5-18-1947

Corrosion Testing of Iron-Tin Alloys by the Salt Spray Method

Bernard T. McDonald

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CORROSION TESTING
OF
IRON-TIN ALLOYS
BY
THE SALT SPRAY METHOD

BY
BERNARD T. MC DONALD

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BUTTE

A Thesis
Submitted to the Department of Metallurgy
in Partial Fulfillment of
the Requirements for the Degree of
Bachelor of Science in Metallurgical Engineering

Montana School of Mines
Butte, Montana

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The purpose of this study was to determine the relative rate of corrosion of iron-tin alloys containing low percentages of tin. Since in the world today, a great deal of work is being done to develop large tin deposits and new methods devised to treat these ores, it is possible that the metal will become abundant and will obtain a more important position in the metal industry. Tin has many desirable properties, one of which is its high resistance to corrosion. Due to its low rate of corrosion as a primary metal, there is reason to believe that tin will impart similar properties when alloyed with a less noble metal. With this in mind, the writer made several investigations to determine the degree to which corrosion was retarded, when alloys of different compositions were subjected to a corrosive atmosphere.

Up to the present time, much work has been performed in industry on the problem of corrosion, but as yet comparatively little has been accomplished toward a solution of the corrosion problem in general. Some metals have been developed that are resistant to certain types of corrosion, but none of these are entirely resistant to corrosion under more than a limited set of conditions. A great deal has been done to control the ravages of corrosion by the use of protective coatings for the metal and by removing the main causes of the trouble, as in deoxygenation of water and the use of neutralizers. With all that has already been accomplished,
the problem is far from being solved.

It is estimated that the annual deterioration of metals is two percent of the total tonnage in use. This figure is large in itself but is much less than it would have been if during the past ten or twenty years, the subject had not been given considerable attention on the part of certain leading manufacturers and research organizations.

All metals tend to revert to one or another of the forms in which they were originally found in the earth's crust unless precautionary measures are taken. The forms to which they degrade are usually oxides of the metal since these are more stable. The rapid formation of iron rust, when the clean metal is brought in contact with water and air, is the most common example of this action.

Previous work has proven the value of plating tin on iron to improve its corrosion properties. The ordinary tin can, so common today, is the most prevalent example. However, up to the present time, few if any investigations have been carried out on alloys of the two metals as regards their resistance to corrosion. Perhaps it is because of the large difference in the melting point of the two metals that has discouraged its production and the need for corrosion comparison. Since little work has been done on this type alloy in the past, and due to its possibilities in the future, an experiment of this type is in order.
CHAPTER II
THEORY OF CORROSION

The importance of corrosion has attracted much scientific research in order to determine the main causes for it and by what means it may be best retarded. Many theories have been concluded for certain type metals when subjected to a particular environment, but it was not until the electrochemical theory was advanced that the general action of corrosion for all metals could be explained. The principles of the electrochemical theory are simple, but their application is more complex due to the many variations in the solution or materials which may be in contact with the metal concerned.¹

When a metal is placed in water, or any solution, a difference in electrolytic potential takes place between various sections of that metal, with the result that a cell is set up and the most anodic area goes into solution. Since the solution must remain electrolytically neutral, the metal dissolved must replace positive ions and in the case of an aqueous solution, hydrogen will be liberated. This hydrogen when first evolved, gathers on the surface of the metal and forms a thin invisible film. The presence of this film obstructs further progress of the reaction by insulating the metal from the solution, and by the tendency of the hydrogen to reenter the solution and thus oppose corrosion.

For corrosion to proceed, it is necessary for this
hydrogen film to be removed. This happens mainly by the combination of the hydrogen with oxygen in the solution to form water or by its evolution as a gas. When this film is removed, the original reaction is permitted to continue with the result that more metal is dissolved and hydrogen plated out at a rate determined by the speed of removal of this film. The rate of destruction of this protective film is determined by the concentration of dissolved oxygen in the water next to the metal and this in turn depends upon the degree of aeration of the water, the temperature, pressure, dissolved salts present and other less important factors.

Likewise, the same explanation for corrosion applies when two dissimilar metals are in contact. A galvanic cell is set up between the two and the most anodic goes into solution while the other remains intact.

The electrochemical theory also accounts for the corrosion that takes place in cavities. A difference in potential exists between the unaerated area within the cavity and the aerated surface area, with the result that a current is caused to flow and corrosion proceeds. The products of corrosion build up in the anodic portion, the unaerated area, and a further change in the oxygen concentration occurs, causing the action to continue. Since the rate of attack is determined by the supply of oxygen to the whole surface outside the pit, and it is all concentrated on the small area within the cavity, extensive penetration will occur at this one point before any appreciable thinning takes place.
on the surface. 8

It is now the general belief that all corrosion is electrochemical in nature. The acceptance of this theory was slow and was preceded by many individual investigations to determine the action of pitting. Pitting, being the most destructive result of corrosion, is logically explained by this theory and was the one important factor that was lacking in previous explanations.
CHAPTER III

INFLUENCE OF INTERNAL FACTORS ON CORROSION

Composition

The composition of a metal is very important as it influences the solution pressure of the metal, the hydrogen overvoltage, and the tendency to form protective coatings. However, it is generally believed, that foreign elements have much more influence on the physical properties than on the rate of corrosion.¹

Chappell⁴ carried out several investigations to determine the effect of different amounts of carbon in iron and steel. It was found that carbon, while having an important effect on the physical properties of the metal, did not materially change its rate of corrosion. This conclusion, refers only to the presence of combined carbon and not free or uncombined carbon.

When part or all of the carbon present is in the form of graphite flakes or free carbon, a galvanic cell is set up and the metal corrodes more rapidly. The presence of graphite tends to localize corrosion since it is cathodic to iron. Being electronegative with respect to iron, a current is caused to flow from the graphite to the metal surrounding it, with the result that the iron goes into solution and pits are formed. This rapid solution of metal around the graphite results in what is known as "Graphitization" of iron.
Other metals produce similar effects when alloyed with iron, being present either in the free or combined state. It has been proven, that, if a metal such as iron were in a condition of high purity, corrosion will be reduced to a minimum. However, such a pure metal would be difficult to make on a large scale and the cost would more than balance its' corrosive qualities.

Grain Size

Grain size, like composition, has no great effect on the corrosion of a metal. The manufacture of metals and alloys determines the internal structure of the finished product, differing with different methods of treatment used. Results of experimental work conducted by Chappell, indicate a slight difference in the corrosion rate of quenched, tempered and annealed steels. The quenched steel appeared most corrodible while the annealed samples displayed a high resistance to solution. While it has been proven that a different rate of corrosion exists in metals of similar composition but varying grain size, the degree is not pronounced and its' effects are not considered.
CHAPTER IV

APPARATUS

Introduction

Accelerated tests have been devised for the purpose of determining the rate of corrosion of different metals or alloys when used under similar conditions in service. These tests are carried out in the laboratory and by properly controlling the different conditions under which the metal is to be subjected, its life can be closely approximated and the metal with the best corrosion resistance determined for that particular use.

The numerous tests that were put in use in the laboratory were necessary in order to determine the effects of different environments on metals and alloys. Some were devised for metals exposed to industrial atmospheres, some for testing metallic coating, others for water line corrosion tests, and some for the testing of submerged objects. There is no one test known at the present time which could be used accurately to determine the relative life of any metallic object when subjected to different conditions.

With this in mind, the Salt Spray Test was chosen as the method best suited for this study. The Salt Spray Test was originally designed to test coatings on metals but is also used quite extensively to evaluate the resistance of metals to corrosion in marine service or on exposed shore locations. In this investigation, carried out in the laboratory, it was not the intention of the writer to simulate
any certain coastal atmosphere, but merely to measure the relative rate of corrosion between different alloys of iron and tin when subjected to the same conditions.

Description

The apparatus involved was easy to construct and required little attention when once in operation. It consisted of a rectangular box made of Alberine stone, a sodium chloride solution of known concentration, an atomizer to spray the solution, and a test rack to hold the specimens. Since in a corrosion test no metal should be involved in the construction, everything used was made of stone, glass or other non-corrodible material.

Air from the compressor entered the box after being passed through a filter of glass wool and a series of bottles containing distilled water. The filter cleaned the incoming air of any oil or foreign material that might have come through the line from the compressor. The water saturated the air as it passed from one bottle to the next and thus the concentration of the salt solution was kept constant. The pressure was controlled by a column of mercury of definite height, and if the pressure increased above the predetermined figure, the mercury column served as a release valve. This release of excess pressure served to maintain the desired pressure. A manometer was also connected in the circuit, but it only served to measure the pressure in the line, and since constant control was necessary, the column of mercury was installed.
The atomizer was located in the lower end of the box and produced a fine mist of salt solution which surrounded the specimens. A baffle plate was placed between the samples to be studied and the atomizer and was used to keep the spray from impinging directly on the alloy samples. On top of the tank was a glass plate which was sealed around the edges to restrain the escape of corrosive media. In order to prevent the pressure of the mist from building up, a glass tube was run from the box to the outside of the building. The box was inclined at an angle of $15^\circ$ with the horizontal, thus preventing any droplets of solution from falling from the glass cover onto the specimens.

The alloys being studied were set on glass rods that ran crosswise in the tank and were placed in such a manner that one was not touching the adjoining sample, and also that they were not located one under the other. This prevented any external contact between dissimilar metals and also prevented contamination.
Photograph of Apparatus
Sketch of Apparatus

Side View

Top View

Scale ~ 3 in. = 1 ft.
Melting and Casting

Due to the large difference between the melting points of the two metals, it was necessary to resort to the following procedure for preparing the alloys. A weighed amount of armco iron was first charged to a carbon crucible in an induction furnace and the contents heated until molten. To this, tin was added in the form of small droplets which were wrapped in a thin foil of iron. The covering of the tin by iron, and the melting of the bulk of the charge prior to adding tin, served to decrease the losses of the latter metal at the high temperatures used. Upon completion of the melting cycle, the contents were self agitated due to the inherent properties of the furnace, and to insure a complete homogeneous mixture, they were further mixed by means of a carbon rod. After about one minutes time, the power to the furnace was turned off, the crucible removed and set to cool in air. The reason for charging and cooling in the same crucible was to decrease the amount of enclosed gases and thus the number of blowholes present in the finished alloys. Piping was noticed in each of the six different composition samples but only for a short distance below the surface and in the shaping that followed, this portion was rejected.
Shaping

The size or shape of the specimen varies with the purpose of the corrosion test, the nature of the materials being tested and the testing apparatus used. In general, the ratio of surface area to mass should be large and that of edge area to total area small. For this reason, the use of flat circular specimens is preferred.

In the preparation of this type sample, it was necessary to first machine down the castings to a smooth uniform surface and then to separate the desired from the unwanted portions, by use of a lathe or saw. Difficulty was encountered in cutting and shaping by either method which indicated the necessity of annealing. In an attempt to soften the metal, the various alloys were heated in an electric resistance furnace to a temperature of one-thousand degrees centigrade for several hours and were then allowed to cool slowly in the furnace.

Surfacing and Cleaning

In the preparation of specimens for testing, it is necessary that they all be treated in the same manner, since the condition of the metallic surface is important, particularly in the early stages of corrosion. In most tests it has become the accepted practice to roughen the surface of the metal slightly with emery paper, number 0 being specified for most metals. Care must be taken when applying this surface treatment in order not to overheat and thereby oxidize the test pieces by too harsh abrasion. The sides were also
subjected to the same degree of roughening by careful use of a flexible-shaft emery wheel employing the same grade paper.

Since rate of corrosion is most commonly expressed as weight loss per unit of area, it is necessary to measure as accurately as possible the exposed surface. This was done by use of a micrometer to determine the number of square inches and then by conversion, the area in square decimeters was determined.

The pieces being tested need to be cleaned thoroughly to remove any oil or foreign material from the surface. Samples, after being roughened by emery paper, might contain cement and this has to be removed before the test can proceed. The cleaning was accomplished by washing with a coarse brush in water and then by successive washings in alcohol and ether.

After the specimens were surface treated and cleaned, they were weighed on an analytical balance. The weights were recorded and used to determine rate of corrosion by the loss in weight method. All samples were weighed on the same balance and with the same degree of accuracy.
CHAPTER VI

ASSAYS

Carbon, in the form of graphite, was added to the surface of the charged metal prior to melting, in order to prevent oxidation. With the presence of this graphite and also because of the use of carbon crucibles, there was reason to expect the resulting alloys to differ considerably from the predetermined composition. Coupled with this was the possibility of loss in tin content at the high temperatures required which also results in a composition change.

Since the purpose of this study was to determine the relative rate of corrosion of iron-tin alloys, it was necessary that the exact percentages of iron and tin in each sample be known. Slight impurities other than carbon were introduced in the iron used, but since they are small in comparison, they were neglected.

The material used for analysis was the filings or chips produced while machining, after the outer crust had been removed. The dichromate method for iron and the combustion method for carbon were employed in all determinations. The extent to which tin was present in each alloy was found by difference.

The results of the chemical analysis follow:
<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Compositions from weights used</th>
<th>Results of Assays</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fe%</td>
<td>Sn%</td>
</tr>
<tr>
<td>1.</td>
<td>100</td>
<td>0</td>
</tr>
<tr>
<td>2.</td>
<td>98</td>
<td>2</td>
</tr>
<tr>
<td>3.</td>
<td>96</td>
<td>4</td>
</tr>
<tr>
<td>4.</td>
<td>94</td>
<td>6</td>
</tr>
<tr>
<td>5.</td>
<td>92</td>
<td>8</td>
</tr>
<tr>
<td>6.</td>
<td>90</td>
<td>10</td>
</tr>
</tbody>
</table>
CHAPTER VII

CORROSION TEST RESULTS

Units for Reporting Corrosion Rates

Terms used to report corrosion rates should include units of weight, time, and area or depth of penetration per unit of time. The most popular methods are "milligrams per square decimeter per day", abbreviated mdd., and "inches penetration per year", abbreviated ipy. The latter term represents the depth to which uniform corrosion would penetrate if a specimen were exposed to corrosion, on one side only, for one year.

Weight loss units can be converted into penetration units by using the equation:

\[ \text{mdd.} \times \left( \frac{0.0014437}{d} \right) = \text{ipy.} \]

where \( d \) is the density of the metal in grams per cubic centimeter.

The Jolly balance was used to determine the densities of the alloys under consideration. The results of this determination follow:

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Density (grams/cc.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>7.70</td>
</tr>
<tr>
<td>2.</td>
<td>7.24</td>
</tr>
<tr>
<td>3.</td>
<td>7.26</td>
</tr>
<tr>
<td>4.</td>
<td>7.14</td>
</tr>
<tr>
<td>5.</td>
<td>7.26</td>
</tr>
<tr>
<td>6.</td>
<td>7.13</td>
</tr>
</tbody>
</table>
Testing Conditions

In any corrosion test, it is necessary for all the conditions under which the test was carried out to be definitely stated so that at any time the testing conditions may be duplicated and the results be adequately reproducible. Included among these conditions are:

1. Composition and volume of solution.
2. Temperature.
3. Aeration and agitation.
4. Pressure.

The solution used in the laboratory was a one normal solution of sodium chloride. Three liters of fresh salt solution were placed in the corrosion apparatus each week, after first draining out the contaminated liquid and washing the box thoroughly. The weekly change of solution was necessary in order to prevent incorrect results due to contaminated media. From beaker tests, Friend concludes that, with increasing concentration of salt solution, the corrosion first increases to a maximum and then decreases to a low figure.

The rate of corrosion increases with an increase in temperature. This increase is shown to be almost linear in a closed system in which the oxygen is held in the system for a long period of time. High temperatures tend to lower the overvoltage of hydrogen on the metal and increases corrosion by permitting more rapid evolution of hydrogen gas from the surface. Our corrosion process was conducted at room
temperature which remained relatively constant at 23°C.

With an increase in the agitation and aeration of the corrosive liquid, the rate of corrosion increases. They both tend to bring more oxygen in contact with the metal surface, thus removing the hydrogen that was evolved. Agitation also removes the protective coating and exposes more of the metal to the corrosive media.

The pressure used in a salt-spray test is very important. It has been proven by experiments, that an increase in pressure results in a corresponding increase in the rate of corrosion. This is explained by the combination of the oxygen with the evolved hydrogen, with the result that more metal goes into solution. The pressure of the tests conducted in the laboratory was maintained at 5.9 lbs/in.\(^2\) gauge.

Duration of Tests

When a corrosion test is first started, erratic results occur being due to the surface condition of the metal. In general, the initial rate of corrosion is much greater than after the action has proceeded for some time. The test should continue until a reasonable amount of corrosion has taken place and the action proceeds at a uniform rate. For this reason, the duration of testing was set at approximately two weeks and three separate tests were conducted.

At the end of each two week period, the samples were removed from the salt spray, cleaned, weighed, and examined. Also several photographs were taken to be used as a means of
comparison. The loss in weight, being the principle measure of corrosion employed in these tests, was determined and the results of samples of different compositions were compared. The alloys were then returned to the testing apparatus and exposed for a similar period of time.

Originally, four samples of each composition alloy were to be used, but the conditions encountered limited my study to one of each type. The results obtained from this experiment are not as accurate as those arrived at when a larger number of specimens are employed. In order that rate of corrosion be compared with length of exposure time, it is necessary that the protective film that forms on the surface of the metal remain untouched until the test is concluded and this was not the case in this experiment. Due to the limited number of specimens with which the test was conducted, the original cycle of corrosion was interrupted. The oxide film was removed between tests and the samples returned with the metallic surface completely exposed.
Data

Results of First Exposure Period -- 377 hours.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Wt.</th>
<th>Previous Wt.</th>
<th>Wt. Loss</th>
<th>mdd.</th>
<th>ipy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.9230</td>
<td>25.0900</td>
<td>3.1670</td>
<td>1575.0</td>
<td>0.2940</td>
</tr>
<tr>
<td>2</td>
<td>12.8620</td>
<td>13.0175</td>
<td>0.1555</td>
<td>88.40</td>
<td>0.0175</td>
</tr>
<tr>
<td>3</td>
<td>17.3800</td>
<td>17.5150</td>
<td>0.1350</td>
<td>70.50</td>
<td>0.0140</td>
</tr>
<tr>
<td>4</td>
<td>30.3890</td>
<td>30.5425</td>
<td>0.1535</td>
<td>65.60</td>
<td>0.0132</td>
</tr>
<tr>
<td>5</td>
<td>24.9840</td>
<td>30.1550*</td>
<td>5.1710*</td>
<td>2470.0*</td>
<td>0.4880*</td>
</tr>
<tr>
<td>6</td>
<td>38.7660</td>
<td>38.9375</td>
<td>0.1715</td>
<td>64.30</td>
<td>0.0130</td>
</tr>
</tbody>
</table>

* Error caused in weighing original sample before subjection to corrosive media. Previous weight should be 25.1550, weight loss 0.1710, mdd. 81.6, and ipy. 0.0162 inches.

Results of Second Exposure Period -- 331 hours.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Wt.</th>
<th>Previous Wt.</th>
<th>Wt. Loss</th>
<th>mdd.</th>
<th>ipy.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>21.7670</td>
<td>21.9230</td>
<td>0.1560</td>
<td>88.40</td>
<td>0.0165</td>
</tr>
<tr>
<td>2</td>
<td>12.7020</td>
<td>12.8620</td>
<td>0.1600</td>
<td>103.40</td>
<td>0.0205</td>
</tr>
<tr>
<td>3</td>
<td>17.2420</td>
<td>17.3800</td>
<td>0.1380</td>
<td>82.00</td>
<td>0.0162</td>
</tr>
<tr>
<td>4</td>
<td>30.2350</td>
<td>30.3890</td>
<td>0.1540</td>
<td>74.80</td>
<td>0.0151</td>
</tr>
<tr>
<td>5</td>
<td>24.8270</td>
<td>24.9840</td>
<td>0.1570</td>
<td>85.30</td>
<td>0.0170</td>
</tr>
<tr>
<td>6</td>
<td>38.5980</td>
<td>38.7660</td>
<td>0.1680</td>
<td>71.60</td>
<td>0.0144</td>
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</tbody>
</table>
Results of Third Exposure Period -- 285 hours.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Wt.</th>
<th>Previous Wt.</th>
<th>Wt. Loss</th>
<th>mdd.</th>
<th>ipv.</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>21.6450</td>
<td>21.7670</td>
<td>0.122</td>
<td>80.2</td>
<td>0.01495</td>
</tr>
<tr>
<td>2</td>
<td>12.5400</td>
<td>12.7020</td>
<td>0.162</td>
<td>122.0</td>
<td>0.0242</td>
</tr>
<tr>
<td>3</td>
<td>17.1000</td>
<td>17.2420</td>
<td>0.142</td>
<td>98.0</td>
<td>0.0194</td>
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<tr>
<td>4</td>
<td>30.0850</td>
<td>30.2350</td>
<td>0.150</td>
<td>84.8</td>
<td>0.0171</td>
</tr>
<tr>
<td>5</td>
<td>24.7000</td>
<td>24.8270</td>
<td>0.127</td>
<td>80.1</td>
<td>0.0158</td>
</tr>
<tr>
<td>6</td>
<td>38.4650</td>
<td>38.5980</td>
<td>0.133</td>
<td>65.8</td>
<td>0.01325</td>
</tr>
</tbody>
</table>

* Results of Third Exposure Period -- 285 hours.

<table>
<thead>
<tr>
<th>Sample No.</th>
<th>Wt.</th>
<th>Previous Wt.</th>
<th>Wt. Loss</th>
<th>mdd.</th>
<th>ipv.</th>
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<td>21.7670</td>
<td>0.2340</td>
<td>153.7</td>
<td>0.0287</td>
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<td>12.7020</td>
<td>0.3180</td>
<td>239.0</td>
<td>0.0475</td>
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<tr>
<td>3</td>
<td>16.9250</td>
<td>17.2420</td>
<td>0.3170</td>
<td>219.0</td>
<td>0.0434</td>
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<td>4</td>
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<td>24.8270</td>
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<td>38.5980</td>
<td>0.2800</td>
<td>138.5</td>
<td>0.0279</td>
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</tbody>
</table>

* Cleaned Electrolytically.
First Exposure Period -- 377 hours.

(Cleaned in water, alcohol, and ether).
Second Exposure Period -- 331 hours.
(Cleaned in water, alcohol, and ether).
Third Exposure Period -- 285 hours.
(Cleaned in water, alcohol, and ether).
Third Exposure Period -- 285 hours.
(Cleaned Electrolytically).
1. First Exposure Period
2. Second Exposure Period
3. Third Exposure Period (Electrolytically Cleaned)
4.
Photographs

Sample No. 6 after first period of exposure shows adhering coating that surrounds corroded area.

100X Photomicrograph of sample number 2 showing uncombined carbon present

Sample No. 2 after second period of exposure, to show effect of uncombined carbon on the localization of corrosion (pitting).
Discussion of Results

After cleaning the corroded samples, the loose coating was easily removed but there remained a hard-adherent coat which in all cases outlined the most corroded areas. This material, as determined by noted authorities in the field, is ferrous hydroxide. Beneath this clinging substance, the metal appeared relatively uncorroded and before weighing the specimens, it was necessary that this coat be removed. The method employed was to scrape it free with a dull instrument, being careful not to damage the underlying metal, and then to continue cleaning according to the normal procedure.

Localized corrosion was noticed to some extent on all alloys, but the most predominant pitting occurred on sample number two. As shown in the photo-micrograph, this alloy contains considerable free or uncombined carbon. In the preparation of this sample, it was noticed that the metal had penetrated deeply into the sides of the crucible, with the result that it became saturated in carbon and the graphite added to prevent oxidation merely remained uncombined. The part that free graphite plays in the corrosion of metals was discussed previously.

Also, sample number two was the only one studied in which the presence of a pipe existed. Due to this small cavity on the surface, corrosion products built up and were not removed by the ordinary methods of cleaning prior to weighing and recording the results. Had this been cleaned by various other methods, in the case of the second exposure
period, the weight loss due to corrosion would have appeared larger. The specimens resulting from the third period of exposure time were, however, cleaned by an accepted electrolytic method after cleaning and weighing using the water, alcohol and ether washings. The results proved that pitting was present in all specimens as an increase in weight loss over the previous method was obtained. The data obtained from this second cleaning merely amplified the previous results of washing and did not give a uniform relation between rate of corrosion and composition as was anticipated.

The electrolytic method of cleaning used, consisted of a cell possessing the following conditions:

Electrolyte -- 5% sulphuric acid (by weight)
Anode -- Carbon
Cathode -- Test Specimen
Cathode C.D. -- 20 amp. per sq. dm.
Inhibitor -- 2cc. organic inhibitor per liter.
Temperature -- 74°C.
Exposure Period -- 3 minutes

Immediately upon their removal from the cell, the samples were washed in alcohol and ether, weighed and recorded.
CHAPTER VIII

CONCLUSIONS

1. A sharp decrease in the rate of corrosion occurred on alloys containing 5.25% tin.
2. The combined carbon present had no great effect on the rate of corrosion of the alloys.
3. Loss in weight due to corrosion increased on repeated exposures, due to prior formation of pits and removal of protective coatings.
4. Pitting took place on all samples despite their smooth surface appearance before testing.
5. The presence of a tightly adhering coat prevents the underlying material from corroding while the loose coating offers little, if any, protection.
6. As a comparison between relative rates of corrosion of similar alloys made from powders, reference is made to the thesis by Robert W. Gambill. His experiments indicate that rate of corrosion increases with an increase in tin content of the alloy. Since the alloys used in his experiments were made by Powder Metallurgy, and complete diffusion was impossible, the corrosion, it is believed, increased because of galvanic action between dissimilar metals in contact.
SUGGESTIONS FOR FURTHER RESEARCH

1. The determination of other properties for alloys of this type would prove useful and interesting. Included among these are the following:
   (a) Magnetic qualities
   (b) Hardness properties
   (c) Electrical conductivity

2. Corrosion resistance properties for iron-tin alloys possessing a high tin content.

3. Corrosion resistance of similar metals as determined by other testing methods.
BIBLIOGRAPHY


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