

to the cathode it could not be expected that his method would hold for experiments with a carbon anode.

The method offers, however, such a simple procedure for arriving at the proper current density required to prevent corrosion that it seemed worth while to apply it to the results of the authors' experiments. In Table II are given the results of these experiments, to which have been added the values for the current densities calculated from the loss in weight of the unprotected plates and the electrochemical equivalent of iron. The "observed" values for the current densities in column 6 were obtained graphically from the curves in Figs. 2, 3, 4, 7, 8 and 10. The agreement between the observed and calculated values is remarkably good. The differences are well within the experimental error.

It may, therefore, be concluded that Harker's method of calculating the current density required to prevent corrosion, from the loss in weight of the metal under the given conditions, is not limited to cases in which an anode of the same metal is used.

TABLE II

Results plotted in figure	Number of Exp.	Acid conc.	Stirrer R. P. M.	Length of run. Hours	Current density milliamp. per sq. inch		Weight lost by un- protected plate (mg.)
					Obs.	Calc.	
Apparatus I:							
2....	4	N/5	...	45.0	3.0	2.2	344.6
3....	6	N/10	...	47.0	3.0	3.4	551.5
3....	7	N/10	...	20.0	3.0		140.5
3....	9	N/10	...	23.5	1.5	2.7	221.0
3....	8	N/10	...	22.0		2.0	151.5
Apparatus II:							
4....	11	N/10	...	22.5	0.45	0.5	43.0
4....	12	N/10	...	22.0	0.45	1.2	93.5
7....	39	N/100	35	24.0	1.6	1.3	75.9
Apparatus III:							
7....	38	N/100(a)	35	24.0	1.6	1.0	64.3
7....	40	N/100	35	24.0	0.8	0.7	44.6
7....	30	N/100	35	24.0	0.8	0.7	41.4
8....	48	N/1000	450	24.0	2.0	2.7	170.0
8....	45	N/1000	110	24.0	1.6	1.4	88.3
8....	46	N/1000	110	24.0	1.6	1.2	72.8
8....	42	N/1000	35	24.0	0.8	0.7	44.5
8....	41	N/1000	35	24.0	0.8	0.6	41.0
10....	51	N/10	35	24.0	1.6	2.2	133.8
10....	49	N/50	35	24.0	1.2	1.1	71.3
10....	50	N/50	35	24.0	1.2	1.3	80.9

(a) Oxygen saturated.

THE NATURE OF THE ACTION OF THE ELECTRIC CURRENT

Harker's view that the current does not actually prevent metal from entering the solution from the cathode, and that its protective action is due to the deposition of metal from the anode, is contradicted by the authors' experiments in which carbon anodes only were used. The action of the current, then, is to prevent the formation of ferrous ions at the cathode by increasing its negative charge. In the absence of any depolarizer, especially of dissolved oxygen, an infinitesimal current should produce an electromotive force large enough to neutralize the solution tension of the metal. When oxygen is present, it combines with the hydrogen ions liberated at the cathode and hinders polarization. The supply of hydrogen ions furnished by the current must be equivalent to the

supply of oxygen in the vicinity of the cathode before the solution tension of the cathode can be completely neutralized.

CONCLUSION

It has been shown that the corrosion of iron submerged in sulfuric acid solutions may be prevented by imposing a counter E. M. F. The density of the current required to prevent corrosion depends on various factors, the more important being acid concentration, amount of dissolved oxygen and degree of circulation of electrolyte. The influence of these factors has been studied and curves have been given showing the current density necessary under various conditions. It has been found that the current density required can be calculated, within the limit of experimental error, from the loss in weight of the unprotected metal under the given conditions.

U. S. BUREAU OF MINES
PITTSBURGH, PA.

PAINT AS AN ENGINEERING MATERIAL¹

By MAXIMILIAN TOCH

The progress that paint chemistry has made since 1905 is by far greater than the progress that was made from its earliest invention up to that date. It is very difficult for me to imagine that my first book on "The Chemistry of Paints" stimulated others to continue the work which I had started, and if the little that I have done to enlighten the manufacturers and consumers has brought about the progressive results, I certainly have been rewarded for all the work I have ever done on the subject.

The first skyscraper ever built was the Gillender Building, corner of Wall and Nassau Streets, which was razed two years ago. Chemists knew before this building was demolished that linseed oil paint was not the best material for the protection of steel of large buildings. The question as to whether our monumental buildings are permanent has been a source of great worry to many chemists and engineers. Fortunately, if any of the steel contained in buildings like the Woolworth Building, Metropolitan Tower, the Singer Tower and dozens of others should show signs of corrosion and disintegration, the process is so slow that preventive methods could be applied, for a beam could not corrode in a masonry wall without cracking or bulging the wall. I have in mind one building in Maiden Lane where this actually occurred; the wall of the fifteenth floor was cut away, the corroded beam exposed, thoroughly scraped, painted and reinforced, surrounded by concrete, and the brick wall replaced.

From the street level up, every skyscraper in the world is safe, but from the street level to the grillage beams is the dangerous point. Of course, a small building could be "jacked up" and a grillage beam replaced. In large buildings—two of which I have in mind—where the grillages were affected by leaky electrical currents, the foundation beams were uncovered, scraped clean and painted, and then a grout

¹ Abstracted by the author from an address presented before the N. Y. Section of the American Chemical Society, Chemists' Club, Feb. 7, 1913.

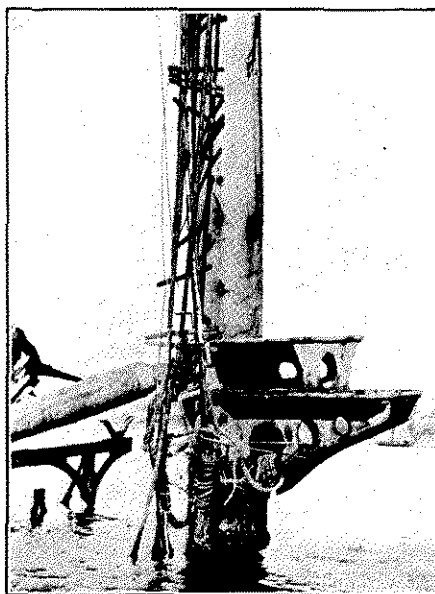
of almost pure neat cement injected all over the surface. Of course, it would be out of the question to "jack up" a building like the Woolworth Building, or the Metropolitan Life, even though Archimides said, "Give me a fulcrum and I will move the world;" but it is a source of great satisfaction to know that

bridges would last ten years if they were not repeatedly painted and watched. The railroads are much wider awake to this condition than the municipal governments. Politics and paint do not mix very well, as is evidenced by the condition of some of our bridges. It may be very safely said, that all of our elevated



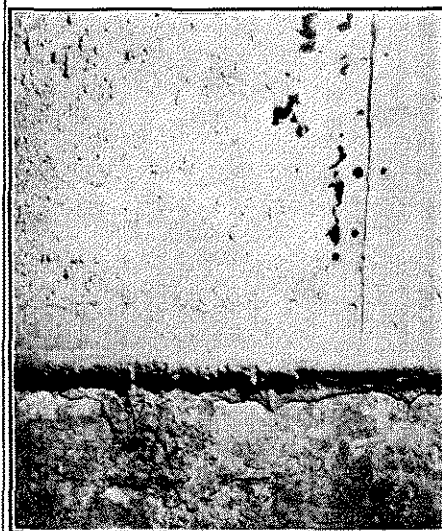
STEAM PUMP OF MAINE

Submerged 13 years. Put in excellent condition by a few repairs



MAST OF MAINE

Had 15 coats of paint. Exposed to elements for about 11 years and still in good condition



INTERIOR PLATES ALONGSIDE COAL HOIST

Complete corrosion in spots only

engineers and architects in charge of these buildings have taken sufficient precautions to prevent any danger whatever, either from electrolysis by means of stray currents, or from corrosion by means of dampness. All the sensational talk about the danger of the newer skyscrapers not lasting fifty years is utter "rot," for not one of these buildings is so con-

railroads in New York City and all of the battleships of the United States Government depend for their life on the frequency with which they are painted. My examination of the battleship "Maine" when the wreck was uncovered last year showed that not a vestige of paint remained, and it furthermore showed that wherever steel and copper, or iron and bronze,



BRONZE BINNACLE AND STEEL VENTILATOR SHAFT OF MAINE

Electrolytic corrosion: bronze preserved and steel dissolved



ELECTROLYTIC CORROSION BETWEEN BREECH LOCK AND STEEL OF 10-IN. GUN

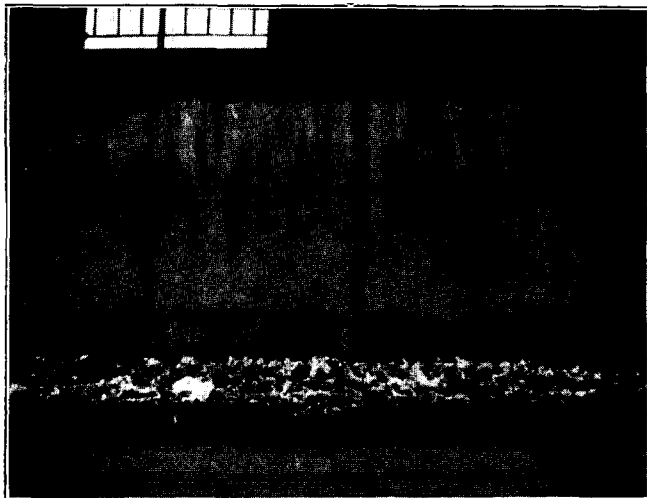
structed that should any danger result it could not be remedied in due time.

That paint is an engineering material of incalculable value is evidenced by the fact that none of our

were in close proximity, an electric battery was formed, and the iron was completely dissolved.

The aphorism that "Cement protects steel permanently against corrosion" needs some little explanation. Unfortunately, this saying is true and correct,

and still more unfortunately, there is no such thing in building construction as cement. I know that this sounds ridiculous in view of the fact that in 1912 upwards of sixty million barrels of cement were used in concrete construction, and a large part of it was used in reinforced concrete construction, which means that steel rods were embedded in it; but you must bear in mind that cement is never used as such in any kind of construction, but a mixture of cement, sand

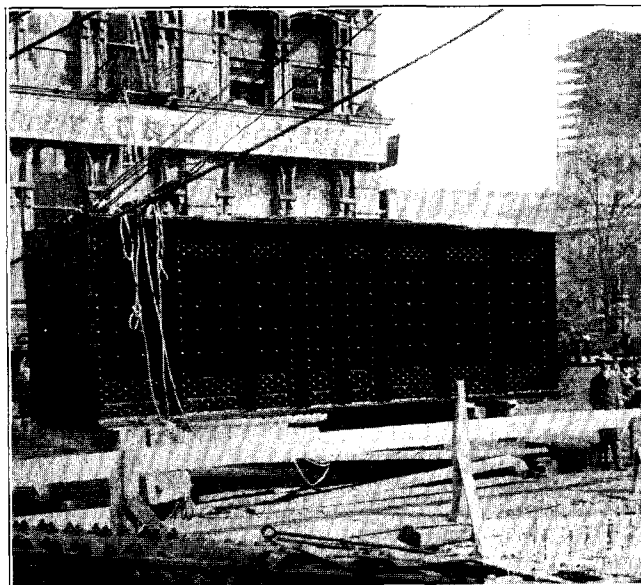


CONCRETE WALL SHOWING RUST OF REINFORCING ROD

and broken stone is used; the average percentage of cement contained in most engineering operations is 15 per cent., so that when we talk about cement being used we really mean concrete, which under many circumstances is a nondescript mixture. It is a trifle out of place for me to go into the reasons why cement is not used, but why concrete is used, and only one or two examples will suffice to indicate. Cement is entirely too rich and entirely too expensive to use by itself, and sand and other ingredients which are added to cement can never under any circumstances be classed as adulterants, particularly sand, because when a cement grout is used that is too rich it will crack or craze, as the case may be. If you were to drive a tack with a 10 lb. sledge hammer you would undoubtedly accomplish the object and you might possibly destroy or break the material into which the tack was driven, but if you use a weak little 2 oz. hammer you accomplish the result better and without any ill effects. The same comparison holds true as to the use of aggregate in cement. The dilution of the cement with inert material saves money and gives better engineering results, but yet when we add 85 per cent. of material which may be cinders, broken stone, or sandy material containing more or less soluble salts, and when the workmanship is taken into consideration, and voids are produced, it is quite obvious that rust may start in concrete surroundings, and the small percentage of cement will be insufficient to overcome or check the oxidation. There is a wall in the City of New York which shows this fact very markedly, and in a wall of this type an insulating paint or insulating material would have prevented the oxida-

tion of the steel and the subsequent cracking of the wall.

This then leads me to the general subject of the more modern type of paint containing no saponifiable oil, but made entirely of such materials as are unaffected by alkali. Such tremendous structures as the Pennsylvania Terminal in New York City, and Metropolitan Life Tower and Building, the Woolworth Building, and the newest and largest of all engineering structures, the New York & Connecting Railway—not yet finished—are types of modern structures in which the old-time linseed oil paints have been superseded, and protected by more scientific paints. Perhaps the most remarkable fact in all these instances is that fifteen years ago perhaps, one concern in the United States started a campaign of education and convinced many prominent and well-known engineers that paint was an engineering material and that no one material is suitable for all purposes with the result that the paint industry has been raised from empiricism to an exact science. Ten years ago nobody dreamed of painting cement floors or cement walls on account of the tradition that it was impossible to paint concrete. It is quite true that it is impossible to paint new concrete with a linseed oil paint owing to the resulting chemical reaction of the combination of the oil and the lime in the concrete, and yet when the first patent was taken out on this subject nobody infringed because it was believed that it could not be a success, and after it was demonstrated that this was a success it was the same story as "Columbus and the egg," and everybody imitated and made a business of it.



WOOLWORTH BUILDING FOUNDATION GIRDER PAINTED WITH AN INSULATING PAINT

The United States Navy, through one of its most efficient Naval Constructors, Mr. Henry Williams, has kept pace with the paint progress, and Mr. Williams' article, a treatise on the subject of "Newer Paint Conditions in the United States Navy," read

before the Eighth International Congress of Applied Chemistry, was copied not only by every paper in the United States but was heralded throughout Europe; and those who want to know what excellent progress has been made in this branch of the Government, I

been the subject of considerable investigation, for it is self-evident that the quality of the set of a cement determines the ultimate strength of the concrete of which it is a constituent.

Experimenters do not seem to agree very well as to the mechanism of this setting, nor as to the factors that exert the greatest influence during the time that the hydrolysis is taking place. Consequently there is a diversity of opinion as to the method to employ during the processes of manufacture or as to what subsequent treatment the cement must undergo, in order that the manufacturer may at all times put upon the market a cement whose behavior may be predicted, and whose quality will show no deterioration during long-time storage.

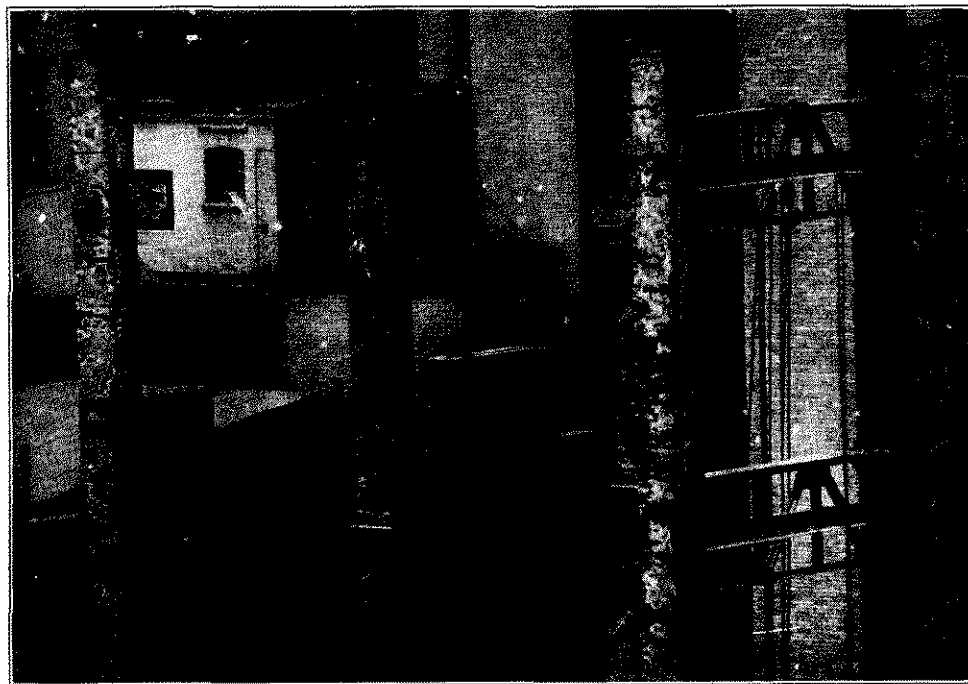
The consensus of opinion seems to be that the initial set of a cement is due to some action for which the aluminates are responsible, or to which they at least contribute in a large measure.

Also it seems to be quite well agreed that the retarding action of gypsum is due, if not to the formation of a double salt with the aluminates, at least to the fact that it slows down their hydrolysis and consequently delays the initial set of the cement.

It has been the writer's good fortune to have been at various times connected with the operation of Portland cement plants using materials abnormally high in alumina, and he invariably found that it was impossible, under those conditions, to vary the lime content of the cement over any extended range without causing trouble. If the lime was carried high (63-64 per cent.), the cement approached too closely the danger line of unsoundness, while if it dropped too low (60.5-61), the factory was troubled with quick setting cement.

Quick setting cement resulting from such operation is not so responsive to the retarding action of gypsum as one more nearly normal in composition. Sometimes it will be quick setting direct from the grinding mills, while at others it will develop a quick set after short storage. Quite often it will show a reversion to quick set if an excess of gypsum is added. The writer had his attention called to a condition where two sections of a plant were operated with differences of 30 per cent. in the gypsum added.

None of the cases of quick set in the writer's operating experience ever developed serious difficulties, as the setting times were watched very closely, and at a suspicion of trouble in the stored materials a quick



TELESCOPIC PHOTOGRAPH OF THE 12TH STORY OF THE GILLINDER BUILDING, SHOWING THE STEEL IN PERFECT CONDITION, BUT NO PAINT LEFT. EACH BOLT-HEAD IS EXCELLENTLY PRESERVED

would refer to his excellent treatise on the subject which is to be found in the transactions of the Eighth International Congress of Applied Chemistry.

320 FIFTH AVE., NEW YORK

CONTROL OF INITIAL SETTING TIME OF PORTLAND CEMENT¹

By E. E. WARE²

It is well known that Portland cement, as burned in the rotary kiln, is so quick setting that it cannot be used without the addition of some retarding material, such as gypsum or plaster of Paris. It is not necessary to make this addition of retarding agent when dealing with the product of a set kiln, probably for the reason that the cement contains the ash of the fuel as well as most of the sulfur.

Occasionally there has been reported a cement of such a nature as to be quick setting even after the addition of the regular amount of retarder, and this paper is in the nature of a report on the commercial manipulation of a 100,000 barrel lot of such quick setting clinker. The manufacturer was interested, *first*, in correcting the material on hand, and *second* in establishing a routine of operation that would prevent a recurrence of the trouble.

The setting and hardening of hydraulic mortars has

¹ Paper presented at Fifth Annual Meeting of the American Institute of Chemical Engineers, Detroit, December, 1912.

² Credit is due to L. C. Nodell and P. H. Chang for the experimental work in connection with this paper.