to the point of saturation, we perceive no difference from the former conditions, but at that point another set of conditions come into play. As we go on adding heat, part of the water is vaporized, as before, but, being prevented by the envelope from expanding, it crowds the available space, and the pressure upon the surface of the water is increased, raising the point of saturation gradually, so that not all the heat added now is employed to vaporize the water, a part going to increase the temperature of the fluid up to the new point of saturation. But as the steam is not allowed to expand as much, a less amount of heat is expended in that work, and none at all is required for external work, so that the proportion of the water evaporated for each unit of heat added remains nearly the same, decreasing very slightly. When, therefore, we have added the 1146 heat units which before, under one atmosphere of pressure, were sufficient to heat the fluid and evaporate the whole of the pound, the pressure will have risen in our vessel to nearly thirty atmospheres, and a small amount, say 10 per cent., of the water will still be present as water at the temperature of saturation normal to that pressure, or 450 deg. If now we go on adding heat until we have added 80 units more, we will find all the water evaporated and have a cubic foot of steam at a pressure of 475 pounds per square inch above a vacuum.

If, however, instead of carrying the pressure to this high point we had added only sufficient heat to raise the pressure to 100 pounds per square inch absolute, we should then have evaporated a little over $\frac{1}{4}$ of our pound of water, and the remainder would have been at 327½ deg., the point of saturation at that pressure. And if now we begin to draw off the steam for use, adding heat as required to keep up the pressure, we shall have the conditions of the ordinary steam boilers in which steam is generated for all the purposes required for the uses of mankind. No matter what the size of the boiler, or what is its construction, or the pressure carried, the principles which underlie the generation of steam within it are the same, and are illustrated in the small boiler we have supposed. Many differences may exist as to their advantageous application and the adaptation of the boiler to the best realization of the value of the heat applied, but these questions do not belong to the present discussion.

Having now considered at length the making of steam, let us look into the question of what becomes of it. It is not one of the things made to keep. It will not, like gold or the pyramids of Egypt, remain unchanged for ages. Its life is as evanescent as a cloud. It is made to-day; to-morrow, nay, perhaps another moment, and it is not. Whither does it go, and what is the nature of its taking off?

There are three ways in which steam may cease to exist. 1st. It may convert its heat into work, and die in performing the task set it by its master. 2d. It may give up its heat to another body, having done which it must resume the condition of water. 3d. It may become dissolved in the air, and merge itself into that benefactor as well as tormenter of our race, "general humidity." It is, however, in the first two modes of quitting existence that it makes itself especially useful to man.

This transformation of heat into dynamic as well as into other forms of energy, and *vice versa* each into any other, is one of those strange things in nature which we have only begun to comprehend. That a blow of the flint upon a piece of steel, or the friction of one piece of wood upon another, would produce heat and fire was known from the earliest days, but that the heat produced was the direct result and equivalent of the force exerted was only discovered at a comparatively recent date. And still more recently did we come to understand that for every force exerted, either by man or by animals, or in any of the processes of nature, an equivalent quantity of heat, or some other form of energy, disappears. The changing of heat into light is well illustrated by the incandescence of a piece of white-hot iron or a burning coal into electricity by the thermic pile. Work, or force in action, is turned into electricity when we make the cat's fur sparkle by stroking it, or produce a shock by scuffing along the carpet, as well as by the steam engine driving a dynamo.

Electricity is changed to work through the electric motor, to heat in the incandescent filament of our glow lamps and in the electric welding process, into light directly in the Aurora Borealis and the Geissler tubes. Our electric lighting, however, is done through the intermediary instrumentality of heat. We first set heat loose from its prison in coal, and after transferring it to steam, transform a part of it by a steam

engine into dynamic energy, then change this into electricity, that into heat, and the heat into light. When we have mastered the methods of nature in the glowworm and firefly, we shall look back upon our present methods of lighting as crude indeed.

This is wandering from our subject, but it may lead us better to understand why steam gives up its energy and life when it is set to performing work.

As we have already seen, water in a state of saturation contains all the heat it can hold at that pressure. On the contrary, saturated steam contains the least amount of heat it can hold at that pressure, and the instant any of its heat, no matter how little, is subtracted, or turned into another form of energy, a corresponding part of the steam is condensed into water. When we had our pound of water heated red hot, and at a pressure of 20,000 lb. per square inch, if we had loaded it by a piston to that pressure, gradually reducing the load as it expanded and the pressure grew less, until it had been brought to atmospheric pressure, we should have found that it had exerted about half a million foot pounds of work, and that to cause it all to become steam at atmospheric pressure under those conditions, it would have been necessary to add about 690 heat units more than were necessary when it expanded all into steam without doing work, that amount of heat having been converted into the work done; or, in other words, if we had allowed it to expand doing the work, without receiving any additional heat, about half of it would have remained water at 212 deg.

In like manner, when we had a cubic foot of steam at 475 pounds total pressure, had we allowed it to expand in the same way as before, there would have been about 220,000 foot pounds of work done, and about one-quarter of the steam would have been condensed in the operation.

In the same manner, when the steam in the cylinder of an engine performs work by pushing the piston before it against a resistance, that work, necessitating a transformation of heat, robs the steam, so that at once a portion is condensed. In this way every hourly horse power of work done in an engine by saturated steam demands the condensation of about two and one-half pounds of that steam to supply the energy exerted. If this were all, our power would not be so very expensive, but alas! our machinery and methods are so very imperfect, and the conditions of the problem are such, that from five to twenty-five times that amount of steam, in addition, is compelled to pass through our engines to enable us to secure that amount of work; the balance, being discharged into the condenser or into the air, is of little or no further use to us.

The steam which goes into the cylinder of a steam engine may be divided into three portions, one of which is condensed in doing work, another and generally a larger portion is condensed in giving up its heat to the walls of the cylinder, to make up for heat wasted, both through these walls and from the evaporation of moisture on the surfaces during the exhaust. The third portion, much larger than either of the others, serves as a more or less necessary backing or companionship for the others. Thus when we had our pound of steam at 20,000 pounds pressure per square inch, we found that only half of it would be condensed in doing the work of expanding against resistance. Theoretically sixty per cent. could thus be utilized in a perfect steam engine without any preventable losses. When our pound of steam was at 475 pounds pressure, we found only 25 per cent. condensed in doing the work of expansion. In the best quadruple expansion engines of this day the proportion is a little less than one-fifth; in the best non-condensing engines it is one-tenth, while in the more wasteful it is sometimes only one-fortieth of the steam which is actually used in doing the work. So it comes to pass that every time one of our great ocean steamers, like the City of Paris, the Umbria, or the Teutonic, crosses the ocean, some thirty-five hundred tons of steam gives up its life to furnish the energy which pushes the ship with its cargo through the water, while other seventeen or eighteen thousand tons, in inseparable companionship, yields up its heat to the surrounding ocean, and takes again the form of water.

We have in the United States about 4,000,000 horse power of steam engaged in manufacturing, very little of which runs less than 10 hours per day, and much of it 24 hours, so that we may assume 13 hours as a fair average. There are, also, 35,000 locomotives of perhaps 250 horse power each, running an average of 36,000 miles per year, which would require, say, six hours per day, which, with steamboats, etc., make an estimated average of 120,000,000 hourly horse power each day, so that not less than 150,000 tons of steam is condensed per day, or fifty million tons per year, in doing work, while at least eleven times as much more is compelled to keep it company and pass out of existence, mostly without further use. This calls for some 100,000,000 tons of coal, or the equivalent of other fuel—but this is not all that goes to make steam.

There is much steam used for heating, which never enters an engine. Two reasons may be given why steam is the best of all substances for this purpose; first, it will carry more heat for a given weight, and, second, when it has given up its heat it instantly drops out of the way to make room for another portion to deliver its heat at the same spot. In this it is in marked contrast to air or gases, which, at atmospheric pressure and the same temperature as steam of ten pounds, hold only 1-160 of the heat, and do not part with that readily, the cooled portion remaining in contact with the surface which absorbed its heat, and preventing the access of hotter portions thereto. Hence steam is very extensively used as a means of carrying heat from the place where it is convenient to generate it to the place where it is wanted for use, as in house heating, boiling, drying, etc. The amount used for this purpose is not easy to estimate. The New York Steam Company is the largest provider of steam for house heating, and it supplies during the colder months of the year about 8,000 tons of steam per day, or for the year, summer and winter, say 1,600,000 tons. It is roughly estimated that the amount used in the city of New York alone is 18,000,000 tons per year, and that there is used in the whole United States, say, 150,000,000 tons. Add to this that used for heating and boiling in various processes not counted in manufacturing, and we may safely say that a total of 200,

000,000 tons would be within the truth. This will add another 30,000,000 tons to the coal account, making a total of 130,000,000 tons of coal or its equivalent used per annum for making steam. As the natural gas used during 1891 was equal to some 20,000,000 tons of coal, this, with the petroleum and wood used for fuel, would probably reduce the total coal used for making steam to about one-half the amount mined, which, in 1891, was 150,000,000 gross tons.

We now come to the third way in which steam makes its exodus, that of being dissipated in the atmosphere. Air at a temperature of 58 deg., which is near the average temperature of the earth, has an appetite for vapor which is not satisfied until it has drank in about one per cent. of its weight. The higher its temperature the greater its appetite, and the lower it goes in the thermometric scale, the less moisture it will hold. Thus at 128 deg. it is not satisfied with less than 10 per cent. of its own weight, while at 38 deg., $\frac{1}{2}$ of one per cent. fills it to repletion. So when the teakettle is boiling over the hob, the rising steam is readily absorbed or dissolved by the air, and becomes invisible. And when the passing locomotive throws a cloud of steam into the atmosphere, it, too, soon disappears, as completely as if it never had existed, and, though the air is at a temperature at which steam, as steam, cannot exist under such a pressure, but becomes water, this vapor is uncondensed. It is only when the air becomes over-saturated, as by cooling it until the amount it contains is too great for its appetite, that this vapor takes on the visible form and becomes cloud or fog, and is precipitated in the form of rain. Nature in her own processes provides for a sufficient absorption of vapor by the air to produce the amount of rain needed, but the steam artificially generated and thrown into the air to be absorbed by it is in addition thereto, and to our modes of thinking is prodigious. One concern alone, the Carnegie Steel Company, with its different plants, throws into the air every hour not less than fifteen hundred tons of steam. We have already found that the steam passing through the engines in the United States approximates 600,000,000 tons per annum. Some of this is condensed in doing work, and some in condensing engines, but we are safe to conclude that, together with the steam from dye houses, evaporating kettles for sugar and salt making, and in culinary operations, not less than that amount of six hundred million tons is annually thrown into the air, to be absorbed thereby. Does this enormous quantity affect the amount of rainfall? It probably does, but the processes of Nature are on so grand a scale that even this inconceivable amount may sink into insignificance. Let us see: The annual rainfall east of the Rocky Mountains varies from 20 inches in a very few places to over 60 inches in others, with an average of not less than 36 inches. This amounts, in that territory, to some 9,000,000,000 tons, so that if all the steam made in the whole country were confined to this side of the Rocky Mountains, it could add not over $\frac{1}{100}$ of one per cent. to the total rainfall, or $\frac{1}{100}$ of an inch—not enough to furnish one evening dew. Thus grand are the operations of Nature's workhouse than the most ambitious of man's handiwork! It is not probable that, however much we may in future ages increase our steam plants, we shall ever be able to affect, even to a perceptible amount, the ample provisions Nature has made for her own purposes.

It is not infrequently said that electricity is soon to supersede steam, and that then it may be expected that steam will make its final exodus from the service of man. Is this likely to occur? At present electricity for nearly all purposes for which it is used is made by dynamos run by steam power, and the more electricity is employed under present conditions, the greater will be the demand for steam. But it is not outside the probabilities that man may in the future find out some way to convert the heat of combustion into electricity direct, without the intervention of a steam engine, and when that time comes, if come it does, we may well conceive that one of the uses of steam will be done away with. But there is little probability that there will ever be found a more efficient means than steam for conveying heat from place to place, for which its cargo capacity excels all other available substances, wherefore, even though it be released from the drudgery of making the wheels go round, this oldest servant of mankind will doubtless ever continue to serve him as a common carrier of that necessity of man's existence and prime element in his manufacturing processes: so that the genesis and exodus of steam will probably go on through future ages as it has since creation began.

THE DRAUGHTOMETER.

As an outcome of the stringent legislation as to overloading ships, consequent upon the Plimsoll agitation, the Board of Trade now require a degree of accuracy in loading which is scarcely possible in many cases, save by a method often much to the detriment of owners, *i. e.*, keeping on the "safe side," and probably losing twenty-five or fifty tons of freight. Cases have been frequent of late of shipmasters being fined, in sums ranging from £5 to £100 and costs, or in default, imprisonment, for allowing their vessels to be submerged from 1 in. to 4 in. beyond their load mark. In most of these cases the alleged overloading takes place under circumstances over which the master can scarcely be expected to have proper control. Even under the most favorable circumstances, the ordinary system of finding the draught by 6 in. figures on stem and stern posts—when these are not positively obscured by barges, lighters, quay walls, etc., is troublesome, tedious, and only approximately correct. When the water reaches the top or bottom of the figures referred to, the water line at any of the intermediate inches can only be estimated. These objections to this system are still more marked in cases where there is motion of surface water, such as is generally experienced in open roadsteads, and even in rivers under certain conditions. The results obtained under such conditions are, of course, not nearly accurate enough for the requirements of the Board of Trade. The provision, therefore, of a simple and inexpensive means by which the master can, with confidence, load his vessel to her marks, and the owner get the full benefit of the ship's carrying capacity, is a matter of considerable importance.

An apparatus designed to enable masters to load

their vessels to a fraction of an inch, under all circumstances, has been invented by Captain J. B. Murray, of Glasgow, and is now being made and supplied by Messrs. Whyte Thomson & Co., nautical instrument makers, of Broomielaw, Glasgow. The apparatus in question, which the inventor names "The Draughtometer," is the outcome of a series of years' study of the subject, and of actual experience with an experimental apparatus on board ships which have been under Captain Murray's own command. The apparatus has received the approval of such eminent authorities as Lord Kelvin, Lord Ailsa, Mr. Herriot, of the Board of Trade; Mr. T. J. Dodd, of Lloyd's Register, etc.; and many ship masters and owners and their representatives who have seen it are impressed with the marked advantages to be derived from its use. The principle of the draughtometer is very simple—is almost analogous, in fact, to the ordinary water gauge on steam-boilers—but the details of its working, and the several

THE DRAUGHTOMETER.

purposes to which it may be made subservient on board ship, are skillfully thought out and arranged. It consists, as will be seen from our illustrations, essentially of a graduated vertical dial, or indicator, fixed in a convenient situation forward, and a similar dial fixed aft, on which are marked the feet and inches corresponding to the draught of the ship, and the tons of the ship's displacement due to such draughts, both in salt and in fresh water. Traversing the middle of this vertical graduated dial is a glass tube, which is practically a continuation of a vertical pipe, and its horizontal complement leading down the center line of the vessel and thence across to the ship's skin, where there is a sea cock, A, for the free admission of the water outside. This sea cock is situated near or a little below the level of the minimum load line, and consequently is free to operate throughout the whole range at varying draught due to loading or discharging at terminal ports, and of all intermediate variations between the minimum and maximum draughts during the course

DRAUGHTOMETER.

of the voyage. In the interior of the glass tube—which may range in height from 2 ft. to 6 ft. just as the range of draught and the fixed position of instruments in the ship may determine—is a float formed of aluminum, and so adjusted that the water in the tube, rising or falling, works the piston up or down, as the case may be, representing the loading or discharging. The surface of the water or the piston in the tube gives the draught. The arrow marks on the dial at K represent the maximum load water mark, which, in fixing the draughtometer forward and aft, is made to precisely correspond with, or be in the same horizontal plane with, the official load mark on the outside of the ship. On each side of the draught scale is a graduated scale representing tons of ship's displacement, in salt and in fresh water, corresponding to the draughts—a