The numbers in the following table give the average of these determinations which were in concordance at each weighing.

A method has been recently patented by Cumberland of Melbourne, which aims at the prevention of the corrosion of iron and steel by passing a current of electricity suffi-

Molecules of water fixed by—

Percentage of Anhydrous salt.	Magnesium Sulphate.			Sodium Sulphate.			Aluminium Sulphate.		
	Drying at 15°-18°C. 22°-24°C. 28°-30°C.			Drying at 15°-18°C. 22°-24°C. 28°-30°C.			Drying at 15°-18°C. 22°-24°C. 28°-30°C.		
4% on the weight of the leather Leathers with $\frac{20\%}{10\%}{\frac{5\%}{5\%}}$ of soluble matter.	0.1 7.1 0.4	5.4 0.0 5.7	3.1* 5.2 4.8	2.3 2.0 2.6	2.0 2.8 2.7	2.0 2.2 3.2	11.2 11.2 11.4	9.0 10.2 9.8	9.6 10.4 10.8
2% on the weight of the leather Leathers with $\frac{20\%}{10\%}{\frac{5\%}{5\%}}$ of soluble matter.	0.7 0.5 0.8	0.1 5.3 5.0	5.4 3.3* 5.1	2.7 2.4 3.0	2.2 2.0 2.4	2.5 2.7 2.3	11.5 12.2 10.1	10.1 9.7 12.3	10.0 10.6 11.3
1% on the weight of the leather Leathers with $\frac{20\%}{10\%}{\frac{5\%}{5\%}}$ of soluble matter.	0.9 7.2 7.0	0.0 0.2 5.1	5.2 4.9 5.2	3.1 2.7 3.2	2.4 2.7 2.6	2.2 2.8 3.1	12.8 10.7 11.0	10.0 11.1 10.2	10.7 11.2 9.8

The samples marked * showed crystallisation outside.

On examination of the table we see that magnesium sulphate has taken about seven mols. of water for the leathers which are dried at ordinary temperature. This quantity decreases to five mols. for leathers dried at high temperatures. For aluminium and sodium sulphates, the difference is smaller, depending on the temperature of drying, the amounts being 10-12 mols. of water for aluminium sulphate and three for sodium sulphate.

The results also show that the percentage of soluble matter varying between 5 and 20 per cent. of the leather does not affect the quantity of water fixed by the salt.

In addition we have made some determinations with 100 grms. of small pieces of leather about 1 in. square, put in basins to facilitate the impregnation with the solutions, but the results were not satisfactory, because crystallisation takes place on the surface of the samples and on the bottom of the basins; the number of molecules of water was always smaller than the number given in the above table.

Finally, we have made a determination with larger pieces of leather, with three groups of samples (500 grms. each); the first group with 3.5 per cent. of anhydrous magnesium sulphate on the weight of leather, the second with 3.5 per cent. of anhydrous sodium sulphate, and the third with the same volume of water, doing the drying at ordinary temperature. The results were for magnesium sulphate, 6.8 mols. of water, and for sodium sulphate 3.1 mols.

Sydney Section.

Meeting held at Sydney, on Wednesday, September 21st, 1910.

MR. T. STEEL IN THE CHAIR.

ELECTROLYSIS AS A MEANS OF PREVENTING THE CORROSION OF IRON AND STEEL.

BY G. HARKER, D.S.C., AND J. McNAMARA.

The galvanic effect set up between two different metals placed in a solution capable of conducting the electric current is well known and accounts for the rapid corrosion of iron in contact with copper or brass. The current can be considered as flowing from the iron as anode, to the copper or brass as cathode, while positively charged iron ions pass into solution and hydrogen ions are simultaneously forced out.

ciently strong to reverse the direction given above and so make the iron the cathode. It is put forward as being of special service in preventing the corrosion of boilers. In actual practice a bar of wrought iron is suspended in the boiler to act as the anode and a current of electricity of 1 to 2 amperes at 4 to 8 volts pressure is passed from this through the water to the shell of the boiler. Several marine boilers have been working now for some months under these conditions, and the results are stated to be eminently satisfactory.

The Colonial Sugar Refining Company, Ltd., of Sydney, to whose scientific staff the authors belong, maintains a very large number of boilers at its various mills and refineries, and at times trouble has arisen through bad feed water. The method was consequently of interest to the Company, and in this paper are given the results of some experiments carried out with the object of determining if possible the probable practical value of the process.

In Table I. are set forth the results of some preliminary experiments carried out with small iron and steel plates $1\frac{1}{2}$ in. $\times$ $1\frac{1}{2}$ in. $\times$ $\frac{1}{8}$ in. A small storage battery was employed for the supply of the current, which during the series described in Table I. was delivered at a pressure of 3.3 volts. The resistance of the circuit given in the second column of the Table was made up of that of the solution plus that purposely supplied from a "Standard" resistance box. The anode and cathode plates were placed 5 cms. apart in a beaker with about 115 c.c. of solution, and the resistance between the plates was found to be about 3,22, and 370 ohms for sea-water, acid solution and ordinary tap water respectively. The alteration of resistance during the progress of the experiments, owing to change in composition of the solution, was only of moment in the case of the two experiments in acid solution using iron anodes and no account was taken of it in these preliminary trials.

For purposes of comparison it should be stated that the corrosion of the steel and iron when placed in a beaker for 24 hours with about 115 c.c. of solution was found to be:—

	Steel.	Wrought Iron.
Acid solution	0.08 gram	0.01 gram
Sea-water	0.0033 "	0.0032 "
Ordinary water	— "	0.0028 "

Different pieces of steel made from the same plate gave very varying results but the figures are sufficiently representative for purposes of comparison.

The results given in Table I. show that the corrosion of wrought iron and steel in ordinary water or in sea-water

can be prevented—as judged by constancy of weight of the cathode piece—by even small currents when iron is used as the anode. In acid solution no loss of weight took place with a current of 0.15 ampere with iron as anode, but with platinum as anode the current did not wholly protect the cathode and reference will be made to this later. In the sea-water experiments a green coating of ferrous hydroxide nearly always formed on the cathode and the difficulty of removing this no doubt accounts for the slight gain of weight observed in some cases.

The results of these preliminary experiments were so interesting that it was decided to conduct further experiments using larger plates and also with the object of determining more exactly the size of current which would be sufficient to prevent corrosion under a given condition.

A plate $\frac{1}{4}$ in. thick was bent into circular shape, the dimensions of the cylinder thus formed being 6 in. in depth and 5 in. diameter. The surface area of this cylinder was 70 times that of one of the small plates used previously. By placing a rod of iron in the centre of the cylinder to serve as the anode, conditions were obtained approaching more nearly to those that would be met with in the practical application of Cumberland's method to boilers.

The steel cylinder weighed about 660 grams and it was found that it could be washed with water, dried and reweighed with an error not exceeding 0.015 gram.

Two experiments were first made with acid solutions, as information was wanted as to whether the electrolytic process would be of use in protecting boilers if fed with sour waters from sugar factories. The results appear in Table II., and although the acid solution used was of much greater strength than would ever be met with in practice, it was quite clear that the steel cylinder could be protected by using currents of the quite moderate strength.

In the first experiment 400 ohms resistance were added to the circuit from the resistance box in order to reduce the strength of the current to about 0.01 ampere, in the second the resistance of the cell only was employed.

The alteration in the resistance of the cell owing to solution of iron is shown by the second resistance figure.

An interesting point brought out by these experiments was, that the quantity of current actually used, calculated from the voltage of the battery and the resistance of the circuit, was approximately equivalent to the current calculated from the amount of iron removed from the anode. The electrochemical equivalent of iron is .00029 gram per sec. per ampere, in other words 1.044 grms. of iron is carried by a current of one ampere per hour, and hence from the loss of iron from the anode it is possible to calculate the current flowing. This suggested that, in applying Cumberland's process, it might be possible to determine the strength of current for any given case by finding the rate of corrosion of the steel in the given solution, and then calculating from the electrochemical equivalent of iron the opposing current required. The method was tested in some experiments carried out with sea-water.

The cylinder was first immersed in sea-water for 72 hours and was found at the end of that time to have lost 0.3 gram. Assuming that, in order to keep the iron from dissolving, an amount of electricity has to be passed through the circuit equivalent to that produced by the dissolution of 0.3 gram, we find that 0.288 amp. is required, necessitating a current of 0.004 amp. per hour for 72 hours.

'Three experiments with sea-water were performed using currents of 0.01, 0.004, and 0.0027 amp. respectively. According to the above theory the first current should be larger than necessary to prevent corrosion of the steel, the second about correct, and the third too small; and this proved to be the case.

In the first experiment the steel was completely protected, but the current employed was much larger than necessary and the excess of iron removed from the anode formed a greenish mud of ferrous hydroxide which partly remained on the cylinder. In the second experiment the strength of the current seemed to have been judged very correctly. The plate was quite protected and very little ferrous hydroxide was formed. In the third experiment the current was weak. No ferrous hydroxide but only ferric hydroxide was produced and the cylinder lost

slightly in weight. In the last two experiments (D and E Table II.) the cylinder remained perfectly bright and clean during the whole time it was immersed. It therefore seems likely that in employing the electrolytic process the current required to prevent corrosion can be obtained by calculation from the rate of corrosion of the iron or steel vessel under the given conditions. A current somewhat in excess of that calculated should be employed so as to make certain of protecting the vessel. In the case of a boiler it would, of course, not be possible to determine the loss directly, but if a sample of the steel of which it was made were obtainable the rate of corrosion of this sample in the given liquid under somewhat similar conditions could be obtained. From the ratio of the area of boiling surface exposed to the area of the sample the current required to prevent the corrosion of the larger vessel could be determined. Assuming that the steel of a boiler would corrode at a rate equal to the rate of corrosion of the experimental steel cylinder in sea-water, and that the surface exposed to the water was 2500 square feet, then the surface of the cylinder being 1.25 sq. ft., the current required would be $\frac{0.004 \times 2500}{1.25} = 8$ amperes. This figure

is somewhat higher than Cumberland's estimate of 1 to 2 amp. at 4 to 8 volts pressure, but it must not be forgotten that in determining the rate of corrosion of the experimental cylinder there was free access of air to the seawater and this effect might possibly outweigh the influence of the higher temperature of the water in a boiler. Seawater is also more corrosive than ordinary boiler water and it is quite probable that the estimate of 1 to 2 amperes is not too low. A good deal would depend on the nature of the feed water and the material of the boiler itself.

Up to this time Cumberland's explanation that, by making the plate to be protected the cathode, positive ions of iron are prevented from entering the solution, was accepted as satisfactory. The only disturbing experiments were those in which platinum was used as the anode, in which, although the current employed was far in excess of that required to protect the plate, corrosion still took place to a slight extent. To obtain further information on this point some experiments were conducted with zinc. A rod of zinc was placed in a small beaker filled with $N/5$ sulphuric acid and its rate of solution determined by immersing it for one hour and then re-weighing it. It was then connected to the negative pole of the battery through a suitable resistance and a strip of platinum was connected to the positive pole. The two were then immersed and left for one hour. Even when a current was used 3 or 4 times as strong as that calculated to be sufficient to prevent corrosion the rate of corrosion was only diminished to about half its previous value. Thus a rod of zinc was found to behave as follows:—

			Loss in weight,
			grms.
Immersed one hour without current			0.012
" using "	"		0.0064
" without "	"		0.016
" using "	"		0.0092

The temperature only varied from 15° C. to 15.5° C. The electrochemical equivalent of zinc being 1.22 gm. per hour, the current required for 0.015 gm. would be about 0.012 amp., while that actually employed was nearly three times as great. When a zinc rod was substituted for the strip of platinum as the anode a gain of 0.002 gm. was obtained in one hour, and this gain would have been much greater if the effectiveness of the current had not been reduced by the solution of zinc from the anode itself.

In another experiment in which the zinc dissolved more rapidly the rate of solution was determined in two successive experiments to be 0.2774 and 0.2780 grm. in 30 minutes. The current required was calculated, the resistance, about 8 ohms in this case, adjusted so as to give a current just slightly in excess of that calculated, and a zinc anode was used presenting a much smaller surface than the cathode. The anode lost 0.3412 grm. in 30 minutes, while the cathode lost only 0.0204 grm. and would doubtless have been completely protected but for the solution of some zinc from the anode by the action of the acid.

It was thus clear that in the case of zinc, as in that of iron, the weight of the cathode can be maintained by a current calculated from the actual corrosion of the cathode in the given solution, provided that the ions of the anode are carried through the solution. If a larger current than that calculated be employed the deposition from the anode will increase the weight of the cathode. In the experiments with iron and zinc anodes the cathode metal was dissolving, but its weight was being made up, at any rate in the acid solutions, by deposition from the anode, and this was clearly demonstrated in the last zinc experiment described, in which the deposit of zinc on the cathode derived from the anode could be plainly seen. During the progress of the experiment the cathode appeared to dissolve in the solution and to give off hydrogen gas just as freely as when it was immersed in the acid solution without any current passing. That the iron or zinc should be dissolving from the cathode while simultaneously deposition of the same metal was taking place seems rather strange at first sight, but is not so when we consider the action which takes place when a piece of iron is immersed in a solution of copper salt. Here the ions of iron pass into solution, and the copper ions take their place.

That the passage of a current is in itself not sufficient to keep the cathode protected is shown by the experiments with iron and zinc in which platinum was used as the anode. At the same time the connection of the iron or zinc to the negative pole of the battery does diminish the solution of the metals, but the diminution is much more marked in the case of iron than zinc. If we take it that the piece of steel used in the first experiment described in Table I. would have lost 0.08 gm. in the acid solution if left to itself, then since only 0.0036 gm. was lost when a current of 0.15 amp. was employed, the loss of metal was under 5 per cent. of what it would have been in the absence

During the progress of the first experiment described in Table I., 5 c.c. of solution was taken from the beaker at intervals and tested with potassium ferrocyanide in order to determine whether the quantity of iron in solution continuously increased or whether it reached a certain concentration and then remained stationary. The first test was taken a few hours from the beginning of the experiment and showed the same amount of iron as in all the subsequent tests, proving that only a certain quantity of iron passed into solution. In the experiments with the steel cylinder in sea-water it was found impossible to weigh the cylinder with certainty with an accuracy greater than 0.015 gm. Furthermore, the passage of a current through sea-water generates sodium hydrate, which would not only tend to reduce the corrosion of the cylinder itself, but would also precipitate iron ions passing from the anode. It is therefore doubtful in these experiments whether any iron was deposited on the cylinder itself, but, even making allowance for the occurrence of experimental errors in the weighing, the loss from the cylinder could only have been very slight.

Although the experiments described have shown that the electrolytic process does not actually prevent metal from entering the solution from the cathode, for, where the weight remains constant, deposition is taking place from the anode, yet the tendency of the metal to pass into solution is much diminished. Whether or not the deposition of fresh metal from the anode takes place evenly over the surface of the cathode, forming a coating which may continually be removed and so protect the main body of the metal, is a matter which could only be decided by further investigation.

In conclusion, the authors wish to express their thanks to the management of the Colonial Sugar Refining Co., Ltd., for permission to publish the results of their investigation.

TABLE I.

	Solution.	Resistance of circuit.	Current in amperes.	Anode.	Cathode.	Loss of weight of Anode. grms.	Loss of weight of Cathode. grms.	Time in hours.
A	N/25 Sulphuric acid ..	22 ohms	0.15	Platinum	Steel	—	0.0036	24
B	Do.	do.	do.	do.	Wrought iron	—	0.0080	21
C	Do.	do.	do.	Wrought iron	do.	0.062	0.0107 (gain)	5
D	Water from tap	370 ohms	0.009	do.	do.	0.1537	0.0008	20
E	Sea-water	3 "	1.0	do.	do.	7.5721	0.0010 (gain)	6
F	do.	30 "	0.1	do.	do.	1.3067	0.0	17
G	Dilute acid	22 "	0.15	do.	Steel	0.5921	0.0155 (gain)	Not taken

TABLE II.

	Solution.	Resistance of circuit.	Voltage of Battery.	Current in amperes calculated from 2 and 3.	Time in hours.	Loss of iron from anode grms.	Current calculated from 5 and 6 amperes.	Loss on Cathode (steel cylinder) grms.	Remarks.
A	N/100 Sulphuric acid	414-454	3.8	0.00918 to 0.00837	72	0.7218	0.0000	0.52	In both experiments C and D a deposit of greenish ferrous hydroxide had to be removed from the cylinder. In "D" it was very slight.
B	do.	14-60	3.8	0.27 to 0.063	18	1.2663	0.067	0.25 (gain)	
C	Sea-water	40	4.0	0.01	72	0.8328	0.0111	—	
D	do.	1000	4.0	0.004	72	0.3058	0.0041	—	
E	do.	1500	4.0	0.0027	72	0.2094	0.0023	0.03	

of the protecting current. Probably it would be possible in the case of both iron and zinc by sufficiently increasing the voltage to prevent the solution of the metal completely, but the process would be too expensive to apply on a large scale. The deposition of hydrogen ions from the platinum anode would undoubtedly tend to protect the cathode from the action of the acid, and, furthermore, after the iron or zinc had reached a certain concentration in the solution there would probably be a tendency for the current to re-deposit them on the cathode.

DISCUSSION.

Dr. E. S. STOKES thought that this paper afforded proof of the electrolytic theory of the corrosion of iron. He had prepared a number of specimens illustrative of the same action, which he now exhibited. Bright untinned iron nails were imbedded in a 12 per cent. solution of gelatin containing phenolphthalein and potassium ferrocyanide. One nail was in contact with a small piece of copper, another with tin, and others with zinc. The blue colour showed

the positive polar areas, and the red colour the negative polar areas. Where the nail was cut or wounded a positive polar area was shown.

Mr. R. J. N. FRANKI said that in electric light stations a good deal of pitting occurred in the condenser tubes, and Mr. Cumberland was asked to instal his appliances at the Sydney Municipal Power House. He used a 7 inch plate on each condenser door, and, though corrosion had not been absolutely stopped, it was greatly diminished. There was also a further advantage, that the condensers were kept perfectly clean by the treatment. The same thing was done at the Balmain Power House with the same result.

The CHAIRMAN said that it was well known that an electric current was produced when iron was under strain, the strained part being the anode and the unstrained the cathode; thus the strained part of a boiler would set up an electric couple, and he asked how this couple would be affected by the application of an electric current to the

boiler as a whole. He mentioned the case of a salt water pump, lubricated with sea water, in which corrosion was considerable. On one occasion a large piece of steel was accidentally left inside the pump, and on again opening up the pump after the lapse of some months the steel was found to be badly corroded, but the pump had been protected.

Prof. J. A. SCHOFIELD said that if the mass of iron of a boiler went into solution as a whole, he could understand that a counter current might protect it; but when one part of the iron was electro-positive to another that was electro-negative, he thought the method must fail, as the local action would still continue.

Dr. HARKER, in reply, said that local action occurred all over a boiler, but the application of an external current inhibited that action. In the experiments in which platinum was used as the anode, it was found that, even in acid water, there was no appreciable decrease in the weight of the iron cathode.

Journal and Patent Literature.

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I.—GENERAL PLANT; MACHINERY.

Freezing mixtures. J. Duclaux. *Comptes rend.*, 1910, 151, 715—716.

THE principle of regenerative cooling is applied to the production of low temperatures by the mixing of appropriate pairs of liquids, each portion mixed serving for the cooling of successive portions to be mixed. Carbon bisulphide and acetone have been found the most suitable liquids, allowing a temperature of -48°C . to be rapidly reached; they are introduced into the mixing apparatus by two long tubes (say 1 mm. in diameter), and the mixed liquids are made to flow back over the exterior of the tubes; the temperature is thus easily kept constant for hours, and the liquids are readily recovered by separating with water. In an example given, the use of 100 c.c. of carbon bisulphide and 70 c.c. of acetone per hour was necessary, to maintain a temperature of -43.5°C . in a volume of 20 c.c.—F. SODX.

Colloidal solutions; Filtration of —. A. Schoep. *Bull. Soc. Chim. Belg.*, 1910, 24, 354—367.

IN the preparation of the collodion filters previously described (this J., 1910, 1041) the following proportions of the ingredients have given the best results:—(1) Pyroxylin, 4; castor oil, 3.5; and ether-alcohol, 92.5 parts; and (2) Pyroxylin, 4; castor oil, 4; and ether-alcohol, 92 parts. The solvent consisted of 10 parts of alcohol and 80 parts of ether. By adding to either of these elastic collodions variable quantities of glycerin, mixtures were obtained, which after evaporation of the solvent, left membranes through which certain colloidal emulsions and solutions could be filtered without external pressure. A filtering membrane prepared from collodion No. 1, with the addition of 4 parts of glycerin enabled a mixture of Prussian blue and of haemoglobin to be separated; and water containing 500 micro-organisms per c.c. was rendered sterile by passage through a membrane of this composition. The rate of filtration was 100 c.c. in 10 minutes with a height of liquid in the filter-membrane of 27 c.c. It was proved that there was no adsorption of colloidal bodies by the substance of the membrane during the filtration.—C. A. M.

PATENTS.

Measuring the flow of liquids in closed conduits; Apparatus for —. F. Simpson and A. R. T. Woods, Liverpool. Eng. Pat. 21,769, Sept. 24, 1909.

IN apparatus for measuring the flow of liquids through closed conduits, in which the quantity of liquid passing is indicated by a liquid gauge showing the difference of pressure on the opposite sides of a constriction in the circuit, the claim is for an "obstruent" to form the constriction which consists of a tapered plug in a plug-cock so arranged that by closing the cock, the "obstruent" can be removed for inspection without loss of liquid.

—W. H. C.

Pyrometers and the like; Indicating and recording apparatus for electric —. W. Armour, Irvine, N.B. Eng. Pat. 22,764, Oct. 6, 1909.

THE claim is for a method of recording the temperatures of several different points on one recording instrument by having a suitable arrangement of connections.—W. H. C.

Settling and filtering apparatus. W. Michel, Suhl, Germany. Eng. Pat. 2875, Feb. 5, 1910.

A SERIES of filtering tanks constructed on the spring system is so arranged that the liquid passes in an upward direction through filtering media of progressively increasing fineness supported on trays suspended below the upper edges of the tanks. Overflows and baffle-walls are provided to guide the flow of the liquid. The solids are removed in trucks which run on rails laid along the floor of the tanks and passing through sluice-doors in the lower parts of the division walls between the tanks.

—W. H. C.

Filtering liquids; Apparatus for —. J. Malfitano, Paris. Eng. Pat. 8545, April 8, 1910. Under Int. Conv., April 9, 1909.

A POROUS membrane or bag formed of collodion, viscose, or gelatin hardened by formaldehyde is arranged within a cylinder or tube provided on its inner side with parallel grooves or with a network, the liquid being forced or sucked through under pressure. In the laboratory filter described, the vessel is preferably made of glass.—H. H.