ON THE PRODUCTION OF FRESH WATER FROM SEA WATER.

BY DR A. NORMANDY.

ON THE PRODUCTION OF FRESH-WATER FROM SEA-WATER.

BY DR. A. NORMANDY.

Read before the Chemical Section of the Meeting of the British Association, September 18, 1855.

Sea-water is, as everybody knows, a liquid which contains from three-and-a-half to four per cent. of saline substances, two-thirds of which are common salt, and also a certain portion of organic matters, which impart to it its well-known odour and taste, and render it unfit for drinking or other domestic purposes.

The accidents resulting from an insufficient supply, or from an absolute want of fresh-water in sea voyages, the difficulty of preserving in a pure state that which is stored up, or of procuring a fresh supply of it when it is exhausted, the valuable stowing-room occupied by the tanks containing this most important fluid, have induced many people at various times, and for a great many years past, to contrive apparatuses by means of which sea-water could be rendered fit to drink.

At first sight, one would think that it is sufficient to submit sea-water to distillation to convert it into fresh-water, and that the solution of the problem is altogether dependent upon a still, constructed so as to

produce, by evaporation, a great quantity of distilled water, with a consumption of fuel sufficiently small to become practicable.

Distillation at a cheap rate is, doubtless, an important item, and fuel being a cumbrous and expensive article *on board ship*, it is superabundantly evident that, supposing all the apparatuses which have hitherto been contrived to answer the purpose equally well, that one would clearly merit the preference which would produce most at the least cost; but there are, besides, other desiderata of a no less primary importance, and it is from having neglected, ignored, or been unable to realise them, that all the apparatuses for transforming sea-water into fresh-water, which have been from time to time brought before the public have hitherto, without exception, proved total failures, or (after trial) have been discarded, or fulfil the object in view in a way so imperfect or precarious, that, practically speaking, the manufacture of fresh-water at sea may be said to have been until now an unaccomplished feat.

The other desiderata above alluded to are these :—

When water, whether salt or fresh, is submitted to distillation, the condensed steam, instead of yielding, as might be supposed, a pure, tasteless, and odourless liquid, has *always* an almost intolerably nauseous, empyreumatic taste and odour, which it retains for many weeks. This taste and odour are so disagreeable, and the water so produced being, as is the case with ordinary distilled water, deprived of air by boiling, is, on that account, so heavy, indigestible, and vapid, that the crews invariably refuse it as long as they can obtain a supply from natural sources, even though this may be of so bad a quality as to endanger their health or their lives, as evidenced by the report of the *Times'* own correspondent, in reference to the water supplied to the crews of our ships in the Baltic during the present year.

With a view to remedy these defects, chemical re-agents, such as alum, sulphuric acid, muriatic acid, chlorine, chloride of lime, &c., to be added to the distilled water, have been proposed; but it is evident that the continuous and daily absorption of chemical re-agents might, anddoubtless would, cause accidents of a more or less serious nature, not to speak of the trouble and care required in making such additions, an excess of which

might be attended with dangerous, and possibly with fatal consequences; besides, as a general rule, we have the authority of Liebig to say, that the use of chemicals should never be recommended for culinary purposes, for chemicals are seldom met with in commerce in a state of purity, and are frequently contaminated by poisonous substances. On the other hand, the pumps, ventilators, bellows, agitators, the percolation through porous substances, through plaster, chalk, sand, &c., which have been proposed to aerate the water obtained, and render it palatable, are of a difficult, inconvenient, or impossible application; they are costly, complicated, bulky, or unmanageable; and as to leaving the distilled water to become aerated by the agitation imparted to it in the tanks by the motion of the ships, the report of the correspondent of the *Times*, above alluded to, shows that this method is attended with but indifferent success. I shall presently explain why no system or method of aeration whatever could be attended with success except under certain conditions, and unless it be done in a certain manner, conditions and manners realised in my apparatus.

Another desideratum lost sight of in the endeavours which have been made to accomplish the object (and it is a condition of extreme importance) is to obviate, or prevent the deposit of saline matter which takes place in the apparatus when the limit of saturation has been attained, and which, in a short time after use, interferes, temporarily at least, often permanently, with the working of the apparatus, renders frequent repairs necessary, and in all cases eventually destroys it.

The expansion of metals by heat, and their contraction by cold, is another source of failure; so much so, that it can be most truly asserted, without fear of contradiction, that any fresh-water distilling apparatus for marine purposes, in any part of which solder is employed, is, *ipso facto*, defective, and ought not to be trusted, the soldered parts being sure to give way from the cause just alluded to, and this perhaps (as the event has unfortunately more than once proved), at a time when the machine was most wanted, its unsoundness thus creating the most distressing sufferings, and putting the lives of all on board in imminent jeopardy.

The question, which has hitherto been left unanswered, and yet which must be integrally solved before success could be hoped for, is the following :—

TO OBTAIN, WITH A SMALL PROPORTION OF FUEL, LARGE QUANTITIES OF FRESH, INODOROUS, SALUBRIOUS, AERATED WATER, WITHOUT THE HELP OF MACHINERY OR OF CHEMICAL RE-AGENTS, BY MEANS OF A SMALL AND COMPACT APPARATUS, INCAPABLE OF BECOMING INCRUSTED, OR OTHERWISE GOING OUT OF ORDER.

It is to the solution of this difficult and complex problem that I now beg to call the attention of the Section, and I will proceed to explain the construction of the apparatus by which the object is attained.

It is a known property of steam that it becomes condensed into water again whenever it comes in contact with water at a temperature lower than itself, no matter how high the temperature of that condensing water may be. It is known that the sea and other natural waters are saturated with air, containing a larger proportion of oxygen and of carbonic acid than exists in the air we breathe. Experiments which I undertook several years ago, with a view to determine that amount, showed me that whilst ordinary rain-water contains, on an average, about 15 cubic inches of oxygenised air per gallon, (of which 15 cubic inches of air per gallon about 6 cubic inches are carbonic acid,) sea-water, owing to the various substances which it holds in solution, contains only, on an average, about 5 cubic inches oxygenised air per gallon, of which 5 cubic inches about 0·6 or 0·7 cubic inch are carbonic acid, or, in other words, one gallon of sea-water contains about two-thirds less air than ordinary rain or river-water. I have also ascertained that air begins to be expelled from such waters when the temperature reaches about 130 deg. Fahr. Now, my apparatus consists of two parts—an evaporator and a condenser—joined so as to form one compact and solid mass, screwed and bolted, without solderings or brazings of any kind. The evaporator consists of a space which is pervaded by steam-pipes containing steam, and immersed in a certain quantity of sea-water, a portion of which is to be evaporated ; steam, at

a pressure of about seven pounds, is then admitted into the steam-pipes of the evaporator, which steam-pipes are constantly surrounded by the sea-water to be operated upon, and which thus becomes heated by them. That steam is procured on board of steamers directly from their boilers, and, consequently, at a trifling cost; in sailing-ships it is obtained from a small boiler connected with the hearth, galley, or caboose, and is heated by the fuel necessary for cooking the crew's or passengers' food.

The steam of the above-mentioned pressure being of course hotter than ordinary boiling-water, serves to convert a portion of the water contained in the evaporator into ordinary or *no-pressure* steam, which, as it reaches the condenser, is resolved therein into fresh water. By thus evaporating water under a slight pressure, one fire performs double duty, and thus the first condition, that of economy, is completely fulfilled, for whilst, in the usual way, 1lb. of coals evaporates 8 or 9lbs. of water, the same quantity of coals is thus made to evaporate 16 or 18lbs. of water. In fact, I am in a position to prove by actual experiment, that from the same amount of steam or of coals employed, the machine which I have just described will produce double the quantity of fresh water that can be obtained by simple or ordinary distillation, and I may say, that with an apparatus constructed on the same principle, and which was sent nearly two years ago to Copiapo in Peru, not less than 30,000 gallons of fresh water per diem are obtained from the sea.

The steam issuing from the evaporator, and which is condensed by the water in the condenser, imparts, of course, its heat to the sea-water in it, and as this water is admitted *cold* at the bottom whilst the steam of the evaporator is admitted at the top of the condenser, the water therein becomes hotter and hotter gradually as it ascends, and when it finally reaches the top its temperature is about 208° Fahr.

I said that water begins to part with its air at a temperature of about 130° Fahr., therefore, the greater portion of the air contained in the water which flows constantly and uninterruptedly through the condenser is thus separated, and led through a pipe into the empty space left for steam room within the evaporator when it mixes with the steam.

Now, as about six gallons of sea-water must be discharged for every

gallon of fresh water which is condensed, it follows that the steam in the evaporator, before it is finally condensed, has been in contact with twice as much air as water can take up, the result being a production of fresh water to the maximum of aeration, that is, containing as much air as in pure rain-water, whilst, the upper part of the condenser being open to the atmosphere, all pressure is thus removed from the apparatus.

This aeration of the water, I must again beg to solicit the attention of the Section, is a condition of the utmost importance, and, in fact, is a condition which, were it unaccomplished, would render the apparatus comparatively useless, even though the other desiderata were fulfilled. When the natural waters supplied to our habitations are obtained from impure sources, as is unfortunately too often the case, the evils resulting from their use may in some degree be remedied by putting in practice the recommendation which has been sometimes made of boiling such water previous to employing it as a beverage; unfortunately, the water being thereby deprived of air and of carbonic acid is, like distilled water, though in a less degree, unpalatable, and vapid, and heavy; it is, in fact, of difficult digestion; but there is something worse than that, water which has been boiled, or which has been distilled, by reason of its containing *no air*, has a great tendency to absorb or take *air* from the media where it is kept, so that if distilled water, which contains no air, be kept in a ship's hold, or in an impure and confined place, it will absorb precisely the quantity of air which it can absorb, namely, 15 cubic inches per gallon, and if that air be loaded with organic particles or impure emanations, it will soon become fœtid and putrid. Thus water, though distilled, if kept in tainted rooms, will soon become foul. The empyreumatic odour and taste which distilled water always possesses and retains for a considerable time, is, in fact, due to the destructive action of the heated surface of the vessels in which the water is boiled on the organic substances which are always floating in the air, on those indescribable particles of dust which are seen playing or moving about in a sunbeam, and which have been dissolved or taken up by the water before its distillation. That water has the power of absorbing and dissolving organic matter in this way is of course well known, but it may be illustrated in a very simple manner, as follows:—If water, from whatever source, be

distilled, the distillate will, of course, be fresh water, pure fresh water, but it will have a peculiar nauseous, and empyreumatic taste and odour, stronger in proportion as the heat applied to evaporate it has been more elevated; it is that smell and taste which render it undrinkable for a while. If, when it has become sweet again by long standing, which period may be hastened by agitation in the atmosphere, if, I repeat it, that distilled water be then re-distilled, the distillate will be found to have acquired again the same empyreumatic taste and odour as when it was first distilled. How is this? Because it will, by standing or agitation, have re-dissolved a portion of the air of the room in which it was kept, and along with that air it will have absorbed whatever substances were present, dissolved, or suspended in it, and those substances by their contact with the heated surfaces of the still, yield an empyreumatic product, which taints the distillate. The only condition necessary for distilled water not to become putrid or offensive is to saturate it with *pure air*, because in that case there is no room left for other gases to impregnate it, at least, practically speaking, and in the ordinary conditions of domestic or of ship economy. On board ships, the water which is stored in for the use of crews in the usual way, in the course of about a fortnight becomes putrid and almost undrinkable, because the organic matter which that water contains is undergoing a process of putrefactive fermentation. But about a month or so afterwards the water gradually becomes sweeter and sweeter, until at last it becomes drinkable again, because, eventually, all the organic matter which it contained becomes decomposed, carbonic acid and water being the result, and it ever afterwards remains perfectly good and palatable, because it is saturated with air and cannot absorb more, although that of the ship's hold, where it is kept, is none of the sweetest.

Now, Dr. Stenhouse, three or four years ago, I believe, found that charcoal had the power of purifying tainted air, by burning in an insensible manner the substances to which its bad odour was due; and acting upon that discovery of Dr. Stenhouse, I found that charcoal has the power of destroying the empyreuma of distilled water, *when such water is* AERATED, that is to say, when it contains atmospheric air, or oxygen. I found by experiments, carried on a somewhat extensive scale for many months, that two cubic feet of charcoal are sufficient to remove entirely

the empyreumatic odour and taste of distilled water, produced at the rate of 500 gallons per diem, and that the charcoal *never wants renewing*, because it does not act as a filter, but as a burner, the substance burnt being the empyreumatic product, and the result of the slow combustion thereof being carbonic acid and water. I have every reason to believe, from the length of time during which several of my apparatus have been in operation, that such a filter once made will last for ever, because the charcoal disinfects the water, so to speak, as it does air, not by mechanical separation, but by actual though insensible combustion. The water, as it issues from the apparatus, is perfectly sweet, tasteless, inodorous, completely saturated with a maximum quantity of pure air, it is of sparkling clearness, and being refrigerated in traversing the coiled pipe surrounded by the cold sea-water at the lower part of the apparatus, it is fit for immediate use.

And thus is the second condition, that of aeration, of digestibility, of wholesomeness, accomplished, whereby the water so produced is *at once* drinkable, and so sweet and fresh that it cannot be distinguished from the very best spring water.

I have already stated that sea-water contains a certain quantity of salt in the proportion of about 1lb. of salt to 33lbs. of water. Now, when sea-water is evaporated, all the steam produced therefrom being, of course, fresh water, all the salt which that water contained is left behind, that is to say, the salt previously contained in the evaporated portion is left in that portion which is not yet evaporated, and which is, therefore, more impregnated with salt than before. If this salt be not removed, and the evaporation is continued, it goes on accumulating, furring, and incrusting the vessel, and very soon destroys it. This is, in fact, an inconvenience common not only to all the sea-water stills hitherto contrived, but to the boilers of marine engines; for no boiler or vessel is safe from incrustation as soon as about half of the sea-water admitted in them has been evaporated; that is, when the sea-water has been saturated by concentration so as to contain 1lb. of salt in about 16lbs. of water.

The apparatus which I have had the honour to describe is not liable to these incrustations or deposits of salt, because the sea-water circulates

in it in a constant and uninterrupted manner, and the quantity evaporated (one-sixth) is much less than is necessary to interfere with the perfect solution of the whole of the salt, since the discharged water contains only about one-half per cent. more salt after than before being operated upon; that is to say, the sea-water, as it is admitted into the apparatus, contains, as we said, about 16ozs. of salt in 33lbs. of water; when it is discharged it contains only about 17ozs. of salt in 33lbs. of water, which is an insignificant increase. On the other hand, the different parts of the apparatus being made of stout iron plates, rivetted, and connected in a substantial manner by screws and bolts, without soldering or brazing of any kind, or in any part, it is perfectly impossible that it should go out of order by any kind of accident short of those cases of *force majeure* which, unfortunately, are too often the cause of the ruin or wreck of the ship itself.

There is also attached to the apparatus a valve of a peculiar construction, which I have called a differential or equilibrium valve, by which I am enabled to take from a boiler containing steam *at any pressure*, a quantity of steam of a uniform and self-regulating amount of pressure below that of the boiler; this valve has been adopted in various large engineering establishments, and may be seen in operation at the Royal Arsenal, Woolwich, but as this belongs more to the mechanical than to the chemical section, I will not trouble you with a description of it, though of course, I shall be happy to give subsequently any information respecting it to any person who may feel an interest in such matters.

From this brief description of my Patent Marine Fresh-Water Apparatus, it may be conceived that, by heating the sea-water at only 212° Fahr. by means of steam at only a few pounds above atmospheric pressure, it is volatilised in a most economical manner, and is perfectly free from the saline and organic matters which usually impart to it, in other arrangements, a nauseous odour and disagreeable taste; and that the cheapness and small volume of the apparatus, the large quantity of fresh, salubrious, and aerated water which it produces* at an

* An apparatus 5 feet high, 3 feet long, and 1½ foot wide, produces 24 gallons of fresh water per hour.

extremely small cost, its absolute safety, permanent order, and the ease with which all its parts can be reached, not only render it pre-eminently suited to marine purposes, but that it is likewise admirably adapted to such stations or places as are deficient in one of the first necessities of life, or where salubrious fresh water either cannot be obtained at all, or only in an insufficient, precarious, or expensive manner. Such a place, for example, is Heligoland, in the North Sea, where I have lately erected, by order of the Government, an apparatus capable of producing about 8,000 gallons per day.

STREET BROTHERS, 11, SOHO-STREET, LINCOLN'S-INN, LONDON.