

## The Corrosion Problem in the Beet Sugar Factory

E. B. COLE<sup>1</sup>

The corrosion problem in the beet sugar factory is not a new problem. It has been with the industry since the beginning. However, until the past few years we have not been too concerned about the damage which corrosion has inflicted upon the factory equipment.

Since 1947 we have increased the daily capacity of our principal factories by an additional two-thirds to three-fourths of the original capacity. Since that time there has been an alarming increase in the damage which has occurred to the equipment each year. We believe that the increase in corrosion damage is due directly to the increased slicing capacity and the methods which have been adopted to maintain that capacity.

Last summer we performed a major repair job on the evaporators at our Nyssa factory. We replaced tube sheets, portions of the shell plate, bumped bottoms, and tubes in the first three bodies of a quintuple-effect evaporator. This job cost almost twice as much as the original evaporator station cost when new.

We believe that it may be necessary to replace several more evaporator calandria before very long. It is, therefore, necessary that we find a satisfactory method of solving the corrosion problem. It appears that the problem is more pressing in the evaporator than at any other station. However, there are several pumps and pipe lines which are also subject to corrosion damage. The continuous difluser requires a special study of the problem. In the sugar end the corrosion problem has been a serious one because of the ever present danger of contaminating marketable sugar with scale and corrosion products.

### What is Corrosion?

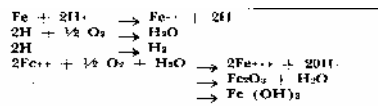
Corrosion is defined broadly as the deterioration or destruction of metal by the electro-chemical or chemical action of the environment upon the metal. Erosion is defined as the deterioration or destruction of metal by a mechanical or physical action upon its surface. Both words are from the Latin rodere, which means to gnaw. Very often the loss of metal is due to a combination of corrosion and erosion.

Ordinary corrosion products are oxides, (hydrates), carbonates and sulfides. At elevated temperatures it is the oxides which are most frequently found, especially in the presence of moisture. The main driving force is the electro-chemical potential between the metal and its environment.

The primary reaction is as shown in Table 1.

Similar reactions apply to the formation of carbonates and sulfides.

Table I.—Primary Reaction in Corrosion of Metal.



<sup>1</sup> Assistant Chief Engineer, the Amalgamated Sugar Company, Ogden, Utah.

This type of corrosion can be recognized by the presence of rust or scale where the metal is exposed to the atmosphere in the presence of moisture. Such are the conditions which prevail in open tanks and around machinery and structural steel which is exposed to the weather or to heat and high moisture conditions. This is the most easily recognized form of corrosion and the most readily prevented.

When corrosion takes place inside of a closed vessel such as the continuous diffuser or the evaporators, we are not made aware of the damage as readily, nor is it as simple a job to prevent the corrosion damage. Where there is much movement of the process liquors or materials, the products of corrosion are being continuously carried away. In this manner there can be considerable damage from corrosion without an accumulation of corrosion scale to announce the fact. In fact, in certain cases the corrosion can proceed so uniformly and leave a surface so smooth that it is impossible for one to assess the extent of the damage without drilling holes and measuring the thickness of the metal remaining.

This type of corrosion is due to the interaction of the metal and its environment, the metal supplying the positive ions, the environment the negative ions to form an oxide, carbonate or sulfide film which if not disturbed would act to protect the metal from further corrosion damage. But due to the activity of the environment the scale or film is removed and the metal again supplies ions to the reaction *in* a continuous cycle of self destruction.

Another very interesting form of corrosion is that due to the stray electric currents which are set up when two metals having different positions in the galvanic series are subjected to an electrolytic environment. This is known as galvanic and stray current corrosion.

This form of corrosion can be detected quite readily in the evaporators by a pronounced grooving *in* the tube sheet around the ends of the tubes on the liquors side of the heating surface.

Bronze impellers in cast iron pump volutes suffer from this damage. Even a stainless steel impeller may be subject to considerable damage if it is piped up with a lead pipe line in the boiling out acid system.

Care should be taken in prescribing metals for corrosion service so that we do not set up an electrolytic couple which will suffer from accelerated corrosion damage. See Table 2 in order to obtain an idea of the order of the galvanic series.

#### How Can Corrosion be Stopped?

There are three courses of action open: 1. Change the environment so that corrosion is less likely to occur. 2. Protect the metal with a film of corrosion-resistant material. 3. Insulate the dissimilar metals from each other to destroy the electrolytic couple. Or pursue all three courses of action at once.

The treatment of boiler feed water to prevent scale and corrosion is a familiar example of a change in environment. The dosage of the diffuser with formaldehyde is another example. Another, but not so obvious, example is the practice of deaerating boiler feed water, or deaerating evaporator

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$Fe + 2H^+$	$\rightarrow$	$Fe^{++} + 2H$
$2H + \frac{1}{2} O_2$	$\rightarrow$	$H_2O$
$2H$	$\rightarrow$	$H_2$
$2Fe^{++} + \frac{1}{2} O_2 + H_2O$	$\rightarrow$	$2Fe^{+++} + 2OH^-$
	$\rightarrow$	$Fe_2O_3 + H_2O$
	$\rightarrow$	$Fe(OH)_3$

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The treatment of boiler feed water to prevent scale and corrosion is a familiar example of a change in environment. The dosage of the diffuser with formaldehyde is another example. Another, but not so obvious, example is the practice of deaerating boiler feed water, or deaerating evaporator

Table 2.—The Order of the Galvanic Series of Metals.

Corroded End (Anodic,  
or Least Noble) Magnesium  
Magnesium Alloys Zinc  
Aluminum 25  
Cadmium  
Aluminum 17ST  
Steel or Iron Cast  
Iron  
Chromium-iron (active) Ni-  
Resist  
18-8 Stainless (active) 18-8-3  
Stainless (active) Lead-tin  
Solders Lead Tin  
Nickel (active)  
Inconel (active)  
Brasses Copper  
Bronzes  
Copper-nickel Alloys  
Monel  
Silver Solder Nickel  
(passive) Inconel (passive)  
Chromium-iron (passive)  
18-8 Stainless (passive) 18-8-  
3 Stainless (passive) Silver  
Graphite Gold Platinum  
Protected End (Cathodic, or  
Most Noble)

supply liquors. At the present time there is no practical method of changing the environment in the evaporators to prevent corrosion. In fact, the contrary course is followed. By using proprietary compounds, we have attempted to prevent the formation of scale. This has contributed considerably to the increased corrosion damage in the evaporators in recent years.

There is very little freedom in changing the environment in the process vessels, as the requirements of the sugar process must be served first.

The second course open is that of applying a protective film to the metal to prevent corrosion. There is a wide variety of materials to choose from. There are oil base paints, which may serve very well for ordinary rust prevention. This remedy is usually not too expensive. There are plastic paints which serve very well to protect metals under more severe conditions of corrosion. The cost of these plastics is only a little more than the best grade of oil paints. The use of plastic paints is generally limited to service at temperatures below 50° C. and also where the abrasion is not too severe. Most plastic films scratch easily. Rubber and some of the special synthetic rubber compounds can extend the temperature limit up to 65° C. and to conditions of moderate abrasion. Rubber is fairly expensive to

apply and is difficult and expensive to maintain. The only non-metallic linings which appear to be able to give satisfactory service up to temperatures of 150° C. and resist moderate to severe abrasion are fused glass and the baked phenolic plastic paints. More will be said about these later.

There is a wide selection of corrosion-resistant metal surfaces to choose from. There are the surface films such as the anodizing or the alodyne process for protecting aluminum. The surface hardening processes for steel such as nitriding or carburizing will also improve the corrosion-resistant properties of the steel at the surface. We can apply an integral clad surface which will protect the base metal, Alclad for aluminum and Stain-Clad, Ni-Clad or Monel-Clad surfaces for steel. We can apply a corrosion-resistant surface by electroplating or metal spray methods. Thin sheets of corrosion-resistant metals can be applied in the manner of wall paper, except that we use plug welding and continuous seam welds at the edges to make the sheets adhere to the base metal. For certain applications the vessel may be made of sheets or plates which are 100 percent of the corrosion-resistant metal.

Before proceeding let me point out that these corrosion-resistant metals protect themselves by acquiring a tough, very resistant, oxide film on the surface of the metal, thus protecting the base metal or alloy underneath. In order for stainless steel to develop its maximum corrosion resistance, it must be made passive by forming a tough oxide film by treating the surface with an oxidizing agent, such as nitric acid, sodium chromate or ferric sulfate in the form of a rinse or bath.

The third course of action is that to be used in preventing the damage which results from galvanic or stray current corrosion. If we can effectively insulate the two dissimilar metals from each other then we can prevent the completion of the electric circuit and thus reduce the chances of galvanic corrosion. An alternate method is to cover one metal completely with a non-conducting, corrosion-resistant material, thus preventing the completion of the electric circuit and the resultant galvanic corrosion. Still another scheme is that of deliberately sacrificing one metal in order to protect the more important metal. This last scheme is known as "Sacrificial Anodic Protection." The usual method is that of placing a magnesium anode in the vessel, thus allowing the magnesium to suffer the corrosion. This last scheme must be used with caution and only after careful study, otherwise, it may backfire and form a new set of couples which may localize the corrosion in another vital area.

Very often, when we find that some particular part or piece of process equipment is being made unserviceable due to corrosion, the immediate response is to replace it with one made of stainless steel. In so doing we merely reverse the couple; the part which formerly was anodic now becomes the cathode and the rest of the system becomes the anode and suffers from the corrosion damage.

Now that we know what corrosion is and know of the general methods for combating it, what shall be done about it? To make the problem specific, let us outline a method for protecting the evaporators from corrosion.

We shall assume that in order to assist in preventing scale formations we shall continue to use the protective colloids in the evaporators. We shall also assume that we do not have an adequate corrosion inhibitor available for use. Deaeration of the thin juice is the only remaining device which can be used to alter the environment in the evaporators. We shall heat the juice to three or four degrees above the atmospheric flash point and allow it to flash into a covered vessel. The dissolved and entrained gases, mainly oxygen, carbon dioxide, sulfur dioxide and ammonia, are partially stripped from the liquor and carried from the vessel by the flashed vapors. This method of deaeration has proven effective in decreasing the corrosion damage in the first effect due to the presence of dissolved gases.

Let's assume that the evaporators we are planning to protect are already installed and that there are no major repairs necessary, but that we wish to protect the vessels from corrosion.

A look at the non-metallic corrosion-resistant films shows us that only two are suitable, fused glass and the baked phenolic lining. A fused glass lining is out of the question because of the necessity of shipping the vessel to the vendor's shop for the job. This leaves only the baked phenolic lining. Of the metallic linings, thin stainless steel has the greatest merit. It is the easiest to work and the lowest in cost. Surface preparation to receive the stainless sheets is simple; requiring only a vigorous wire brushing. However, it is almost impractical to consider lining the surface of the tube sheet with stainless steel sheets. Furthermore, a passive stainless steel lining will rearrange the electrolytic couple so that the copper tubes become the anodes and thus become the victim of galvanic corrosion.

We have come to the conclusion that the most suitable lining for these vessels is the baked phenolic lining. We have had a considerable amount of experience with this material and are fully aware of its disadvantages, but believe that its superior corrosion and abrasion resistance offset the difficult and tedious job of applying it.

The preparation of the surface of the steel must be meticulous in every detail. Sand blast or shot blast must be used and every last bit of scale must be removed. Every crevice and corner must be cleaned. Then, before a new rust film can form, a temporary protective film must be applied. This job should be done in relatively small patches so that the sand blasting does not get too far ahead of the temporary primer.

When the whole of the surface is cleaned and protected, the first primer coat of phenolic is applied. Brush or spray painting is permissible, but it is advisable to use a brush to cover weld seams, or fill in crevices or cracks. After the first primer coat the paint is given a short bake at low temperature to drive off the plasticizers and harden the paint. A second primer coat and two finish coats are also applied in the same manner, each coat followed by a short bake. After the last finish coat is applied, the paint is given a long high temperature bake to fuse and set the lining. If alternate coats of paint are of a contrasting color it aids materially in obtaining thorough and effective coverage. To obtain the best results follow the instructions that come with the paint.

The baked phenolic lining will give almost unlimited service under any conditions that exist in any sugar factory process. If applied under the proper conditions, and if the work is thorough and careful, and if the job is planned properly so as not to waste labor, the cost of this lining will be materially lower than that of a stainless sheet-lined vessel.

In painting around the ends of the tubes, care should be taken that the phenolic paint covers the outside of the projecting tube ends. This will isolate the steel shell from the liquor and prevent the galvanic grooving which occurs in the tube sheet around each tube end.

If it becomes necessary to replace tubes the outside of the tubes at each end can be given a coat of phenolic paint and permitted to air dry for several days before being inserted in the tube sheet, after which a short high temperature bake will set the paint and fuse the paint in the rolled joint.

We feel that, even for a new vessel, there is considerable justification in using the baked phenolic lining instead of stainless steel.

Pump casings and impellers are ideal subjects for the application of a baked phenolic lining, as are thick juice filters, standard liquor tanks, acid and soda system tanks and pumps. Also, short lengths of flanged pipe and fittings can be lined with a baked phenolic paint.

For longer pipe lines with several turns, a new type of plastic pipe which is formed from a fiberglass reinforced thermo setting polyester has been found to be very practical. Its cost is very competitive, it can be used at temperatures up to 110° C, and any pressure up to 1,000 psi. It has high mechanical strength and is easily installed after a little experience.

We believe that it is no longer good business to ignore the damage which corrosion inflicts upon the metal of our process equipment and that we must solve the problem at once. We also believe after a careful study of the problem that it is possible to solve the problem effectively and economically. At this time two products which are relatively inexpensive hold great promise—the baked phenolic linings for vessels, pumps, parts, and fittings and a Fiberglass reinforced polyester pipe, for pipe lines which are subject to corrosion.

I believe that it would be of great benefit to the sugar industry as a whole if the several companies would exchange information relative to the corrosion problem and the methods by which each company expects to solve the problem.

Table 3.—Plastic Material Selection Guide.

	Temp.	Pressure (In order of lowest to highest)	Impact Str. (In order of weakest to strongest)	Price (In order of lowest to highest price)
Hard Rubber	120*	Polyethylene	Hard Rubber	Polyethylene
Polyethylene	125*	Hard Rubber	Saran	Butyrate
Butyrate	130*	Butyrate	P.V.C.	Fiberglas
Polyvinyl Chloride	160*	Uscolite (Std.)	Butyrate	P.V.C.
Saran	170*	Saran	Uscolite	Uscolite
Uscolite	170*	P.V.C.	Polyethylene	Saran
Fiberglas	250*	Fiberglas	Fiberglas	Hard Rubber



Table 4.—Plastic Pipe Stocks.

Manufacturer	Trade Name of Product	Technical Name of Product
Krayloy Plastic Pipe Company, Incorporated	Krayloy P	Polyethylene
	Krayloy O	Cellulose Acetate Butyrate (Fenite)
	Krayloy D	Polyvinyl Chloride Unplasticized (P.V.C.)
U. S. Rubber Company	Uscoite	Copolymer of Styrene, Butadiene, Acrylonitrile
E. E. Mills Refin Company	Saran	Vinylidene Chloride
American Hard Rubber Co.	Fiberglas	Fiberglass Reinforced Polyester
	Ace	Hard Rubber