Magnetic Water Treatment Apparatus

NOTES ON ITS EFFECTIVENESS*

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This report deals with the results of an examination, carried out at the CEBELCOR laboratory in Brussels, of an apparatus for the magnetic treatment of water (CEPI apparatus, super model, type 3/8, No. S7734). It was found possible with the aid of this apparatus to reduce to one-third of its normal amount the incrustation produced in an easily incrustable laboratory distiller fed by drinking water of the Brussels water supply. The following description covers, first, the apparatus itself, then the working method adopted and, finally, the results obtained.

APPARATUS

THE apparatus consists largely of a *Hydrex* laboratory distiller with a capacity of 2 to 2.5 l./hr. of distilled water and is shown in Fig. 1. It was chosen because it has a tendency to develop incrustations and because it can be easily dismantled and cleaned.

The feed water to be examined passes through the flowmeter *A* and the bottom of the cooler *B* to the upper part of the condenser *D*, where it condenses the steam produced in the boiler. The water then flows to the overflow tank *F*, which serves to feed the boiler *G* at a constant level. Surplus water is drained off by the overflow pipe, passed through two filters *H* and *K*, and released to the drain.

The distilled water obtained through the condensation of the steam on the cold wall of the condenser roof *D* is collected in a ring-shaped catch drain, cooled in the cooler *B* and kept in the gauged tank *L*.

The different parts of the apparatus consist of the following materials:

Flowmeter *A*, tube *J* ..	Glass
Cooler *B*, condenser *D* ..	Tinned copper
Pipes *C* and *E*	Brass
Tank *F*, boiler *G* ..	Tinned steel
Filters *H* and *K* ..	Cotton fabric

The flowmeter is connected with the distiller and with the water tap (or with the apparatus for magnetic treatment) by rubber hoses and glass tubes.

WORKING METHOD

On the basis of prior tests to establish a suitable working method for the assessment of the effectiveness of anti-incrustation treatment, the distiller was used in the following way:

Water supply flow: 26 to 29 l./hr.
Heating gas consumption: 0.85 cu.m./hr.
Duration of each distilling operation: 40 hr. without interruption.

Total water consumption for each operation was therefore 1,040 to 1,160 l. (*i.e.* 1,100 ± 60 l.). Of this quantity, 85 to 95 l. (*i.e.* 90 ± 5 l.) were distilled and 955 to 1,065 l. (*i.e.* 1,010 ± 55 l.) released to the drain.

Water temperatures were as follows:

13° ± 1°C. at the inlet of cooler *B*.
27° ± 4°C. at the outlet of cooler *B* (thermometer t_1).
65° ± 3°C. at the outlet of condenser *D* (thermometer t_2).
68° ± 3°C. at overflow tank *E* (thermometer t_3).
64° ± 3°C. at the outlet of filter *H*.
59° ± 3°C. at the outlet of filter *K*.

Under these conditions, salts were precipitated, especially $CaCO_3$, some of which form a more or less marked incrustation at the bottom of the boiler, the rest remaining in suspension in the water and being collected as a sediment on filter *H*.

Each of the parts of the distilling apparatus (cooler *B*, condenser *D*, large tube *E*, overflow tank *F* and boiler *G*) was weighed before each distilling operation with a precision of 0.1 g. After each operation, the distiller was drained and the sediments in suspension in the boiler water were collected on a filter. Subsequently, each part of the apparatus was carefully dried and rubbed down with a soft brush in order to remove any deposits which may have formed and which could easily come off. These parts were then re-weighed. Any increases in weight would then correspond to the weight of the firm incrustations formed on the walls of each part of the apparatus during the distillation.

The sediments collected during the distillation on filter *H*, as well as those which remained in suspension in the boiler water and those which could be easily removed from the different parts of the apparatus, were dried and weighed. Thus is obtained, for each operation, the weight of the incrustations and the weight of the sediments (including the easily detachable deposits). The sum of these weights yields the total weight of the solid salts separated from the water during the operation.

Table 1 gives an example of the

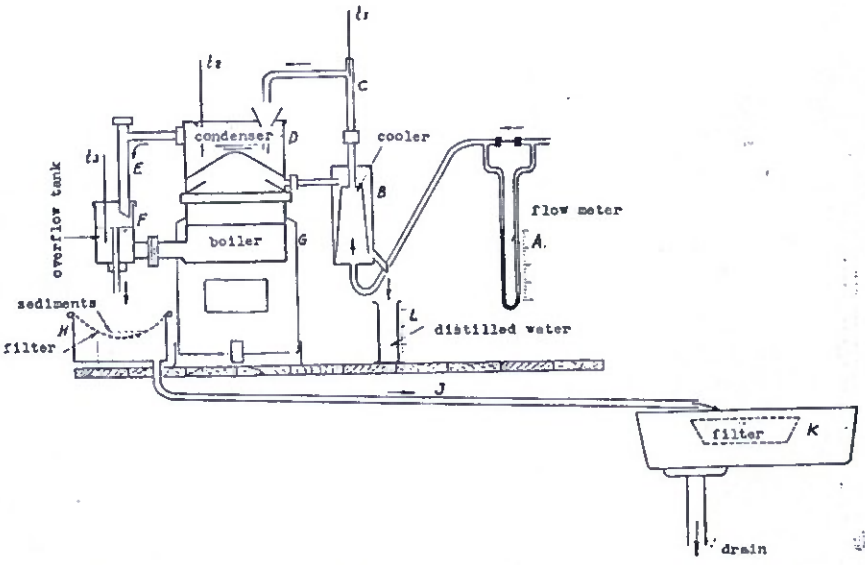

Fig. 1. Apparatus for the study of the encrusting action of water.

*Translation of Technical Report RT 24, Centre Belge d'Etude de la Corrosion (May 1955).

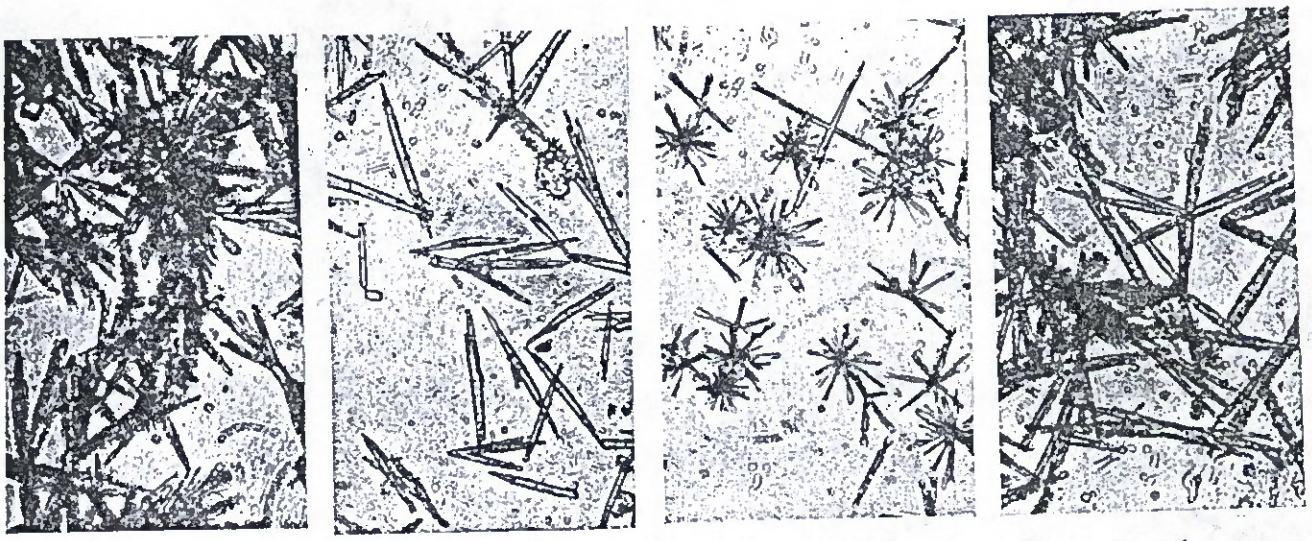

Photo 1 Photo 2 Photo 3 Photo 4

Influence of magnetic treatment on the morphology of crystals obtained by boiling Brussels drinking water; untreated water on the left (Photo 1). *(See text overleaf.)*

different weights (in grammes) determined during a particular test.

From the weights tabulated below, the weights of the sediments and incrustations formed per litre of distilled water produced were obtained, as well as the percentage shares of deposits separated in the form of sediments and incrustations, respectively. These results are regarded as criteria for the encrusting action of the water.

In the case of operation No. 121 tabulated above, during which 88 l. of distilled water were produced, these figures are as follows:

Weight of sediments: 109.5/88 = 1.24 g./l.
Weight of incrustations: 11/88 = 0.13 g./l.
Percentage of sediments: 109.5/120.5 = 90.9%.
Percentage of incrustations: 11/120.5 = 9.1%.

The effectiveness of water treatment can now be assessed by determining these figures, first, for untreated raw water and, second, for the same water after anti-incrustation treatment.

RESULTS

From our experience, it can be stated that, however strictly the working method was kept constant, it was not possible to obtain exactly the same results.

This is mainly due to the unavoidable fluctuations in the composition of the water supply and perhaps also to changes in the apparatus (possibly changes in the condition of the walls). As has been shown by G. Piccardi[1] and Mme. C. Boute,[2, 3] such a lack of reproducibility may be due to atmospheric and meteorological changes which it would be difficult to control.

For that reason, each operation was repeated several times, maintaining conditions as identical as possible. Also, each series of tests carried out with magnetically treated water was preceded and followed by a series of tests with untreated water.

In this way, 27 distilling operations (Nos. 102 to 128) were carried out in five groups, as follows:

Series	*Nos.*	*Town water*
1st	(102 to 107) ..	Untreated
2nd	(108 to 113) ..	Magnetically treated
3rd	(114 to 120) ..	Untreated
4th	(121 to 124) ..	Magnetically treated
5th	(125 to 128) ..	Untreated

Influence of magnetic treatment on water characteristics

The drinking water in Brussels, which was used to feed the distiller, has the following general characteristics (in French degrees):

Temporary hardness and alkalimetric degree ..	TAC : 25°
Total hardness	TH : 32°
Calcic hardness	TCa : 25°
Magnesic hardness ..	TMg : 7°
Chlorides	Cl^- : 2.2° (16 mg./l.)
Sulphates	SO_4^{--}: 5.3° (56 mg./l.)
*p*H value	approx. 7.6

The *p*H value was measured repeatedly before and after the magnetic treatment (where the water has been passed through the treatment apparatus at a flow of 26 l./hr.), using different measuring methods:

	Before treatment	*After treatment*
(*a*) Beckman glass electrode No. 1190	7.35 7.55 7.65	7.35 7.70 7.75
(*b*) Beckman glass electrode No. 290 FR	7.59 7.64	7.73 7.70
(*c*) Quinhydron electrode	7.10 7.15	7.30 7.20
(*d*) Hydrogen electrode	7.40 7.60	7.62 7.72

These results show that, generally speaking, the treatment causes a slight rise of the *p*H value of the water.

During the tests previously carried out with non-magnetic water treatment devices[4] it had been observed that success was frequently related to the extent to which these devices caused the iron in the water to go into solution.

We therefore investigated whether the magnetic apparatus examined caused such a dissolution of the iron. First the apparatus was filled with

Table I. Weight Characteristics of Distillation Operation No. 121

	Distiller		*Deposits*		
	Before	*After*	*Sediments*	*Incrustations*	*Total*
Boiler *G*	6,746	6,759.5	7.5†	6	13.5
	—	—	23.5*	—	23.5
Condenser *D*	2,252	2,263.5	7.5†	4	11.5
Large pipe *E*	568	569.5	0.5†	1	1.5
Overflow *F* and filter *H* ...	74	144.5	70.5*	—	70.5
Total			109.5	11	120.5

*Suspended sediments. †Deposits easily detached by rubbing.

distilled water (volume, 70 cc.), and the quantity of iron dissolved in the water after 24 hr. determined. This operation was carried out four times and yielded the following results:

Date	Weight of iron in 24 hr. in milligrammes	
	Per 70 cc.	Per litre
26.2.55	0.11	1.5
2.3.55	0.15	2.2
5.5.55	0.04	0.5
11.5.55	0.14	2.0

Moreover, in the case of two of the operations which will be discussed below, the quantity of iron in the Brussels drinking water used for the feeding of the distiller was determined before and after passage through the magnetic apparatus. The results were as follows:

No. of operation	Iron contents (mg./l.) with a flow of 26 to 29 l./hr.	
	Before treatment	After treatment
123	0.020	0.024
124	0.020	0.028

The treatment thus results in a *very slight* increase in the iron contents of the water.

In order to examine the influence, if any, of the magnetic treatment on the morphology of the $CaCO_3$ crystals precipitated by the heating of the water, samples were prepared for examination under the microscope.

These samples were obtained by placing a glass slide in a beaker filled with the water to be examined, which was then boiled for 10 min. The glass slide on which the crystals became deposited during the boiling was then removed from the beaker, cautiously dried, and placed under the microscope.

The *untreated water* generally shows ramified and entangled acicular crystals (Photo 1). The *magnetic treatment* will sometimes produce a modification of the morphology of the crystals, which will then cease to show ramifications and entanglements (Photo 2), or which will gather like the spines of a hedgehog (Photo 3). Sometimes, though still remaining an effective means of impeding incrustation, the treatment will only cause a hardly noticeable change in the crystallisation, at least as far as the here-adopted examination method is concerned (Photo 4).

Influence of treatment on the working characteristics of a distiller

The following table shows the composition of the water at the inlet and outlet of the distiller as well as the corresponding changes in composition, in the case of a temperature of 68° ± 3°, in the overflow tank. The magnetic treatment of the water does not affect these values:

	Inlet	Outlet	Modifications
TAC	25°	18° ± 1°	7° ± 1°
TH	32°	25° ± 1°	7° ± 1°
TCa	25°	18° ± 1°	7° ± 1°
TMg	7°	7°	0°
Cl^-	2.2°	2.2°	0°
SO_4^{--}	5.3°	5.3°	0°

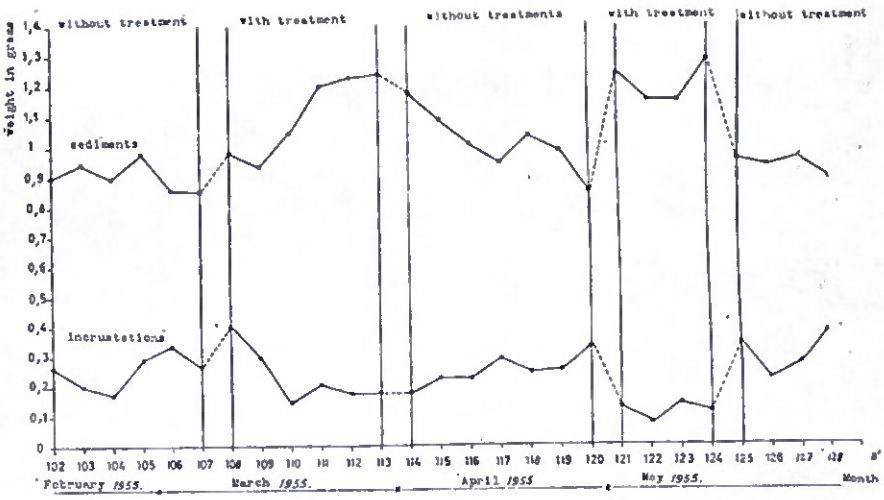

Fig. 2. Weight of sediments and incrustations per litre of distilled water produced.

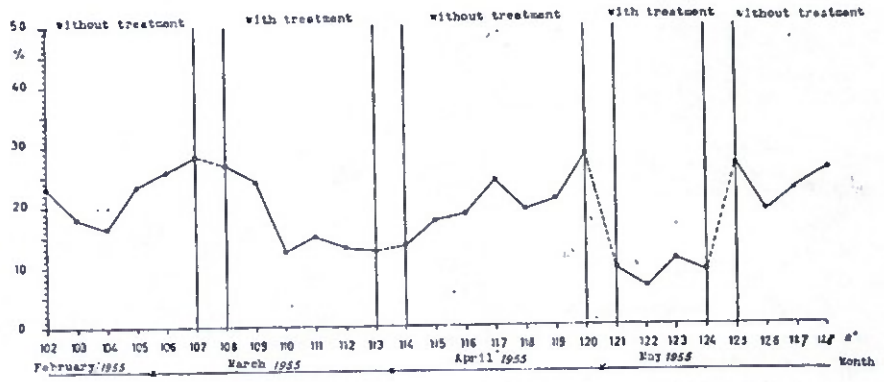

Fig. 3. Percentage of salts separated in the form of incrustations.

The 1,040 to 1,160 l. of water which enter the distiller during each operation thus introduce into the latter 250 mg. of $CaCO_3$ per litre of water, in solution, *i.e.* 260 to 290 g. per operation. The 955 to 1,065 l. of water drained away carry, in solution, 170 to 190 mg. of $CaCO_3$ per litre of water, *i.e.* 162 to 203 g. per operation. Accordingly, the weight of $CaCO_3$ separated during the distillation in solid form (*i.e.* as sediment and incrustations) can vary between 78 and 109 g. per operation. In practice,

Table 2. First Series: Untreated Drinking Water

Operation No.	Distilled water produced (l.)	Total weight, sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	Per litre of distilled water produced: Weight of sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	% incrustation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
102	98	116	89.5	26.5	1.18	0.91	0.27	23.0
103	93	108	88.5	19.5	1.16	0.95	0.21	18.1
104	92	99.5	83	16.5	1.08	0.90	0.18	16.7
105	89	114	87.5	26.5	1.28	0.98	0.30	23.5
106	90	105	78	27	1.16	0.86	0.30	25.9
107	95	114	81.5	32.5	1.20	0.86	0.34	28.3
Average	93	109.5	84.7	24.8	1.18	0.91	0.27	22.5

however, we have found weights ranging from 110 to 120 g.

Tables 2, 3, 4, 5 and 6 show the results obtained, in accordance with the working method outlined, during the five series of tests referred to.

The illustrations, Figs. 2 and 3, show, for the different tests carried out, the weights of sediment and incrustations, respectively, per litre of distilled water produced, and the proportion, in per cent., of solid salts separated in the form of incrustations.

These tables and figures give rise to the following observations:

The *first series of tests* (operations Nos. 102 to 107), concerned with untreated water, show that the weights of sediment and incrustations per litre of distilled water produced are, according to six tests, 0.86 g./l. and 0.34 g./l., respectively. Under these conditions, the proportion of solid salts separated in encrusting form amounts to 28%.

During the *second series of tests* (operations Nos. 108 to 113), concerned with magnetically treated water, it was observed that this treatment is only acting progressively. It reached its full effect only at the fourth test, *i.e.* after 120 working hours (three 40-hr. periods of continuous operation, with interruptions of 32 hr.). The weight of sediment then collected rose to 1.24 g./l. (compared with 0.85 g./l. without the treatment), whilst the weight of incrustations decreased to 0.18 g./l. (compared with 0.33 g./l.). The proportion of solid salts separated in encrusting form thereby decreased to 13% (compared with 28%).

The *third series of tests* (operations Nos. 114 to 120), carried out with untreated water, *i.e.* under the same conditions as the first series of tests, has revealed a hysteresis phenomenon similar to the one found during the second series of tests, but in the opposite sense. The final distillation test yielded 0.85 g. of sediment and 0.34 g. of incrustations per litre, which is practically the same result as that obtained during the first series of tests (0.86 g. and 0.34 g., respectively). This corresponds to 29% of sediments.

With the *fourth series of tests* (operations Nos. 121 to 124), the disincrusting action of the magnetic treatment apparatus showed immediately an excellent effect, without any hysteresis phenomenon. The last test yielded 1.29 g. of sediment per litre (compared with 1.24 during the second test) and 0.12 g. of incrustations per litre (compared with 0.18 g.). This corresponds to 8% of incrustations (compared with 28 and 29% during the two tests with untreated water,

Table 3. Second Series: Magnetically Treated Drinking Water

Operation No.	Distilled water produced (l.)	Total weight, sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	Per litre of distilled water produced: Weight of sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	% incrustation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
108	88	124	87.5	36.5	1.40	0.99	0.41	26.8
109	95	117	89	28	1.24	0.94	0.30	24.2
110	86	104	91	13	1.20	1.05	0.15	12.5
111	91	128.5	109	19.5	1.41	1.20	0.21	14.9
112	87	122.5	107	15.5	1.41	1.23	0.18	12.8
113	82	116.5	101.5	15	1.42	1.24	0.18	12.7
Average	88	118.8	97.5	21.3	1.35	1.11	0.24	17.8

Table 4. Third Series: Untreated Drinking Water

Operation No.	Distilled water produced (l.)	Total weight, sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	Per litre of distilled water produced: Weight of sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	% incrustation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
114	87	119	103	16	1.36	1.18	0.18	13.3
115	85	112	93	19.5	1.32	1.09	0.23	17.5
116	88	109.5	89.5	20	1.24	1.01	0.23	18.5
117	89	111.5	85	26.5	1.25	0.95	0.30	24.0
118	89	115	93	22	1.29	1.04	0.25	19.4
119	91	113.5	90	23.5	1.25	0.99	0.26	20.8
120	84	100	71.5	28.5	1.19	0.85	0.34	28.5
Average	88	111.5	89.3	22.2	1.27	1.01	0.26	20.5

Table 5. Fourth Series: Magnetically Treated Drinking Water

Operation No.	Distilled water produced (l.)	Total weight, sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	Per litre of distilled water produced: Weight of sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	% incrustation
(1)	(2)	(3)	(3)	(5)	(6)	(7)	(8)	(9)
121	88	120.5	109.5	11	1.37	1.24	0.13	9.5
122	89	110	102.5	7.5	1.23	1.15	0.08	6.5
123	103	133.5	119.5	14.5	1.29	1.15	0.14	10.8
124	53	75	68.5	6.5	1.41	1.29	0.12	8.5
Average	83	109.8	100	9.8	1.33	1.21	0.12	9.0

Table 6. Fifth Series: Untreated Drinking Water

Operation No.	Distilled water produced (l.)	Total weight, sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	Per litre of distilled water produced: Weight of sediments and incrustations (g.)	Weight of sediments (g.)	Weight of incrustations (g.)	% incrustation
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
125	84	109.0	80.5	28.5	1.29	0.95	0.34	26.4
126	90	103.5	83.5	20.0	1.15	0.93	0.22	19.1
127	83	102.5	80.0	22.5	1.23	0.96	0.27	22.0
128	90	109.0	80.0	29.0	1.20	0.88	0.32	26.6

and compared with 13% during the preceding test with treated water).

Finally, during the *fifth series of tests* (operations Nos. 125 to 128), again carried out with untreated water, *i.e.* under the same conditions as the first and third series of tests, an increase in the incrusting action of the water was again observed. The last test during that series yielded 0.32 g. of incrustations per litre, corresponding to 26.6%.

CONCLUSIONS

The aggregate results of the tests described above show that the magnetic treatment of water by means of the CEPI apparatus, super model No. S 7734 E, functioning under normal working conditions, is able to reduce the encrusting effect of the Brussels drinking water used for the feeding of a *Hydrex* laboratory distiller with a capacity of 2 to 2.5 l./hr. of distilled water.

The quantity of incrustations formed during the distillation tests has been reduced from 0.33 to 0.12 g. The proportion of solid salts separated in the form of incrustations has been reduced from 29 to 8%.

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The Painting of Ships — Concluded from page 306

ments of ship building and repair yards as to the best methods, but the over-riding economic importance of ships being in service for as many days in the year as possible is against good painting practice. There appears to be no easy solution to the problem of improving conditions for the painting of ships; more time is the main requirement, but this is costly.

Acknowledgment. *The author thanks the directors of British Paints Ltd. for permission to publish this article.*

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Agricultural machinery

A special issue of *World Crops* dealing with motorised agricultural machinery appearing this month will contain articles on 'The Application of the Hand Tractor in Underdeveloped Areas,' by R. P. D. Moore; 'Developments in Motorised Agricultural Machinery,' by E. Harris and W. E. Klinner; and 'Progress in the Mechanisation of Farming in the Colonial Territories,' by J. E. Mayne.

Other technical articles this month will include: 'Improved Plant for Paint Manufacture' and 'Conjugation in Drying Oils' in *Paint Manufacture*; 'Current Trends in Automatic Process Control,' by F. B. Hinderwell, B.SC., A.M.I.E.E., in *Chemical & Process Engineering*.

HUMIDITY CONTROL IN TANKERS

Last month and the month before we have published descriptions of some of the exhibits seen at the recent Engineering, Marine and Welding Exhibition, held at Olympia, London. The following account concludes the report of items likely to be of interest to CORROSION TECHNOLOGY *readers.*

Cargo protection

ONE of the greatest problems facing the oil shipping companies is corrosion of the cargo tanks, particularly when petrol and other light oils are carried. Various coatings, paints and compositions have been applied in the past, but there is no evidence that any of them have permanently resisted corrosion in cargo oil tanks.

The *Cargocaire* system, demonstrated at Olympia, tackles the problem in quite a different way by drying the tanks prior to loading and keeping the ullage space dry throughout the voyage. Based on the control of environment by never allowing the presence of water and the presence of oxygen to occur simultaneously in the tanks, corrosion is claimed to be halted. When the tanks are emptied or partly filled with cargo the vacant space is kept filled with air from which practically all water has been removed. When the tanks are filled with ballast water, oxygen is excluded as much as possible by pressing the ballast right up into the ullage trunks and allowing it to overflow on deck. The only oxygen which is then available is the small amount dissolved in the water, which is soon exhausted and cannot be replenished if the tanks are kept full.

Immediately ballast has been pumped out the *Cargocaire* system provides means of introducing dry air into the bottoms of the tanks which blows through, drying the tank surfaces and maintaining the relative humidity at a safe level. Steel will corrode in the presence of sea salt ten times as fast in an atmosphere of 80% humidity as it will in an atmosphere of 50% relative humidity; below 50% it practically ceases.

The *Cargocaire* system of dehumidification can also be applied to moisture control in factories and warehouses.