XII. *Additional Experiments and Observations on the Application of Electrical Combinations to the Preservation of the Copper Sheathing of Ships, and to other purposes.* *By Sir* HUMPHRY DAVY, *Bart. Pres. R. S.*

Read June 17, 1824.

I HAVE already had the honour of communicating to the Royal Society the results of my first researches on the modes of preventing the chemical action of fluid menstrua, such as saline solutions, or sea water containing air, on copper, by the contact of more oxidable metals.

For some months I have been engaged in a series of new experiments on this subject, so important to the navigation and commerce of the country: and through the liberal and enlightened views of Lord MELVILLE, and the Lords of the Admiralty, who desired the Commissioners of the Navy Board and of the Dock Yards to give me every assistance in their power, and all the facilities which our magnificent Naval establishments at Chatham and Portsmouth furnish, I have been enabled to conduct my operations upon a very large scale. At this advanced period of the session, it will be impossible for me to give more than a very short notice of experiments which have been tried under a great variety of circumstances, and the details of which would occupy some hours in reading; but I cannot deprive myself of the pleasure of stating the satisfactory and conclusive nature of

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the results, many of which have even surpassed my expectations.

Sheets of copper, defended by from $\frac{1}{40}$ to $\frac{1}{1000}$ part of their surface of zinc, malleable and cast iron, have been exposed, for many weeks, in the flow of the tide in Portsmouth Harbour, and their weights ascertained before and after the experiment. When the metallic protector was from $\frac{1}{40}$ to $\frac{1}{150}$, there was no corrosion nor decay of the copper; with smaller quantities, such as from $\frac{1}{200}$ to $\frac{1}{400}$, the copper underwent a loss of weight, which was greater in proportion as the protector was smaller; and as a proof of the universality of the principle, it was found that even $\frac{1}{1000}$ part of cast iron saved a certain proportion of the copper.

The sheeting of boats and ships, protected by the contact of zinc, cast and malleable iron in different proportions, compared with those of similar boats and sides of ships unprotected, exhibited bright surfaces, whilst the unprotected copper underwent rapid corrosion, becoming first red, then green, and losing a part of its substance in scales.

Fortunately, in the course of these experiments, it has been proved that cast iron, the substance which is cheapest and most easily procured, is likewise most fitted for the protection of the copper. It lasts longer than malleable iron, or zinc; and the plumbaginous substance, which is left by the action of sea water upon it, retains the original form of the iron, and does not impede the electrical action of the remaining metal.

I had anticipated the deposition of alkaline substances in certain cases upon the negatively electrical copper. This has actually happened. Some sheets of copper, that have

been exposed nearly four months to the action of sea water, defended by from $\frac{1}{35}$ to $\frac{1}{80}$ of their surface of zinc and iron, have become coated with a white matter, which, on analysis, has proved to be principally carbonated lime, and carbonate and hydrate of magnesia. The same thing has occurred with two harbour boats, one of which was defended by a band of zinc, the other by a band of iron, equal to about $\frac{1}{35}$ of the surface of the copper.

These sheets and boats remained perfectly clean for many weeks, as long as the metallic surface of the copper was exposed; but lately, since it has become coated with carbonate of lime and magnesia, weeds have adhered to these coatings, and insects collected on them; but on the sheets of copper, defended by quantities of cast iron and zinc, bearing a proportion below $\frac{1}{150}$, the electrical power of the copper being less negative, more neutralised, and nearly in equilibrio with that of the menstruum, no such effect of deposition of alkaline matter or adherence of weeds has taken place, and the surface, though it has undergone a slight degree of solution, has remained perfectly clean: a circumstance of great importance, as it points out the *limits* of *protection;* and makes the application of a *very small* quantity of the oxidable metal, more advantageous in fact than that of a larger one.

The wear of cast iron is not so rapid; but that a mass of two or three inches in thickness will last for some years. At least the consumption in experiments which have been going on for nearly four months, does not indicate a higher ratio. This must however depend on the relation of its mass to that of the copper, and upon other circumstances not yet ascertained (such as temperature, the relative saltness of the sea,

and perhaps the rapidity of the motion of the ship;) circumstances in relation to which I am about to make decisive experiments.

Many singular facts have occurred in the course of these researches. I shall mention some of them, that I have confirmed by repeated experiments, and which have connections with general science.

Weak solutions of salt act strongly upon copper; strong ones, as brine, do not affect it; and the reason seems to be, that they contain little or no atmospheric air, the oxygene of which seems necessary to give the electro-positive principle of change to menstrua of this class.

I had anticipated the result of this experiment, and upon the same principle of some others.

Alkaline solutions, for instance, impede or prevent the action of sea water on copper; having in themselves the positive electrical energy, which renders the copper negative. Lime water even, in this way, renders null the power of action of copper on sea water.*

The tendency of electrical and chemical action being always to produce an equilibrium in the electrical powers, the agency of all combinations formed of metals and fluids is to occasion decompositions, in such an order that alkaline, metallic, and inflammable matters are determined to the negative part of the combination, and chlorine, iodine, oxygene and acid matters to the positive part. I have shown in the Bakerian Lecture for 1806, that this holds good in the Voltaic battery. The same law applies to these feebler

* I am at present engaged in applying this principle to experiments on the preservation of animal and vegetable substances.

combinations. If copper in contact with cast iron be placed in a vessel half full of sea water, and having its surface partially above that of the water, it will become coated with carbonate of lime, carbonate of magnesia, and carbonate of soda; and the carbonate of soda will gradually accumulate till the whole surface in the air is covered with its crystals:— and if the iron is in one vessel, and the copper forming an arc with it in another; and a third vessel of sea water in electrical connection by asbestos or cotton is intermediate, the water in this intermediate vessel continually becomes less saline; and undoubtedly, by a continuance of the process, might be rendered fresh.

I shall not take up the time of the Society, by referring to some obvious practical applications of these researches, to the preservation of finely divided astronomical instruments of brass by iron, of instruments of steel by iron, or zinc: my friend Mr. PEPYS has already ingeniously taken advantage of this last circumstance, in inclosing finely cutting instruments in handles or cases lined with zinc, and many other such applications will occur. I cannot conclude, without mentioning particularly my obligations to Sir BYAM MARTIN, the Comptroller, and Sir ROBERT SEPPINGS, the Surveyor of the Navy, for the interest they have taken, and the zeal they have shown in promoting these researches; and without stating how much I owe to the care, attention, and accuracy of Mr. NOLLOTH, Master Ship-wright, and Mr. GOODRICH, Mechanist in the Dock-yard at Portsmouth, in superintending the execution of many of the experiments.