ticles, yet few pretend to define "power." With its present vague meaning it should not be considered a *scientific* term, but if we agree upon the definition given by Mr. Nystrom, it will be as specific as any other term used in science. Morin, in the work above referred to, says, p. 12, "we use the words *power* and *resistance* to denote those forces which favor motion, or those which oppose it;" while the general meaning is, *ability* to do something. We speak of water-power, horse-power, steam-power, power of a lens, power of the wind, mechanical powers, physical power, moral power, and many other abilities, without any idea of the measure of those abilities. It would be a decided gain to physics if it had a specific meaning, and the term force substituted for power in those indefinite expressions.

On the Incrustation of Marine Boilers. By Mr. JAMES R. NAPIER.

From the London Mechanics' Magazine, November, 1864.

Read before the Institution of Engineers in Scotland, February 17, 1864.

In the Transactions of this Institution, 1859,60, will be found a paper which I wrote, chiefly for the purpose of showing that regenerators, as ordinarily constructed, were much too small for the object intended. But I have there also stated (page 46) that "when these regenerators are made with a sufficient amount of surface, so that abundance of water can be supplied to and discharged from the boilers with little loss of heat, then there will be *no incrustations*," &c. In the last paragraph of the paper I have, with more caution, said, "that this amount of discharge and surface, *it is expected*, will prevent incrustation, and save nine-tenths of the heat at present lost by the ordinary method of blowing off."

The object of the present communication is to show that the practice here recommended leads to results the very opposite of what was expected. Believing, as I then did, in the ordinary theory of blowing off from the boiler before the water became saturated with salts, that an abundant feed and blow-off would prevent the lime depositing, and therefore prevent the incrustations; and being desirous of saving the heat which would otherwise be lost by the great amount of blow-off which I believed to be necessary, I had a regenerator made for the S.S. "Lancefield" with about ten times the surface which it had been customary to give to such apparatus; but the results, as stated at a recent meeting, were so much at variance with my understanding of the ordinary theory, that I think a statement of the facts will help others to a clearer knowledge of the matter.

The vessel then, sailed from Glasgow about noon every Thursday for the Hebrides, lay in one of the lochs there from Saturday evening till Monday morning, and arrived again in Glasgow on Wednesday, to recommence on Thursday a similar voyage. The steam was up or at hand all the voyage; about fifteen stops, of two or three hours each, were made each week, during which time the boiler was supplied with feed by a Giffard's injector, but little or no blow-off.

While steaming, however, the quantity of water continually discharged through the regenerator was so great that the glass hydrometer used for ascertaining the density showed very little difference between the sea and the boiler-water. The boiler was worked in this manner for about four weeks, and then examined; when, instead of being found, as I expected, clean, with little or no scale or deposit, the coating was much thicker, than usual, but soft, very much like newly made mortar, not difficult, before getting dried, to scrape off all accessible places, but which when dry was nearly as difficult of removal as the ordinary compact scale.

During one of the voyages, when I was personally directing the experiment, and had for some time been keeping the greatest amount of feed on the boiler which the engine could supply, I observed the water in the gauge-glass get muddy, but did not then discover the cause. About two years before this I found the same soft limy deposit in the S. S. "Islesman's" boiler, when trying similar experiments on the same station; but as I had disregarded the "Islesman's" experience, and did not then know the experience of others, the "Lancefield's" regenerator was continued, but with lesser quantities of feed and discharge, for about six months, when the tubes of the apparatus giving way, it was discontinued. I was fortunately saved further trouble, and the expense of repairing it, by discovering in the *Annales des Mines* for 1854, an interesting paper by M. Cousté, "On the Incrustations of Boilers." He there shows that the sulphate of lime can be deposited by heat alone, without any evaporation, and that at a temperature of 124°, cent., or two atmospheres of pressure, sea-water in its natural state is very near the point of saturation. As the "Lancefield's" boiler was loaded to nearly 40 ℔s of absolute pressure, and worked generally to about two atmospheres, or 255° Fahr., or about the point of saturation of the lime, it is clear that the greater the amount of sea-water supplied to the boiler, the greater would be the quantity of lime deposited in it. And although there was a constant discharge from the surface by a conical tube, only some of the deposited matter—that which had not attached itself to the boiler—could be so discharged. If this be not the true explanation of the deposit in the "Lancefield's" boiler, of the difficulty of working boilers with sea-water at higher pressures, and of the ordinary experience that boilers are cleaner when worked at a greater density, it will remain for others to explain it.

M. Cousté's experiments, however, appear to me to be conclusive. He suggests a method of getting quit of the lime by filtration at a high temperature. The following extract from his paper shows the conclusions he arrived at from his experiments:—

1. The sulphate of lime is less soluble in hot than in cold, fresh, or sea-water.

For temperatures above 100° cent. the solubility of the sulphate of lime in sea-water diminishes nearly in proportion to the increase of temperature; and, consequently, this solubility diminishes very rapidly with the corresponding increase of pressure.

The following table indicates this solubility for different temperatures, as well as the degrees of concentration at which the saturation of sulphate of lime has place:—

Degrees of the Areometer corresponding to the Saturation.	Temperatures.	Pressures in Atmospheres.	Solubility or Proportion of Sulphate of Lime in 100 of Water at Saturation.
	Degrees.	Atmos.	
12½	103·00	1	0·500
12	103·80		0·477
11	105·15		0·432
10	108·60	1¼	0·395
9	111·00		0·355
8	113·20		0·310
7	115·80	1½	0·267
6	118·50		0·226
5	121·20		0·183
4	124·00	2	0·140
3	127·60		0·097
2	130·00	2½	0·060
1	133·30		0·023

This table expresses that, for example, sea-water boiling at atmospheric pressure, or 103°, will arrive at saturation of sulphate of lime when it will have acquired the concentration of 125° of Baume, and then it will contain 0·500 per cent. of this salt; at 1·25 atmospheres, or 108·6° of temperature, the water will be saturated with sulphate of lime, when the areometer marks 10; it will then contain 0·395 per cent. of sulphate of lime; at two atmospheres, or 124° of temperature sea-water in its natural state, and before it has experienced any concentration, is very near the point where the saturation takes place—for the natural water-marks from 3 to 3·5°,—and in this case the saturation takes place at 4° of concentration.

2. Sulphate of lime becomes wholly insoluble either in sea-water or in soft water at temperatures comprised of 140 and 150° centigrade; and if we expose at these temperatures water containing some of this salt in solution, it is entirely precipitated in the form of little crystals, or of very thin pellicles, according as the salt is more or less abundant in the solution. The sulphate thus precipitated is redissolved after the cooling, but as much more slowly as the temperature at which it is deposited is elevated. That which is deposited at 150° takes many days to re-dissolve.

In the discussion which followed the reading of the paper,

Mr. Elder said he had a good deal to do with the working of boilers at from 30 lbs to 35 lbs pressure without surface condensers, and in some cases he had seen very extraordinary deposits. One naturally expected to find most deposit in the section of a boiler where there was most salt and lime; but in a boiler divided into eighteen parts he had found to his surprise, that although in the last section there were two-and-a half times more salt in the water than in that of the first section, yet he could ascertain little difference in the quantity of deposit of lime in any section. He had therefore come to the same conclusion as the President, that the deposit depended upon the temperature of the water, and not upon the quantity of lime in it. The great difficulty they had to contend with in preventing deposit, was that of keeping the circulation in such a state as that the currents would prevent the deposit, for it was found that where there was a current in a boiler the lime did not deposit to any extent. There was certainly no evidence to show that the lime deposited more on account of the presence of a greater quantity of it. The Americans ran with a pressure of 40 lbs at sea, and they did not appear to suffer much from deposit. They seemed to overcome the deposit of lime by cleaning the boiler whenever they got into port. He was aware of boilers working at 30 lbs for six or seven years, and the deposit was not greater with that than at lower pressures. He was quite satisfied, with the President, that the lime deposited with pure sea-water, and with sea-water having twice or thrice the usual quantity of salt in it, was the same.

Mr. Lawrie remarked that apparently it was Mr. Napier's opinion that beyond a certain pressure the deposit of sulphate of lime was not aggravated by an increased pressure.

Mr. Elder observed that, though the lime separated from the water, yet it did not necessarily settle down unless it got into eddies. Where the heating surface was, it had no great tendency to deposit. It was found that the deposit occurred in places where there was no great current.

Mr. Lawrie said that they would naturally expect to find it down below the furnace. He asked whether it had been found in practice that there was a greater or less deposit in boilers working at 60 lbs pressure than at 30 lbs? He would infer from the discussion that the deposit of sulphate of lime was not greater at the higher pressure.

Mr. Elder had observed boilers working with salt-water for three or four months at 45 lbs pressure, and he could not say there was much difference between the deposit at that pressure and at 25 lbs. He believed, however, there was a greater tendency for the lime to separate from the water, but it did not necessarily settle down over the heating surface of the boiler.

Mr. Lawrie said that the gunboats, of which the late Mr. Hughes had great experience, worked at a pressure of 60 lbs, and no extreme difficulties have been experienced in them.

Professor Thomson suggested that the water might be filtered in a tube 10 or 12 feet long, in which it could be heated up to 150° cent., but this would probably take a good deal of power.

Mr. Elder remarked that nearly every engineer knew of examples of furnace crowns and furnace sides of steam boilers with salt-water tumbling in on account of the deposit of lime or salt on those parts; and it was always considered to be the result of too little blowing off, any such accident being prevented by sufficient blowing off. Were there not other deposits formed at a greater degree of saturation? Suppose they had a quadruple strength of salt in the boiler, was the salt deposited of an injurious kind when it got to a certain density? When did the injurious deposit begin ? He believed that when water got to those densities, the lime and the salt formed a crust, and became a non-conductor, and the surface got nearly red hot, and tumbled in. Now, if the lime came out at a temperature of 220°, one would suppose that it would do the same at 230° or 240°. He would have expected that the furnace of the "Lancefield" would have fallen in.

Mr. Jas. R. Napier answered that the sides of most furnaces bulged between the stays, but he did not know the cause of it.

Mr. Lawrie remarked that there seemed to be one very important fact ascertained—that the extensive use of refrigerators could not be attended with the good that was expected from them.

Mr. Jas. R. Napier explained the construction of the "Lancefield's" regenerator, and in reply to inquires, stated that it was about 11 feet high, 20 inches in diameter, and fitted with iron tubes of about ½-inch bore. The tubes gave way at the bottom near the feed inlet. It was very efficient while it lasted. Where there was less water discharged there would be less heat to be saved. Still, the regenerator would always be useful in saving a great portion of the heat that would otherwise be lost.

Mr. Elder observed that the regenerators in the "Shamrock" and "Thistle" wore away rapidly at the ends of the tubes, which were of brass, where the current of water impinged against them, which he believed arose from the mechanical friction caused by the velocity of the water. He would have expected that iron tubes would have gone much more quickly; for in the cases he had mentioned there was no appearance of galvanic action.

Mr. Lawrie said the old refrigerators did not wear away quickly, although the water struck against their brass ends.

Mr. Thomas Russell had seen regenerator tubes worn away both from mechanical action and other causes, such as by rust; whilst he also knew that they worked about ten years in the West India boats, and yet seemed pretty perfect after that, and certainly not worn out; so much so, that when they got new boilers, they repaired their regenerators, and continued to work them for years after that. He did not know whether they were still working them.

Manipulation of Metals.

From the London Mechanics' Magazine, October, 1864.

There are many occasions where a knowledge of some simple alloy or a peculiar solder would save hundreds, yes, thousands of dollars, just as a life may be saved by merely tying a pocket-hankerchief tight-