NEAR EAST UNIVERSITY

FACULTY OF ENGINEERING
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ME 400

CORROSION AND CORROSION PREVENTATIO~C:OF./METALS

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ABSTRACT

The aim of this project is to prepare a survey report about fundementals of corrosion and the process applied to pfotect metals against corrosion destruction in the industry. Thetı.ec.essaryknowledge istaken from the litterature given at.the end of the text. Corrôsicmis generally divided in two types: a)Direct corrosion b)Electrochemical corrosion.

Direct corrosiön occurs asa.result of chemical attact of some solution'süch'as acids. Electrochemical.corrosion oçqurs continiously when metals are exposed to atmospheric condition as observed fdrtustinğ öfiron. In practice most common arid destructive corrosion is electrochemic~t:typecottosion. Therefore in.this project mainly electrochemical corrosion is considered:

:~~!)t:r ône>i~ııtaihs,basic info~tİ~fi a~~Utelectrochemical c~~osion in.8l~~g:;4y:fm.~tiq:qş(gygyfisaspect of corrosion and what is the meaning of corrosion for engineering:

Chapter two explain, fundementals of electrochemical corrosion and principle of galvanic cells.

Chapter three introduces, common form of corrosion including galvanic corrosion, pitting, stress corrosion, :frettingcorrosion, concentration corrosion and oxidation of metals.

Chapter four contains, methods appli~dfor corrosion prevention (material selection, alteration of environment, desing rules, prevention against other types of corrosion)

Chapter five deals with metal cleaning, removal of contaminants.

Chapter six devoted to electroplating (cadmium plating, zinc plating, cadmium and zinc compared, chröınitiin plating, rıickelplating)

Chapter seven in~ludes metaUiccoating process (aliıninum coating of steel, hot dip tin coating of steel, hot dip galvanizing)

Chapter eight contains, non-metallic coating process including painting and ceramic coating.

Chapter nine is conclusion.

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CHAPTER I

I. INTRODUCTION

Corrosion can be defined as the deterioration of material caused by chemical reaction in its environment. The corrosion occurs because of the natural tendency for most metals to return to their natural state; e.g., iron in the presence of moisture will revert to its natural state, iron oxide. Metals can be corroded by the direct reaction of the metal to a chemical; e.g., zinc will react with dilute sulfuric acid, and magnesium will react with alcohols.

Electrochemical corrosion is one of the most important classification of corrosion. Four conditions must exist before electrochemical corrosion can proceed: (1) there must be something that corrodes (the metal anode), (2) there must be a cathode, (3) there must be continuous conductive liquid path (electrolyte, usually condensate and salt or other contaminations), and (4) there must be a conductor to carry the flow of electrons from the anode to the dathode. This conductor is usually in the form of metal-to-metal contact such as in bolted or riveted joints.

The elimination of any one of the four conditions will stop corrosion. An unbroken (perfect) coating on the surface of the metal will prevent the electrolyte from connecting the cathode and anode so the current cannot flow. Therefore, no corrosion will occur as long as the coating is unbroken.

One of the fundamental factors in corrosion is the nature of material, Materials are usually selected primarily for structural efficiency, and corrosion resistance is often a secondary consideration in design. The use of corrosion-resistant alloys is not a cure-all for corrosion prevention. Corrosion-resistant metals are by nature passive (more noble) and can cause severe galvanic corrosion of active (less noble) materials. A common occurrence is to replace a corroded part with a corrosion-resistant allor only to find that the corrosion has shifted to another location and increased in severity.

Water intrusion is the principal cause of corrosion problems encountered in the field use of equipment. Water can enter an enclosure by free entry, capillary action, or condensation. With these three modes of water entry acting and with the subsequent confine:ınentof water, it is al:ı:ıiösfcertainithatany enclosure will be susceptible to water intrusiolir

At normal atmospheric temperatures the moisture in the air is enough to start corrosive action. Oxygen is essential fof corrosion to occur in water Yaf ambient temperatures, Other factors that affect the tehdency of a· metalto corrode ate: acidity or a1kalinity of the conduc:tife mecHu:ın:\(pH factor), (2) stability öf the cötrôsiön products, (3) biological organisms (:particlH~:tly anaerobic bacteria), (4) variation in composition of the corrosive medium, and (5) temperature. The corrosion problem is complex. The presel1çe of salts and' ıı.cicl.s ôrtorrıetal surfaces greatıf<increase~ tlie electrical conductivity of any moisture present and accelerates côtrosion. Moisture tends to collect on dirt particles. The maintenance of clean. surfaces ôli passive metals or alloys and alloys plated with more noble metals can be of even greater lnlpt;>ftance than for plain carbôrt steel: I:f srrıaU cotrösi.öiifu:6aSd.evelop‡he· coıtı.bffi~t:iörtô:fsınali active anodes in relation tö large passiv~>cathôdescauses severe pittmğt'IrıiS principle also applies to metals that have been passivatedpy chemical treatments as we)Fas for metals that develop passivation due to e:ııvjrçfnfüe:tıtal conditions (e.g., stainless steel and aluminum). Alloys that owe their qo:rrôsitfrt fesıstfu:'ıpe to passivity ı:llie (susceptibleto a.ccelerated corrosion within crevices.' This•pheıiômenon is caused by· the· fomıaüeıı of an. §~ğ¢ıı cell resulting from a lower ôxygen concentration in the crevice. For.these rea§ö~~c:;',$ı@~tılill6ss!1ct£iust .. be•· maintaiııetl.l:.ln.a. cortôsion-preventive : mea.stıi'~s, <sU6~ ~S paintiıı.ğ a.sdicta.teclbyser\i'icfücconditiônş; föı.ı.s{be observed even on corrosion-resistant materials. Corrosive attack begins on the surface of a metal exposed to a corrosive environment. If allowed'· to pr8ğtess/H:lıe cortosidh works down· into the c8re of the material. Because corrosion never ö:tiğfüates, iı:rthe core, there will alwa:ys be 'evidence on the surface when an ~ttack is in progress. The most common' visible rnaıiifestatio1ls. of corrosion are pitting on stainless steel or aluminum, rust on carbon steel, and intergranular exfoliation on aluminum.

L1 Definition

Corrosion is the deteration of a material resulting from electrochemical attack by its environment. The rate of corrosiôfı.qepends on the temperature and the concentration of the reactants and products. Other factors such as mechanical stress and erosion may also contribute corrosion.

Most metals are corroded by electrochemical attack since. tgyy\haye.<free electrons. They are able to. setup electrochemical cells within .metals themselyes.. l\.1ost metals are corroded to same extentlJy w'at.er and atmosphere. Then can also be corroqed by direct chemical attach from a ch~rrıiçfllsolµti()iı.Sucdıs.acids.

Most metals exist in the nature in combined state, such as oxides, sulfides, carbonates and silicates. In there combined st~te, their energy is lower. In metallic state, their energy is higher, thus they have tendency to react chemically to form compounds. Compounds have lower energy and µave more stable structure. For example iron oxides exist normally in nature, are reduced by thermal energy to iron, which is higher energy state. When iron is exposed to -atmosphere, it tends to return to oxide by corroding (rusting) to lower its energy.

Nonmetallic materials, qeramicş f~d .pl~~Jics can be deteriop:ıteq lJy \direçt cheınical attack, not by electrochemical ~iaçl.<.

Corrosion caused enormous economic loss. Therefore ngineers must concerned about corrosion control and prevention.

Corrosion is defined as the destruction or deterioration of a material because of reaction with its environment. Some İnsist that the definition should be restricted to metals, but often the corrosion engineers must consider both metals and nonmetals for solution for a given problem.

Corrosion bas been classified in many different ways. One method divides corrosion onto low-te:rnparatureand high-temparature corrosion. Another separates corrosion onto direct combination (or oxidation) and electrochemical corrosıon. The preferred classificationhere is;

1) Wet corrosion
2) Dry corrosion

Wet corrosion occurs when a liquid is present. Tlıis usually involves aqueous solutions or electrolytes and accounts forJhe greatest.amount of corrosion.<byfar. ,A common example is corrosion of steel by water, Dry corrosion occurs in theabsençe of a liquid phase or above the dew polı,ıt oftlıe)~ııvironment. Vapors aµclgases are usually the corrodents. Dry corrosion os most.s{eel.byflttruıcegases.

The presence of even small amounts of moisture could change the corrosion picture 9ompletely. For example; dry chlorine is practically noncorrosive to ordinary şteel, but moist chlorine, or chlorine dissolved in water, is extremely corrosive and attacks most of the common metals and allays. The reverse is true for titanium-dry chlorine gas is mote corrosive than wet chlorine.

Corrosion can be fast or slow. Sensitized 18-8 stainless steel is badly attacked in hours by- polyphonic acid. Railroad tracks usually show slight rusting-not sufficient to affect their performance over many years. The famous iron Delhi Pillar. in India was made almost 2000 years ago and is almost as good as new. It is about 32 feet high and 2 feet India-meter. It should be noted, however, that it has been exposed mostly to arid conditions.

Most)ron. .ores cont~ odq~s of iron, and rusting of steel by wa.terarıd oxygen result in a hydrated iron ocide. Resultinf is a term reserved for steel and.iron corrosion, although many other metals from their oxides when corrosion occurs.

1.2 Corrosion Engineering

In any case, Corrosion represents a tremendous economic loss arid much can be done to reduce it. These large dollar figures are not surprising wlietı. we consider that corrosion occurs, with varying degrees of severity, whenever metals and other materials are used.

In fact the economy would be drastically changed if-there we:reiriôcörr6sförı.For example, aırtomobiles,"ships, 'uhderğröund pipelines and household- appliım.cesY•wöüld not require coatings. The stainless•steel in.dtı.st:ty would essential disappear and copper would be used only for electrical purposes.···]M:ôst metallic plants, as Well as consımıer products, would be made.of steel or casfırö:ı:ii

Although corrosion is :inevitable,·its cost can be considerably·reduced. For example, an inexpensive magnesinm anode could double the life of a domestic hot water tank. Washing a car to remove road deicing salts is helpful. Proper seleption of materials and good design reduce costs of corrosion. A good mainten.ance pain.tin.g program pays for itself many times over. Here is where the corrosion engineer enters the picture and is effective his or her primary function is to combat corrosion.

A side from its direct cost in dollars, corrosion is a serious problem because if definitely contributes to the depletion of our natural resources. For example, steel is niade fröin iron are, and our domestic supply öf hi~h grade directly smelt able iron are has dwjndled. Another important factor concerns the world supply of metal resburces. The rapid industrialization of many countries indicates that the competition for and the piece of metal resources will increase.

Corrosion·engineering is 'the application.of science and art to···preverif Or control corrosion damage economically and safety.

Iıi order to reform their function properly, corrosion engineers must be well versed in the practices and principles of corrosion; the chemical, metallurgical, physical, and mecfürtı:ical properties. of materials; corrosion testing; the+nature of corrosive environments; the availability and fabrica.tion of materials, computers, and design. They also must have the usual attributes of engineers a sense of human relations, integrity, the ability to think and analyze; an.awareness of the importance of safety, common sense, a sense of organization, and of prime importance, a solid feeling.for, economics. In solving corrosion problems, the corrosion engineer .must select to method that will nıa:xii:nize pro:fits;;Onedefinition of economics is simply-there is no free.lunsh.

In the past relatively few engineers received aducation training in corrosion. Most of the people then engaged in this field had chemical, electrical or metallurgical back grounds. Fortunately this picture has changes.

Particularly all environments are corrosise to some degree. Some examples are air and moisture' fresh, distilled, salt and mine waters, rural, urban, and-industrial-------- atmospheres; steem and other gases such as chlorine, ammonia, hydrogen sulfide, sulfur dioxide, and fuel gases, mineral acids sucli as hydrochloric, sulfuric and nitric, organic acids such as nophtheniq, acetic and formic, alkalis, soils, solvents, vegetaMe and petroleum oils, and a variety of food products. In general, the inorganic materials are more corrosive than the organic for example; corrosion in the petroleum industry is due more to sodium chloride, sulfur, hydrochlpric and sulfuric acids, and water, than to the oil, naphtha or gasoline.

Higher temperatures and pressures usually involve more sever• corrosion conditions. Many of the present-day operations would not have been possible or economicalwithouMhe use of corrosion-resistant materials.

Automobiles are pointed. because rusted surfaces are not. pleasirig.:to the. eye. Badly corroded and rusted equipme11.tinplant would leave a poor impression.and the observer. In many rural and urban environments it would be cheaper to make to metal rhicker :in the first place (corrosion allowance) then to apply and maintain a point coating. Outside surfaces or trim and buildings are often made of stainless steel, aluminum, or copper for the sake of appearance.

Constructional saving can be obtained in many types of plant through the use of corrosion-resistant materials of contraction. One example is classic respect. A chemical plant effected an annual saving of more than .$10.000 merely by changing the bolt material on some equipment from one allay to another.more resistant *to* the conditions involved. The.cost of this chang~ was/negligible. In another case a waste acid recovery plant operated in the red for severalrtıontlıs until a serious corrosion problem was solved, This plant was .built to take care .of an important waste. disposal problem. Application ôf cathodic protection: can cut leak rates in existing underground pipelines to practically nil with attendant large saving in repair costs, Maintenap.ce costs rare scrutinized because the labor picture accents the necessity for low cost operation.

Frequently plants are shut down or portions of a process stopped because of unexpected corrosion failures. Sometimes there shutdowns are caused by corrosion involving no change in process conditions, but erroneously regarded as incapable of increasing severity of the corrosive co:nditiop.s. It is surprising how often some minor ¢lıarige in. process or the addition of a new ingredient changes corrosion characteristics complet¢ly. The prô:tectio;nof a chemical pômpound vital to national defense is an example. Tô >increaseitş produotion, the temperature of the cooling :ttıediQm in a heat enchanger system was lowered and the time :teqtritedper batch decreased. Lowering the temperature of the cooling medium resulted, hoetver, in more severe thermal gradient across the metal wall. They, in turn, indÜöed higher stresses in the metal. Stress was shut down with production delayed for soıri.etmıe.

Contamination of product: In n:ıanfcases.the market value of the products is directly related to its purity and quality. fi'reedofufrom Contaminationis a vital factor in the manufacture handling of transparent plastics, pigments, foods, .drt.igs and semiconductors. In some cases a very <small amount of corrosion, which iritrodq,ces certain metal ions intç the solution, rriliy cause catalytic decomposition of a product for example, in the manufacture aııd tiiınspôrting of concentrated hydrogen peroxide or hydrazine.

Loss of valuable products: No particular concern is attached to slight leakage of sul:fic acid to the drain, because it is a cheap gallon requires promote corrective action. Slight loses of uranium compounds or solutions are hazardous can be very costly materials of construction well warranted.

Effect on safety and reliability: The handling of hazardous materials such as toxic gases, hydrofluoric acid, con.centra.ted sulfuric .and nitric acids, explosive and flammable materials, radioactive substances and chemicals at high Temperatures and pressured demands the use of construction materials that minimize corrosion failures, stress corrosion of a metal wall separating the fuel and oxidizer in a missile could:cause premature mixing, which could result in a loss of millions of dollars and in personal injures. Failure a smallcomponent or control may result infailure or destruction of the entire structure. Corroding equipment can cause same daily harmless compounds to become explosive. Economizing on materials of construction is not desirable if safety is risked.

CHAPTER II

II. FUNDAMENTALS OF CORROSION

2.1 Electrochemical Corrosion OfMetal

The electrochemical nature of corrosion can be illustrated by the attack on zinc by hydrochloric acid. When zinc is placed in dilute hydrochloric acid, a vigorous reaction occurs; hydrogen was is evolved and the zinc dissolves, forming a solution.of zinc chloride. The reaction is:

$$Zn+ 2HC1 \sim ZnCh + H2$$

Noting that the chloride ion is not invdlved iti the reactions, this equations can he written in the simplified form:

$$Zn+ 2H^{+} \rightarrow Zn^{2+} +H2$$

Hence, zinc reats with the hydr.< [illegible] ?f the acid solution to form zm: c ions and hydrogen gas. Examining the above: equation, it can be seen that during the reaction, zinc is oxidized to zinc ions andhydr'oğenions are reduced to hydrogen.

- Oxidation (ANODIC REACTION) $Zn \sim Zn^{2+} + 2e$
- Reduction (CATHODIC REACTION) $2W$ $2e \sim H2$

An oxidation or anodic reaction is indicated by an increase in vaiance or a production of electrons. A decrease in valance change or the consumption of electrons signifies a reduction or cathodic reduction. Equations of oxidation and reduction are partial reaction; both must occur simultaneouslyand the same rate .on the metal surface. If this were not true, the metal would spontaneously become electrically charged, which is clenearly impossible. This leads

When viewed from the standpoint of partial processes of oxidation .and reduction, all corrosion can be classified onto a few generalized reactions. The anodic reaction in every corrosion reaction is the oxidation of a metal to its ion. This can be written in the general form:

$$M \rightarrow M^{+n} + ne$$

In each.ease-the number ofelectrorıs produced equals the valance at the ion.

There are several different cathodic reactions that are frequently.encountered in metallic corrosion. The most common are:

Hydrogen evaluation: $2{:}W + 2e \sim H_2$
Oxygen reduction: $O_2 + 4W + 4e \sim 2H_2O$
Metal ion reduction: $M_3 + e \sim M^{2+}$
$M^{*+}{:}e \sim M$

During corrosion, more than one !ôxi_datiorı. arid one redüctiôni re~ctioıi may occur. Wheıi an allôy is côrtôded, its cômpôiieiit metals go into csôlutiçın: as>their respective ions. More importaııtly, more than ô:ô.e: reduction reaction can öc8urTô.uring corrosion, Consider the corrosion of zfü.öYin aerated hydrolic acid. Two cathodiq reactions possible: the evohıtiorı ofhydroğen.'a±ıdtli.eteducing of oxygen.

Since the anodic and cathodic reactions occurring during corrosion are mutually dependent, it is possible to reduce corrosi~fi.:,iby'f¢ducingthe rates of either reaction. In the above case of impure hydrochloric ~tiq, i'it)ban. be made less corrosive by removing the ferric ions and consequently reducing the total rate of cathodic reduction. Oxygen reduction is eliminated by preventiııg/air from Contacting the aqueous solution or by removing air that has been dissolved. Iron will not corrode in ~ir-free wateror seawater because there is no cathodic reaction possible.

Ih the surface of metal is coated with paint or other no conducting film, the rates of both anodic and cathodic reactions will bee greatly reduced and corrosion will be retarded. A corrosion inhibitor is a substance that when added in small amounts to a corrosivereduces its.corrosivity. Corrosion inhibitors function by interfering with either the anodic and cathodic reactions or both. Many of these inhibitors are organic compounds; they function by forming an impervious film on the metal surface or by interfering with either the anodic or cathodic reactions. High molecular weight amires retard the hydrogen evolution reaction and subsequently reduce corrosion rate.. It is obvious that good conductivity must be maintained in both the metal and the electrolyte during the corrosion reaction. Of course; it is not practical to increase the electrical resistance of the electrolyte or corrosive and thereby reduce corrosion. Very pure water is much less corrosive than impure or natural waters. The low corrosivity of high purity water is primarily due to its high electrical resistance, These methods for increasing corrosion resistance are described in greater detail in following chapters.

2.2 Galvanic Cells

Most metallic corrosion involves electrochemical reactions, it is important to understand the principle of electrochemical galvanic couple; or cell. When two dissimilar metal electrode is immersed in equeous solution, they form galvanic cell as shown in figure; Depending on the relative electrode potentials of the metals, are becomes anod, the other one cathode. When two electrodes are connected by a wire and voltmeter, the electrons produced at anode due .to oxidation reaction will flow to cathode and certain potential can be measured.

Zn^{2+} ions are dissolved in the ekectrode, thus Zn becomes corroded,

Cu^{2+} ions are reduced to Cu atoms.

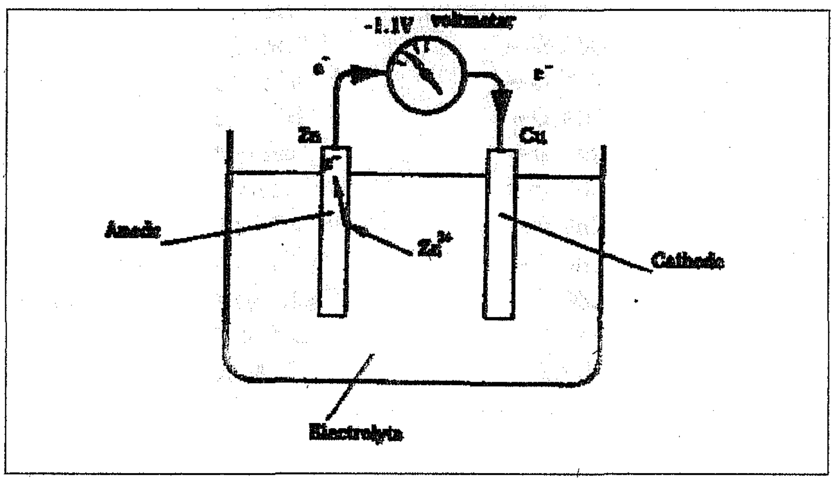


Fig.1

Every metal has a different tendency to corrode in a particular environment. Tendency for metals to form ions in a equeous solutions can be determined by a half-cell metho. By this method standard electrode potential of metal versus standart hydrogen electrode. is measured. Electrolytesiin.tb.ehalf cells contain one more solution of metal and hydrogen. The metals whidL are more reactive than hydrogen have negative potential, so they are anode, These\metals are oxidized to form ions; H ions are reduces to for H gas. Some other metals which are less reactive than H have positive potential, so they are cathodic agains H; therefore they are reduced.

- Standard electrode potentials of some metalS{45°C)

Table I Standart emfserie~ of metals

	Metal-metal ion equilibriuni (unit activity)	Electrode potential vs. normal hydr<:>gen electrode at 25°Ct yqlts
	$Au-Au^{+3}$	+1.498
	$Pt-Pt^{+2}$	+1.2
Nôbleôr cathodic	Pd..Pd^{+2}	+0.987
	$Ag-Ag^{+}$	+0.799
	$Hg-Hg_2^{+2}$	+0.788
	$Cu-Cu^{+2}$	+o.337
	H_2-H^+	0.000
	Pb-Ph:1-2	·····>0.126
	Sn-Sn"?	--0.136
	Ni-Ni+:z	"-0.250
	Co-Co,+2	-0.277
	$Cd-Cd^{+2}$	-0.403
	fe-Fe^{+2}	-0.440
	$Cr-Cr^{+3}$	-.0.744
	zn~zn+l	-0.763
Active or anodic	Al-Al+~	-1.662
	Mg-Mg+1	-2.363
	$Na-Na^{+}$	:.._2.714
	K-K.+	-2.925

Standards electrode potential measurements requires an electrolyte is a one molar solution at 25c. the actual potentials vary with concentration and temperature. The effect of metal ion concentration Ci and temperature T on the standard electrode potential E_0 is calculated by Ners equation as follow';

$$E = E'' + \frac{0{,}p592T}{N} \log C;$$

Where, E= new potential of half cell, Bo = standard potential of half pf c~ll,J.1 == tıl.l:tlll)er electrons transferred per atom and C;= molar concentration of ions. Most electrolytes are dilute, C;<l. Therefore electrode potentials in Table I are shifted in the anodic direction.

Some .many important engineering n:ı~tals form passive flhn 011 their surfaces. Tp~y do *pot* pehave. in. galvanic cells as thtt~tıw.daı:c:l electrode potentials W-():Uld indicate.

Thus for practical application wheI"ç cprt,.)sion is important factor,.a 11ew type of series called galvanic series has.. been deyelopeq for. anodic-cathodic rel_~t~9~hip. 'T'lı~~ ~ galvanic series must be determined for eyery.qôI"tqsive environments. ·A galvanic series for metals and allays exposedto flowing s_~a}Y"~\er is given in table 2.for example for (Fe-Zn) couple, Zn is more active than Fe, therefore Zn is anodic, while Fe is cathodic for Zn. Sn is an cathodic side for Fe. Fe is on anodic side, therefore for (Fe-Sn) couple, Fe will be corroded, Sn iş protected. For (F~-Zn) couple Fe will be Pt()t~pted~ Zn is corrodecl.

CHAPTER III

III. COMMON FORMS OF CORROSION

3.1 Uniform Corrosion

Concentration cell corrosion occurs wheıi two or more·areas of a metal surface are in contact with different concentrations ôftl:ıeYSa:tne solution. There are three general types of concentration cell corrosion: (T)'metal fon concentration cells, (2) Oxygen concentration cells, and (3) active-passive cells.

In the presence of water, a nigh concentration of metal ions will exist under faying surfaces and a low concerittatioıı dfmefal 'iô:tıs will exist ııdjacei:ı.t to>the crevice created by\the faying surfaces. An dectricıil p<'.lfei:ı.fütl will exist between the two points. The area>cYfthe metal in côntcJ.cf with th.~>Jö'\V cOhcentration of m&f~ff iöıis will be cathodic arid will be pr0tectedOa:n.d tlıe aı:ea ôr'ffietal in contact with the<'.hfg1ıin.et~ı ion concentration will be anodic and corroded. This condition can be eliminated by sealing the faying surfaces in a manner to excltıde moisture. Proper protective coating application with inorganic zinc primers 'is hlsö effective in reducing faying surface corrosion.

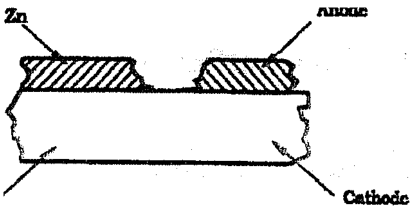
A water solution in contact wifli tlie fu.etal surface will nô:ı'1.ilhlly côl:ıttıin dissolved .oxygen, An oxygen cell can develop at any point where the oxygen inthe air is not allowed to diffuse uniformly into the solution, thereby creating a difference in oxygen concentration between two points. Typical locations of oxygen concentration cells are µnder either meta~~ or nonmetallic depoiits(dirt) on thei~s~aı surface and under faying sutfaces such as riveted lap joints. Oxygen cells can also develop under gaskets, wood, rubber, plastic tape, and other materials in contact with the metal surface. Corrosion will occur at the area of low--oxy~enconcentration (anode). The severity of corrosion due to these conditions can be minimized by sealing, maintaining surfaces clean, and avoiding the use of material that permits wicking of moisture between faying surfaces.

Metals that depend on a tightly adhering passiv film (usually an oxide) for corrosion protection; e.g., austenitic corroşıQl.1~f¢Sistant steel, can be corroded by active-passive cells. The corrosive action ıı.sually!'<starts as an oxygen concentration cell; e.g., salt deposits on the metal surface in tlı.e ptrs~~ce Of water containin~ oxygen can create the oxygen cell. If the passive filnıis brok~l.lıpel.leath the salt deposit, the active metal beneath the film will be exposed to côrtôsi.ve attack. An electrical potential will develop between the large area of the catb.öde (passive film) and the small area of the anode (active metal). Rapid pitting of the active metal will result. This type of corrosion can be avoided by frequent cleaningand by application pfprotective coatings.

3.2 **Galvanic Corrosion**

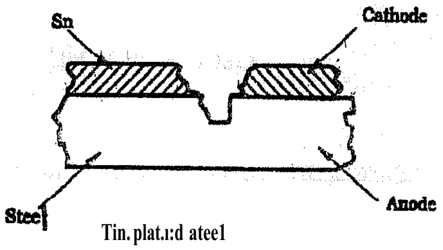
The difference in the electrochemical potential of two dissimilar metals can be cause.of the corrosion. For example; galvanized steel (basically iron) is coated with Zn film. When Zn is on steel are couple in an aqueous environment, since Zn is on the anode since on the galvanic series will be corroded, while steel on the cathode side will be protected.

In another case of dissimilar metals, steel sheet is plated with Sn film. Sn is a very high corrosion resistence. If the steelsheet is uniformly plated by Sn film, it will be protected by Sn film against corrosion. However when Sn film is perforated or scratched, the steel sheet will be exposed,to env:irqnment.Since Sn is on cathodic side anodic steel will not be protected by Sn therefore it will be corroded as shown in figure.



Galvanized steel

(a)



Tin.plat.ı:d ateel

(b)

Fig2

Fig3

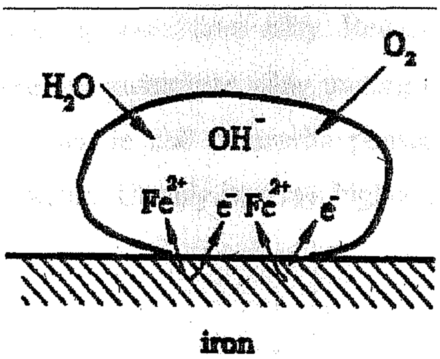


Fig.4

Atmosphere contains oxygen and moisture. Moisture condensed on the surface of iron forms an electrolyte as shown in figure.

Anodic reaction (oxidation):

$$Fe \rightarrow Fe^{2+} + 2e^-$$

Cathodic 'reaction (reduction):

$$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$$

The overall reaction is detained by .adding.those reactions;

2Fe + 2H20 + 02 ~ 2Fe2+ + 40Fr ~ 2Fe (OH)2·

Ferrous hydroxide, Fe $(OH)_2$ precipitates into electrolyte. It is oxiqized. further to produce ferric hydroxide:

2Ffr(OH)2 $+ H_2O + 1/2O_2 \rightarrow 2Fe$ (OH)3

Ferric hydroxide precipitatesasred.brownrüst. It turns to ferrooxide sometimes:

2Fe $(OH)_3$ ~\Fe.203 + 3H20

In most cases single phase allay has higher corrosion resistance than a multiphase allay: since electrochemical cell is created in multiphase allay; since electrochemical cell is created· in multiphase allay. Relatively one phase is anodic, the other one is cathodic, Therefore ml.lltip.ha.se allay undergo corrosion with higher rates. For example; steel contains ferrite an.d.detrı.enfite:iphasesAnodic cementite forms a galvanic cellwith cathodic ferrite, Usuallyiitônhas higher corrosion resıstance than iron carbôn allays or steels.

Martensitic steel has a single phase;.<Temperedmartensite has· many galvanic cells and boundaries .of ferrite and carbide.particles. Therefore it has higher eorrosion rate than tnartensite.

The grain, boundaries have anodic bı:,lıaviorsince they have higher energies due to atomic disordering in the are. Therefore g:ta.in boundaries are more chemically active (anodic) than g:ta.iii:m.atrix..···

3.3. **Pitting**

Pitting is a form of extremely locaJizeH>iattackthatresult in hcHes>lıı<the2trietal. These holes may be small or large: in diameter; but: in most cases they\a.re?relativeıy small- Pits are sometimes isolated or· so clôse>tôgether that they .Jo͏ök'. like a)rough surface. Generally a pit may be described as a cavity or hole with the surface diameter about the same as or less than the depth.

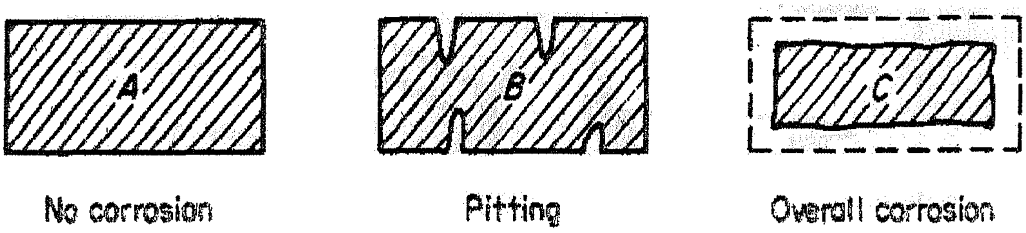


Fig. 5

Diagrammatic representation of pitting corrosion as an intermediate stage.

Pitting is one of the most destructive and insidious form of corrosion. If courted equipment to fail because of perforation with only a small percent .weighı-loss of the entire structure. .Ifis often difficultto detect pits because of their small size and because thepits are often covered.with'corrosion.products. In addition, it is difficultto measure qııar.ı.titatively. and compate the extend of pitting because of the varying depths and numbers of pits that may occur under identical conditions. Pitting is also .difficult to predict by laboratory test. Sometimes.the pits require a long time ..;.. severa! 111.oııth or a year - to show up.it actual service..Pitting is .particularlyvicious because it.is a localized and intense form of corrosion, and failures.often occur with.extreme-suddenness.

3.4 Stress Corrosion

Stress corro.sion cracking (sec) refers to cracking caused by4lly simultaneous presen9e of tensile stress and a specific corrosive medium. Many investigators have classified all cracking failures occurring in corrosive mediums as stress-corrosion cracking, including,failure's due to hydrogen embitterment. However, these two types of cracking failures respond differently to environmental variables. To illustrate, cathodic protection is an effective method for preventing stress-corrosion cracking, whereas it rapidly accelerates hydrogen- emıbitterment effects. Hence, the importance of considering stress-corrosion cracking and· hydrogen embitterment as separate phenomena is obvious.

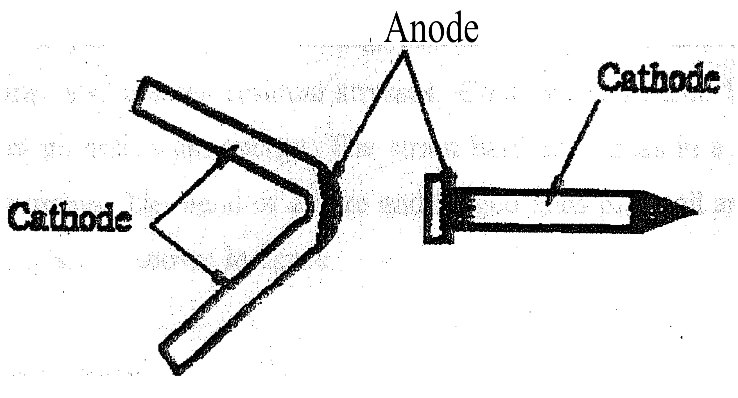


Fig.6

During stress-corrosion cracking, the .metal p:r allay ıs virtually unattached over most of its surface, while fine cracks pı:ogressthôuğht it.·. This cracking phenomenon has serious consequences since it can'. occur-at stress within the range of typical design stress. The stresses required for stress-co:rtösio:ı:ı. cracking are compared with the total range of strength capabilities.

The two classic cases of stress-corrosion cracking are "season cracking" of brass, and the "caustic·embrittlement" of steel. ijoth of these absolute terms describe the environmental conditions present that led to stress cracking. Season cracking·refers to the stress-corrosion: cracking failure of brass ecartridge cases. During periods of heavy rainfall, especially in the topics, cracks were observed in the brass cartridge cases art the point.where .tbe case was crimped to the bullet. It was later found that the important environmental component in season cracking was ammonia, resulting from the decômpôsitiqn..9:fl()tgallicı.matter.

Many explosion pf riveted boilers occurred in early steam-driven locomotives. Examination of the failures showed cracks or brittle failures at the riverl holes.These areas were cold worked during riveting Operations, and analysis of the whitish deposits found the these areas showed caustic, or sodium hydroxide, to be the ın.ajor component. Hence brittle fracture in the presence of caustic resulted in the term caustic embitterment.

In ınetals şııbjec~:~to cold working, plastic deformation increasesJdislbc~tion density, distortions, and creates residual·stresses…Cold. worked metal becomes anodic due to increase in internal stain energy. The strain' hardened areas in a metal are more susceptible to corrosion, The bend of a wire ·aıidfôrged ends of a nail are anodic where corrosion rate is higher as shownin,figtıre.

3.5 Erosion Corrosion

Erosion corrosion is the acceleration or increase on rate of deterioration or attack on a metal because of relative movement between a corrosive fluid and the metal surface. Generally this movement between a corrosive fluid and the metal surface. Generally this movement is quite rapid, and mechanical wear effects or abrasion are involved. Metal is removed from the surface as dissolved ions, or it forms solid corrosion product 'that are mechanically swept from the metal surface. Sometimes movement of the environment decreases corrosio~ ,particularly when localized attack occurs under stagnant conditions, but this is not erosion corrosion because deterioration is not increased.

Bf<;>sion corrosion -is characterized 'ın, "a-ııpearance by grooves, gullies; waives, rounded holes and valleys'and'usually•exhibits a directional pattern, ııı figure· is a•sketch representing erosion corrosion of a heat e:xchangeftube handling water, 'In many cases, failure because of erosion corrosion occur in a relatively short time, and they are unexpected largely because evaluation corrosion test were run under static conditions or because the.erosion effects·were not considered.

3~6 Fretting Corrosion

Fretting describes corrosion ôCcurı.drıg atcq:rıtact areas between ~tyrials ·under load subjected to vibration and slip. It appe@s a.s\pits or grooves I the metal surrounded by corrosion product. Fretting is also calledi:6:ictiôııρxidation, wear o:,ddatioıı,.chaflıιg, and false brinelling. It has been observ~~/{f eıığine components, automotive .parts, bolted parts, between clamp and steel cables of suspension bridges, and other machinery. Essentially, fretting is a special case of erosion corrosion that occurs in the atmosphere rather than under aqueous conditions.

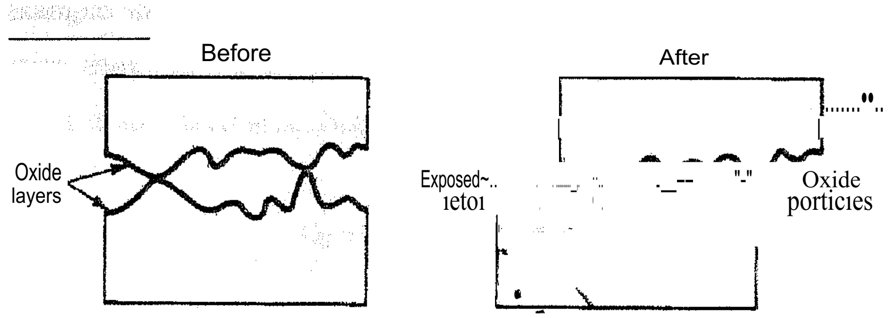


Fig. 7

Sche:ınatic iUustratiôn of the o:xidatfon...wear theory of fretfüig corrosion.

3~7 **Concentration** Cô:rrösion.

Concentration , cells are formed from the differences in electrolyte coınposition. Accor<iingto.Nerst equation, an electrode in dilute electrolyte is anpdic)'Yith respect to a similar electrode in a concentration electrolyte. Therefore corrosion rate is higher where co~cen.tration. of the electrolyte is lower. Corrosion is accelerated in apparently inaccessible places such as crack or crevices, under accumulated dirt or other surface contaminations as show in figure. Oxygen concentration cells develop,:vvhen.therçis .a difference in oxygen concentration on a moist surface of a metal,

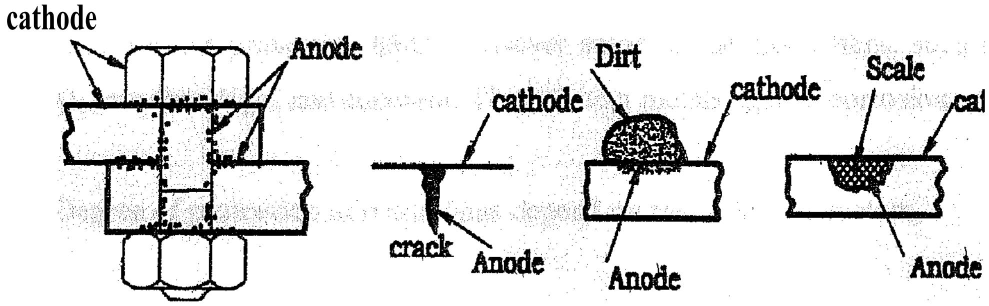


Fig.8

For example the surface of a steel bolf\introduced in a body has?lower)ôxygeb. concentratiôn.1hah external-surface exposed.to atmosphere as show in-:figure.i\Cathöde reaction in theınöist external surfaee.,

02 + 2H20 + 4e· 7 40H-

Since this cathodic reaction which requires presence of oxygen removes electrons from the metal, more electrons must he by adjacent area that do not have as much oxygen. The areas with less oxygen serve as anodes, therefore they are corroded. Figure shows some typical oxygen concentration cells.

The accumulated rust or scale restrict the access of oxygen and establish an anode; and accelerate corrosion in a localized. area. Localized. corrosive attack produces holes or pits in a metal. This form of corrosion can be very destructive for engineering structure and may cause serious damage. This form of corrosion is called pitting corrosion.

3.8 **Oxidation** Of Metals

Metal and allays exposed to air. react with air to form oxide. films. Oxid.ation of metals at high temperatures is particularly important for engineering. design of gas turbines, rocket engines and high temperature equipments in chemical industry. Some metal oxide films become poro-us, some metal .them expand, crack and fall of such as Fe_2O_3. they are not protective films, However some of the oxide films, .such as Cr_2O_3 and Al_2O_3, are firm, tight and coherent. They protect metals against corrosion.

Degree of protection of oxide films depend on the following factors,

1. The volume ratio of oxide to metal consumed by oxidation must be close to 1.
2. The oxide .film must have good adherence to metal.
3. The oxide film and metal must have nearly equal thermal expansion coefficient.
4. The oxide film must have high compactness and low diffusion coefficient.
5. The oxide film must be sufficiently resilient to prevent cracking.

The volume ratio of iron oxide (Fe_2O_3) to iron after oxidation is around 2.15. Therefore due to volume increase of oxide films compressive stresses are introduced, thus oxide film. tends to. crack and spall off. On the other hand, the volume ratios. for Cr_2O_3 and Al_2O_3 are close to 1.

CH.APTER IV

IV. CORROSION PREVENTION

4.0 Introduction

The most common method of preventing corrosion is the selection of the proper metal/alloy for a particular corrosive service.;.;th.eeasiest method is to paint.the surface

Five alterations tö env.itönrtıent can be m.a..de to alleviate corrosion. The effects produced by each change are dependant orrtbe system. Lowering temperature-asually causes a siğrrificatitdecrease in cör:rosio11,·•·butsörı:ı.etimes temperature has no effect on corrosid:rı, ôr even'incH·eases it. Terı:ı.per~ttıre.'affects·· oxygen .solubility.s. decreases as temperature incteases\-'less Oxygen makes boiling •seawater less corrosive

Decreasing velocity generally decreases coqosion, but metals that passivate generally have better resistance to flowing mediums.

Removing oxygen or oxidizers is accomplished by vacuum, inert. gas sparging, or use of oxygen scavengers. One should 'jJe CatefuLnot to remove oxygel,l(-vtj.tl};..11letalş that. requite the. oxidizers to: form their pr<)f¢.¢tive oxide films - these mş,t~riajş\f1!'e poor lıı reducing nön-oxidizing environments

Changing concentration .by. krWefing the i concentration .of corrosive agent generally reduces corrosion. Some sulfuric & phosphoric acids become inert at high concentrations but jf too low, active-passive alloys will not develop their protective layer.

4.1 Materials Selection

The most common method of preventing corrosion is the selection of the proper metal or alloy for a particular corrosive service. Since this is the most important method of preventing or reducing corrosion darna.ge.One•Ofthe most popular misconceptions to those not familiar with metallurgy or corrosion engineering concerns the uses and characteristics of stainless steel. Stainless 'steef! is not stainless it is not the most corrosion-resistant material and it is not a specific alloy.

In many instances cheaper materials or more resistant materials are available. For nitric acid service the stainless; steels arc usually considered first as these have excellent resistance to this medium tinder a wide range of ~xposure conditions Tin or tin coatings are almost always chosen as a container cıfpipiııg :rı:ıaterial For very pure distilled water For many years tantalum has been co~idered and used 'as' ah ultiınat~ corrosion-resistant material. Tantalum is resistant to. most acids at all cönceiitrations and temperatures , and is generali)' used undef' conditions where rninimal corrosion· is required such as implants in the htı:rrıan. bödy. .Atı interesting featü:te abôtıt 'tantalum is that it almost exactly parallels the corrosion resistance of glass. Both glass·and tantalum are resista:ııttö vi.rtuallY an mediums extept hytlf<:> fluoride acid and caustic solutions. For these reason manufacturers of glass-lined equipment use tantalun:ı.iplugşto seal defects sincethis material matches the resistarı£eq($lass,

4.2 Alteration Of Environment

Altering the · environment provides a/versatile means for redu¢in.gtcorrosiqn. Typical changes ip. the medium that are öften¢mployed are (1) loweri:ı.ig/cten:ıperatUI'e, (2) decreasing velocity, (3) removingxc.C.>xygen or oxidizers, ancl (4) ich.aıιgiιig concentratien-In maaycases, .these chan.ğ¢s<can significantlyreduce corre>sion}bμ.t they must be done with care.. The·effects pI'Oducedby these changes vary dependin.ğon the particular system.

4~2.i Lowering temperature

Lowering the temperature usually causes a pronounced decrease in corrosion rate. However, under some conditions, temperature changes have little effect on corrosion rate. In other cases, increasiiig temperature decreases attack. This phenomenon occurs as hot, fresh or .salt. water'sttraised to the boiling point and is the result of the decrease in oxygen soh:ı.bilitY with temperature. Boiling seawater is therefore less corrosive than hotseawater(e;gi;15°F).

4.2.2 Decreasing velocity

This is often used as a practical meth~d or corrosion control As .4jscµsş~d in Sec. 2-7, velocity generally increases. corresive attack, although.. there are, some important exceptions, Metals and alloys thatipassjvity such as stainless steels, generally have better resistance to.. flowing.mediums. thAA,stagnantsolutions..j(ery' high velocities should he always avoided where possible, because of erosion corrosion effects.

4.2.3 Removing Oxygen or Oxidizers

This is a very old corrosion control technique. Boiler feed water was-deaerated by passing it through a large mass of scrap steel. In moderıi practice this is accomplished by vacuum treatment, inert gas sparging, or through the use of oxygen scavengers. Hydrochloric acid that has conta6ted steel during its manufacture or storage contains ferric chloride as an oxidizer impurity, This impure acid, terı:n,e9, *muriatic acid* in commerce, rapidly corrodes nickrd-molybdenum alloys, whereas these materials possess excellent resistance in pure hydrochloric acid. Although deaeration finds widespread application, it is not recommended for active-passive metals or alloys. These materials require oxidizers to form and maintain their protective films and usually possess poor resistance to reducing ör non-oxidizing environments.

4.2A Changing concentration

Decreasing corrosive cdıicentta:tion is usiifilly effective. In ın~hY processes the presence of a corrôsive is accidental. For example, corrosion by the water coolant. In nuclear reactors is reduced by eliminating chloride ions- Many acids such as sulfuric and phosphoric ~c virtually inert at high Côıicerifratiönsat moderate ten:ıperafüres. In these cases, corrosion can be reduced *by increasing* acid concentration

No discussion of corrosion controlwould be complete without mentioning the *magic devices* or *water-conditioning gadgets* that have been and continue to be widely sold for purposes of controlling water corrosion-These gadgets are usually promoted on thq basis that they will "stop corrosion", "prevent scaling", "destroy bacteria", "improve taste an.d odor" or "reduce water hardness". Some manufacturers make .all ofthe above claims for their product! In. every case; the device is based on sonic pseudoscientific principle, is simply constructed, quite .expensive. and totally worthless Several of them consist merely of a pipe coupling that looks identical to those available in any hardware store. Surpassingly . large numbers of these gadgets are installed each year by trained engineers.

J\4}ıgiq. devices should not be confu.seı:l:.+~ith\thewater-softeajn.g .-water-treating and cathodic protection apparatus and systems .sold by reputable manııfacturers. The worthless device is easily spotted by a number Of clues: (1) It is based on a questionable or a "secret" new principle. (2) The a.dye;rrt,jşjng contains an exceşsiy;¢.·tı@ıper(. of testimonials (usually from untrained persons)--.Gl) The promotion makeşlrio ıne11tiqn of any imitations the device will work in any .kind Of water and protect any size system (4) The device is always sold with a complete guarantee.

4.3 Design Rules

There are many design rules which should be follow-ed for best corrosion resistance, Some of the design rules thaL.sh9uld be followed are listed below. It would be helpful if the designer had a good background in corrosion but unfortunately this is usually not the case

- Weld rather than rivet tanks and other containers. Riveted joints provide sites for crevice corrosion.

- Design tanks and other containers for easy draining and easy cleaning Tank bottoms should be sloped toward drain holes so that liquid- cannot collect after the tank . is ..emptied ;Concentrated sulfuric acid is only negligibly corrosive toward steel However if a steel sulfuric acid tank is incompletely drained and the remaining liquid is exposed to the air the acid tends .to .absorb moisture resulting in dilution and rapid attackoceurs.

- Design systems for the easy replace:rnentofcomponents hat are expected to fail rapidly in service. Frequently, pumps in chemical plants are designed so that they can be readily removed fi;om a piping system.

- Avoid excessive mechsnicalustresseseaııdratress concentraıicnssirıcomponerıts exposed to corrosive mediums. Mechanical or residual stresses are one of the requirements for stress corrosion' era.eking. This rule should be allowed especia.nywheri.tu.sinğ·:rnaterials·susceptible:streşs-cörrosion cracking;

- Avoid electrical contact between d.issinülaı-('111etals.to prevent gallvariic corrosion If possible use similar materials tl:ı:fôuğh.dut the entire structure <or insulate different materials from one another.

- Avoid sharp bends in piping systems when high velocities and/or solids ın suspension are involved (erosion corrosion).

- Provide thicker structures to take Care,ofiimpingement effects.

- Make sl,J!e materials are properly selected.

- List complete specifications for all :ınaterials of constrırctiorı > and provide instrtictions to be sure the specs are >followed all the way through to final inspection- Specify quality control procedures if relevant

- Be sure all relevant codes and standards are met.

- Set realistic and scheduled dates for delivery 1 equipr

- Specify .procedures for testing ::aııfü.st§t~ğeypfparts and equipment. For example after hydraulic testing do not letth¢\¢quiprnent sit full or paı:tially :full !of water for any extended period of time. This\could result in microbial corrosion pitting, and Stress corrosion. With regard to storage spare stainless steel tubing showed stress-corrosion cracking when stored near the seacoast.

- Specify operating and maintenance procedures (i.e., scheduled shut downs).

- Properly design against excessive vibratlönsıot. only for rotating.parts but also for heat also for heat exchanger tubes.

- Provide :f6:rF"blarik:eting'~ -with dry air• ôr\inert> gas if vessels "mhaletı. moist marine atıtı.osphere while being emptied,

- Select planf site upwind from othert~ip6llu.ting" plants or ,ıtmospheıte::if relevaııt aııd/or feasible.

- Avoid hot· spots during heat-t:raıısfef opı:ıratiôns, Heat exchangers arı,diôther!:heat. traı:ısfer. devices ..should be decided tô ensure uniform. tempefatuteigradients. Uneven teıtı.petatu:re distribü.tiqtı leadstb local heating and high ·corrosion rates. Further hot spots tend to produce stresses that flay produce stress corrosion cracking failures

- Design to exclude air. Oxygen reduction is one of the most common cathodic reactions during corfösiôn an.cl if oxygen is eliminate ill cor.fösiön •cal often be reduced or prevented. In designing chemical plant equipmentparticülar attention should be paid to agitators liquid inlets arid other points where 'air entrainment is a possibility. Exceptions to this <rule are active-passive metals and alloys. Tifa.ı::ıiuıii arid stainless steels are lnôre<:resistant to acids containing dissolved air or other Oxidizers.

- The most general rule for design is *avoided heterogenic.* Dissimilar metals vapor spaces, uneven heat and stress distributions and other differences between points in the system lead to corrosion da.mage. Hence· in desiğ:tı.fatteınpt to wake all conditions as uniform as possible thrôuğhöut the entire system.

A number of procedures or practices can be used for combating or :rı:ıitii:tnizig galvanic corrosion. Sometimes oneris sufficient, but a combination of eme ôtmöre ıfilty be required. These practices are as follows:

Select combinations of metals as close together as possible in the galvanic serıes.

Avoid the unfavorable area effect of a small anode and large cathode Small parts such as faste:o.ers.sometimes work well for holding less resistant materials.

Irtsulatedissimilarıneta.ls wherev¢r·Cpra:cticableIt is impôrtanfi:tt;>}ii:isülate *completely* ifpossible. A common error in this regard concerns bolted joints suchas two flanges like *a* pipe to *a* valve, where the pipe might *be* steel or lead and the valve a different material. Bakelite washers- tind~t<?tlıe bolt heads and _nuts are'}'assumed to insulate.the two parts vet the %hatık öf theihôW'tôuches both flanges! This pföbleın is solved by platting plastictubes over theıbolt+shank:s··'Plusthewishers sqiifheib81ts are isolated co.p:ıpletely from the flanges Figure 3-5 shows proper insufation.for a bolted joint Tape and paint to increase resistance of the circuit are alternatives.

Apply coatings with caution. Keep the coatings in good repair, particularly the one onthe anodic member.

Add inhibitors if possible to decrease the aggressiveness of the environment.

Avoid threaded jbµıts for materials far apart in the series.<Much of the effective wall thickness of the metal is cut away during the threading operation. In addition spilled liquid or condensed moisture can collect and remain in the thread grooves. Brazedjoiııts are preferred,.using<ıtbtazingallöy noblerthan af least one of the metals to be joined. Welded joints using V\:elds of the same allow are even better.

Design for the use of readily replaceable anodic parts or wake them thicker for longer life. Install a third metal that is anodic to both metals in the galvanic contact.

Erettir)g corrosion can be ~~g);9J.-,practically efuni.1:1.at~d.: in many cases by applying one or more of the following pteyetıtiye measures:

1. Lubricate with low-viscosity, high-tenacity oils and greases. Lubrication reduces friction between bearing surfaces and tçµds to exclude oxygen. Also, phosphate coatings ("Parkerizing") are often used in conjunction with lubricants since these coatings are porous and provide oilı-~ş~tyoirs.

2. Increase the hardness of one or both of the contacting materials. This can be accomplished by choosing a combination of hard materials or hard alloys Table 3-11 lists the relative fretting corrosion resistance of various material combinations. As shown, hard materials are more resistant than soft materials. Also, increasing surface hardness by shot-peening or cold-working increases fretting resistance.

3. Increase friction between.mating.pa.rtş.1:>yt911ghening the surface.. pftç11, bearing surfaces that will be subjected to vibration during shipment are coated with lead to prevent fretting corrosion. Whe11/füe. bearing is placed in .serviç~,. the lead coating is rapidly worn away

4. Use gaskets to absorb vibration and to exclude oxygen at bearing surfaces.

5. Increase load to. reduce slip between mating surfaces,

6. Decrease the load at bearing surfaces. It is important to note that decreasing the load is not always successful, since very small loads are capable of producing damage.

7. If possible increase the relative motion between parts to reduce attack.

4.4 Prevention against other **types of Corrosion**

General prevention ôfcörrösioıi mv.ôlvesthe following concerns: (1) decreasing the aggressiveness of the envirônment,<(2)In.creasmgthe:resistance of the material, (3) eliminating points of stagnation in the solution, and (4) reducing the amount of scratching done to the passivated layer.

Reducing the amount of oxidizers such as chlorides can decrease solution aggressiveness; regulating the temperature, and the acidity of the environment can also slow pitting corrosion. By cleaning the ınatetial ınıd. removing deposits, the chance of pitting .due to imperfections in the passivat~q.layer i~ greatly reduced.

Çorrosioh resistant materials often have a higher alloy content. In ferrous materials, the addition of nickel, chromiünf and molybdenum are generaily beneficial. At temperatures below 70 degrees Celsius, the addition of titanium can reduce the chances of;ıfüiı,g,, Also,: qırbon and ~~,,)l/!~Y detrimental to ~ resistance -of the material. Corrosion inhibitors can be added, but insufficient quantities will cause fewer but deeper pits, thus promoting the corrosion. Lastly, cathodic protection can be used, but due to its expensive nature, it should be considered as a secondary protection.

Stagnant points in a medium can" sometimes be eliminafed With proper hydrodyn~C design, })Ut·. measures .as •·.Simple RSi.İnCreasing the flow jtate:wi.llJı¢lp 1'aise the overallisolutionvelocity.

Scratching cap. be «reduced byr fairlyi obvious methods, .such .as ,removal of sediment from a flowing fluid,

CHAPTER V

V. PREPARATION OF PR.ÔDU@TSFOR CORROSION PROTECTI<l>N>PROCCES

5.0 Introduction

Surfaces of the products to be subjects for corrosion protection of metals have to be freeöf contaınirıatiôns such as sOij, Oil/grease, tııst scale, cutting flmd etc...

All these will. prevent the intimate" côhtact· tequited for corrosion protection tecniques and will interfer with bounding of coating materials and will give poor adherchee.Therefore, before applying any prpcess, surface of the prodııcts should be less and free contaminations. Many different methods are used to clean sudacecf metals.

Some common process such as alkaline cleaning, solvent cleaning; vapor ing and acid cleaning will be introduced in this chapter.

5.1. Metal Cleaning

5.1.1 Alkaline Cleaning

A.Jl(a.Une cleaffih_g is employed for the öily, .semisolidOt solid §dils.l,fröfu .metals before·they·····~~.·•••~lectr~~lated, conversion.eöa~~~t)T~r···Otherwise finished•or· prOcessed." To a great extent, the solutioııs.used for alka.lihe cleaning depend on their properties for cleaning action and effectiveness. Agit~tiöıi of the solution and movement of the work pieces through it, although important, are secondary in their effect.

The principal methods employed in alkalitı.e cleaning are soak, spray, and electrolytic. Other methods are variations uncorporating the essential features of these three.

Unless. the soil is easily remova.ble,<soak cleaning is slower. and less efficient than spray and electrolytic metlıoçis. Q-~tıerally, itis employed only for moderate or small volumes of work.

Spray Cleaning combines the advantages of the detersive properties if the solutions with the impinging action of sprays which loosen the soil mechanically and therefore, provide greater efficiency than the soak method for removing tenacious soils. However, because of foaming problems, spray cleaners have lower detersive properties than Soak cleaners.

Because spray cleaning requires a greater investment for equipment than the soak method, a greater volume of work is needed to justify the higher cost. Moreover, design of the part must be such as to allow the spray to reach all surfaces.

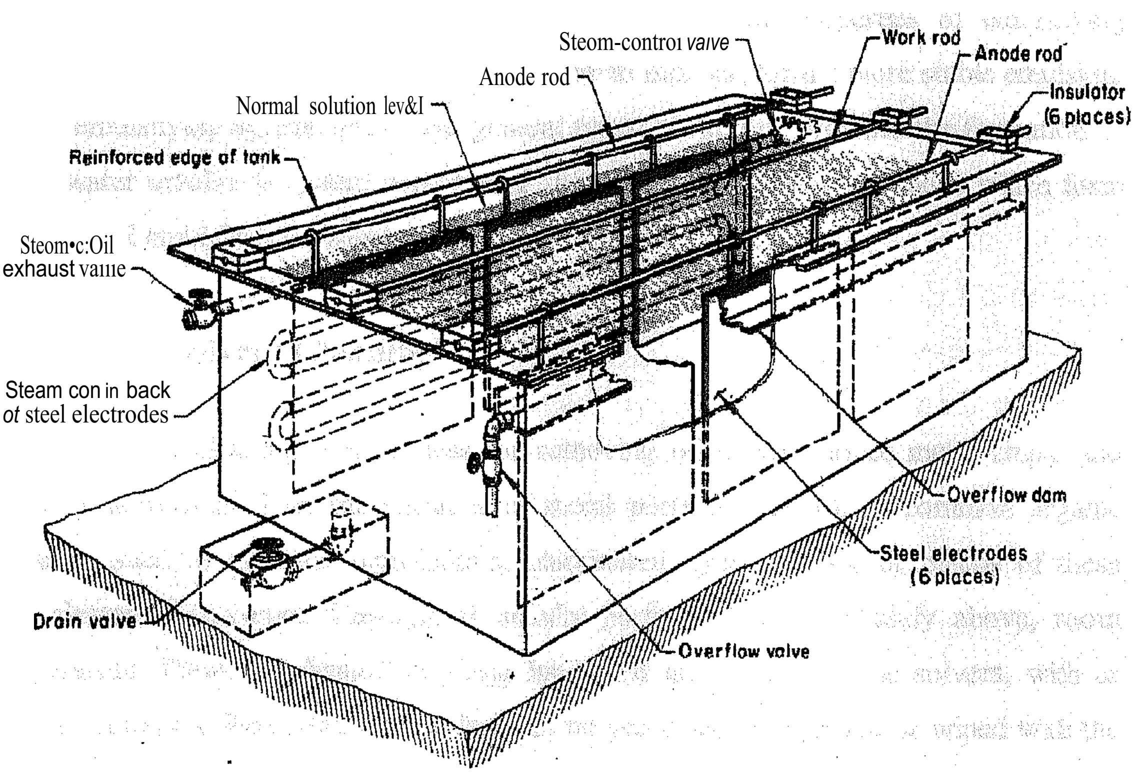


Fig. 9
Typical electrolytic alkaline cleaning tank. Porcelain insulators are attached to the bottom edges of the electrodes, to prevent contact with the sides of the tank.

5.1.2 Emulsion Cleaning

Emulsion cleaning is a process for removing soils from the surfaces of metal by the use of common organic solvents dispersed in aqueous medium with the aid of an emulsifying agent. Depending on the solvent used, cleaning is done at temperatures from room.temperature to 140-180 F.

An emulsion system must contain two liquids, mutually insolublecor nearly so, one of which usually is dispersed in the other in the form of globules:Ingeneral, one of these liquids is a hydrocarbon and the other is water, the dispersed phase isthat which is distributed as gloubes in the other liquid, known as the continuous phase, because oil and water do not mix, an oil-in-water dispersiorı that does not contain an emulsifying agent (or dispersant) requires constant mechaiı:ical agitation to prevent immediate separation of.oil and water into two layers.

The stability of emulsion cleaners depends on the propyrties of emulsifying agents thatare•ca;pable\ofcausing oil andwatertô•:ırıix and form a morcr.Staıble emulsion. These emulsifyirıĝ .agents· ate· of two· general types:\those .that.promote tfü{forınation of oil-in wa.ter efüulsiôlJ.S)(vvater constituting the continuous phase) ·andxthose which form water in...0μ efüül&ions (nıwhichwateris the dispersed phase).

5.1~3 Solvent Cleaning

Solvent cleaning is a process for rerμ.ôving oil, grease, loose metal chips, and other contaminants from the surfaces of nıetal parts by the use of comn:ıoıı organic solvents, such as. aliphatic petroleum's, -.'phlôtiı:ıa.ted>hydro.carbons, or .. blenq.R. OfJhese two clas.se-s C>f. .sgiy~ntş<·Cle~g is .ustı@y p¢tforıned at, or slightly. ab@Ye, .itc>0ıiı temperature'.*i* Parts are cleaned by .being irnn:ı.eı-seq. and soaked in the .. soiv~nt, M7itb. .pr withdut agitation. Parts that are tooJarge JP be lıııııersed are sprayed or wiped with the solvent.

Ultrasonic vibration is sometimes used in conjunction with solvent cleaning to loosen and remove soils, such as. abrasive compoμnds, from deep r~ç~sses: or other difficult-to-reach areas; this reduces the.time reqııired for solvent cleatıirıg.of complex shapes.

Although some .of the solvents. used in. solvent cleaning are the same as those used .in .vapor degreasing,. solyent.çlea.ning differs from vapor degreasing in that the latter process is performed are elevated temperatures. In vapor degreasing, part may be degreased by exposure to. the solventvapof@!·w~ııas by immersion in the hot solvent; drying ıis accomplished by evaporating the> solvent from the parts while they are suspended in .the .hot solvent vapor...In .Solye:ııt cleatıing, parts are dried at roonı temperature or by the use of external heat, centrifuging, or an absorptive medium.

5.1.4 Vapor Degreasing

Vapor degreasing is a generic I term applied to a cleaning process that employs the hot vapors of a chlorinated. Solvent to remove soils - particularly, oils, greases and waxes.

A vapor degreasing unit consists of an open steel tank with a heated sol- a vent reservoir, or sump, at the bottom and a cooling zone near the top. Sufficient heat in introduced into the sump to boil the solvent and generate hot solvent vapor. Because the hot vapor is heavier than airs it displaces ' th~ air and fills the tank up to the ' cooling zone. The hot vapor is condensed when cooling zone, thus maintaining a fixed vapor I level and creating a thermal balance. The temperature differential between the hot vapor and the cool work piece a causes the vapor to condense on the work piece and dissolve the soil.

To supplement vapor cleaning, Sölhe decreasing units are :eqiııppeci *1th facilities f<>r ifutıiefsing the work hı watı-rFc:ıf bc:ıiling solvent and for spraying Work piece surfaces with clean solvent. The efficiency of the liquid phase of the cleaning cycle can be augmented by the appUcati&höf filtras&rıic energy.

5.1.5 Acid Cleaning

Acid cleaning is a process In whiclha solution of a mineral acid, organic acid or acid sat at in coınbinationwitha \V:~~f.Jff~~t·~fdetergent, is employ~d to remove oxide, shop soil grease, and other contanµnants from metal surface as with or without the application of heat. The distinctiôn b~tWJJ:rı acid cleaning and acid pickling is a matter of degree, and there is often some overlapping in the usage of these terms. In general however acid inkling refers to a more severe treatment for the removal of scale from semi finished mill products, for mugs or casting", where as acid cleaning is the term most frequently used whap the acid solution is employed for man or neuronal preparation ·of metal surfaces ρ 'nor to plating, paintmg or stored. Acid pickling is discrissedmdeta.il in the rıext article in tills volume

5.2 Removal of Contaminants

5.2.1. Removal ofUnpigmented Oij and Grease

The common shop oils and greases;' such as unpigmented drawing lubricants, rust-preventive oils, and quenching and focrica.t~f.oils, can be effecti'7elr.removed by several different cleaners. Selection of cleaning.process depends on production flow as well as on required degree of cleanness, available equipment and cost. For example, steel parts µl"a clean and dry condition will rust within a few hours in a humid atmosphere. ·Thus,· parts that are thoroughly clean and dry must go to the next operation immediately,/b@ placed in hold tanks, or....bEı.tfeated with rust pr@v~ııtiy@s. If r;ust preventives are used, the .parts will prob~kly.r~1µire another cleanin~.:pr~2tto.~lı~r processing. Accordingly, a cleaner that leav:esJ3,.teınporaryıı::ıt-prev~ı:ıtiye film. ıniglıt be preferred.

Vapor decreasing is an.effeotive.and.Wid.~1y.usedmethod for?ı-~1'.1.1qvfug.ftwide variety of oils.and. greases. It develops a l.li.gh degree of cleanness which is reproducible because the decreasing fluid is distilled and filtered.

Vapor degreasing has proved especially effective for removing söltıble·soil from carves, such as rolled or welded seams that may permanently .entrftp <>,tlı~;t'. çl~arıers. Vapor degreasing is particularly well adajjtEıd..to cleaning oil-impregnated-pats much as bearings and for removing solvent-soluble soils from the interior of storagç:tııpks.

Solvent cleaning may be used.t9.r¢1J1oye.the common oils atıd greases from metal parts. Methods vary from static immersion to the use of a multistage washer. Seven methods of solvent cleaning, listed in Order of their ascending effectiveness, are as follows:

1. Static immersion.
2. Immersion with agitation of parts.
3. Immersion with agitation of both the solvent and the parts.
4. Immersion with scrubbing.
5. Pressure· spraying in a spray booth.

   Immersion scrubbing, followed 'by spraying.
7. Multistage washer.

A number of solvents and their properties are tabulated in the articles on vapor degreasing and solvent cleaning in this volume. Solvent cleaning is nföstwidely used as a preliminary or conditioning cleaner decrease the time required in, and contamination of the final, cleaner.

5.2.2 Removal of Compounds

Pöli§hin.ğ a:tid bu-ffing cö:rrıpcrunds a.t&/'dplic111t·• to remove ·bed:ı.u.§e<tfi&<soil,Jthey deposit is composed of "bµriied oh" gr~a§e,>:ıneti:ill.ic soaps, waxes; a:tid_iôtlıe:f'vefücles that ate contaminated with fine particles of :metal and abrasive. Consequently, cleaning requirements should be considered when selecting polishing and buffing compounds.

In terms of cleaning requirements, compounds used for ohta~ buffed and polished :finj_shes may be classified as follows:·

1. Liquids - mineral oils and oil-in-water emulsions, or animal and vegetable oils with abrasives
2. Semisolids - oil -base, containing abrasives and emulsions; or water-base, containing abrasives and dispersin.gJtğefüs
3. Solids- greases containing stearic acid, hydrogenated fatty acid, tallow, hydrogenated glycerides, petrplellll. waxes, and combinations that produce either saponifiable or unsaponifiable materials, in addition to abrasives.

5.3 Surface Preparation for **Treatment**

5.3.1 Surface Preparation fo.ı- **Phosphate Coating**

Because the chemical reaction that results in the deposition of a phosphate coating depends entirely on good contact between the phosphating solution and the surface of the metal being treated, arts should always be sufficiently clean to permit the phosphating solution to wet the surface uniformly.

Soil that is not removed can act as. a :rrıechanical barrier to the phosphating solution, retarding the rate of coating, interfering with the bonding of the crystals to the metal, or, at worst, completely preventing .söluti<>ıı. contact. Some so~s. Ccııı .be fqated with tlıM plıqsplıa.t~ crystals .-will be poor, l;lJld tlns will intum affect the a.bility of a sübseq1 l enpaint fib:n to remain contlıuuousioruıı l'roken in service.

Soils sucl;ı as cutting oils, drawing compounds, coolants and rust inhibitors can react with the basis metal and form a film that substantially changes the nature bf the coating,

Precautions must be taken to avoid carryover of cleaning materials into phosphating tanks. This is particularly true for alkaline cleaner, which çati :q.eutralize the acid phosphating solutions, rendering them useless.

5.3.2 Surface Preparation for Painting

Surface preparation has a direct effect on the performance of paint films. The best paint available will fail prematurely if applied prepared surface. The surface also will influence the final appearance of the paint film. Surface irregularities may not paint film. Surface irregularities of the paint film.

The principal surface contaminants that are deleterious to the performance of paint films include oil, grease dirt, rust, mill scale, water, and salts such as chlorides and sulfides.

Mechanical and chemical cleaning operations may be used in combination to meet: ~ rigid :reqtuferiıent of surface clyanness. For example, on scaler-bearing steel intended for an application involving steel intended for an application involving eipösfile fô<cb.ei:):iical environments, complete removal of all oil, grease, rust, mill scale, and any other surface contaminants into tlıe surface of the steel.

5.3.3 Surfaee **Preparation for Electrm>Jatmg**

As has been mentioned previously in this article, the cleanness required for metals that are to be electroplated is of a higher order than for most other applications. In addition to pickling or other descalinı operations (when needed), adequate cleaning requires multistage cycleş, usually comprising all four of the following steps: (a) pre-oleaning with a solvent, to remove most of the soil; (b) intermediate cleaning with alkaline deaners; (~) electro-cleaning, to remove the last traces of solids and other contaminants tµat are especially adherent; and (d) acid tr¥atment and surface conditioning, to, remove llght oxide filrtıs formed during previous deaning processes and to micro-etch the surface..

CHAPTER VI

VI. ELECTROPLATING

6.0 Iıtrodudion

Electroplating is an electrochemiq~ pp:>.fesş. for depositing a. tlıip !~Yef .0f metal on, usually, a metallic base. Objects are eleçtrcıplated to prevent çcır:ı;oşipn,Jo<>'bf~in.a hard surface or attractive finish, to purify metals (as itı the electrorefinµlgofcopp~r), to separate metals for quantitative analysis, or, as in electrotyping, to reproduce a form from a mold. Cadmium, chromium, copper, gold, nickel, silver, and tin are the metals most often used in plating. Typica1 products. of electroplating rılff şily~fJplated tableware, chtomiµnı-plated aıtomobile acc.essories,. and tin-plated foqd contaiıerş:

In the process of electroplating, the ~Rj~ql to be coated is p}ac~dinı a)şC)lution, called a bath, of.a salt ofth<;! coating metaJ.,..a:tıq.Jsçonnected to theµegı:ı.Jiy¢termitıabf an external source of electricity. Another cönc;lu,ötor, often composed öfthe coating metal, is connected to the positive terıniıal öf the electric source. A steady direct current of low voltage, usually from 1 to 6 V, is required for the process. When the current is passed through the solution, atqms ofthe plating metalj1¢pğsif ı:>ll.t pf the solution onto the cathode, the negative eleett~g~,<J'lleseatoms arerepl~$~p'intl1~ b~th by atoms from the .anode (positive el~ctp().cle), ifjt .is composed of the same metal, as with copper and silver. Otherwise they are-replaced by periodic additions of the salt to the bath, as with ~old .and chromium. In either case an equilibrium betweeıi the füetal coming out öf solution and the metal entering is maintained until the object is plated. Nonconducting materials may be plated by first being covered with)ia cö:iiductmg material such as graphite.. Wax or plastic patterns for electrotype and)reôôrdinğ--disk matrices are coated ill this manner.

To ensure a strong and close bond between the object to be plated and the plating material, the object must be cleaned thoroughly by dipping it into an acid or caustic soluti~n, or by making it ~e',,~~~e ~ a cleaning bath for an instant. .To eliminate irregularity in the depth of the plate, and to ensure that the grain at the surface of the plate is öf good qualify and condu.civefo pôli,shing,the current density (amperes per square-foot of -cathode surface) and temperature must be ..carefully .. controlled; Colloids or special compounds are often added to the bath to improve the surface uniformity of the plate,

6.1 Cadmium Plating

Electrodeposits of cadmium are µsydiyxtensively to protect .şteel aµqpaşt if;ql1 against corrosion. Because cadmium is anqdic to iron; the underlyiıg.feq-ouş ııı~tal protected at the expense. of the cadmium plate, even though the cadmium becomes scratched or necked, exposing the substrate.

Cadmium is usually applied as a thin coating (less than I mil Pick) intended to withstand atmospheric corrosion. It is seldom used as an undercoating :fôfntlıet metals, and its resistance to corrosion by most chemicals is low. It is frequently used to coat parts and assemblies that are made up of dissimilar metals, because of its ability to minimize galvanic corrosion. Its excellent solderability is advantageous ın many electrical applications.

Most cadmium plating is done in cyanide baths, which generally ire made up by dissolving cadmium oxide in a sodium cyanide solution. Sodium cyanide provides conductivity and makes possible the corrôsiôn.ôf the cadmium anodes.

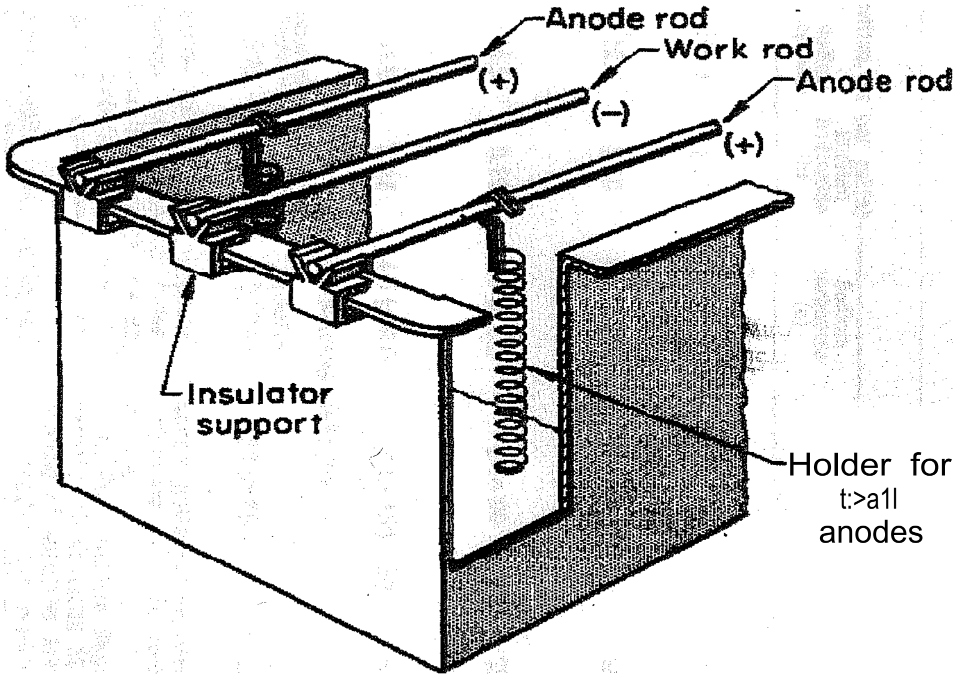
6.1.1 Cyanide Baths

Compositions and operating conditions of four cyanide baths are ğfven. Ill Table 1. Note that for each of these baths a ratio .of total sodium cyanide to cadmiuıllmetal is indicated; maintenance of the recommended ratio is important to the operating characteristics of the·bath.

6.1.2 Anodes

The anode system for cadmium plating from a cyanide solution consists of ball-shaped cadmium anodes in a spiral cage of bare steel, The spherical shape provides a large surface area in relation to weight, without a large in-vestment in cadmium. Ball anodes also make it possible to maintain JIII approximately constant anode area, and little or no anode scrap, is produced Cadinium bails are usually 2 in. in diameter and weigh 1%. lb per ball.

If a cadmium cyanide solution is to be left idle for an ext~µcfedfrp~riod of time (say, for a week: *ot* more), the steel anode cages should be removed. from the şolution, because the galvanic cell set up between the steel and the cachniuın anug.es will accelerate cherniöahdissolutionofthese anodes when the current is off.



Figurel0 typical still plating tank with spiral steel holders for cad:oiiuıı:fba.ll anödes

6.1.3 Bath Temperature

Typical operating temperature ranges for cyanid~and fluoborate baths are given in Table 1. In general, satisfactory plating results are obtained by controlling bath temperature with.iri ±5 °F during plating, when greater precision is required, temperature should be controlled within ±2 °F.

Table 2. Typical compositions and operating conditions of cadmium plating solutions

[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	For use in still tanks. Good efficiency, fair throwing power. Also used in bright barrel plating.
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	For use in still tanks and automatic plating. High throwing power, uniform deposits, fair efficiency. Not for use in barrel plating.
[illegible]						4.0 to 8.0	[illegible]	[illegible]	[illegible]	Primarily for use in still tanks, but can be used in automatic plating and barrel plating. High efficiency and good throwing power.
4	4.5 to 1	[illegible]			[illegible]	4.0 to 6.0	[illegible]	[illegible]	[illegible]	Used for plating cast iron. High speed and high efficiency.(e)
						Fluoborate Solution				
		Cadmium fluoborate	Cadmium metal	Ammonium fluoborate		Licorice				
5	..	32.20	12.60	8.00		0.134	30 to 60		70 to 100	Widest use is for barrel plating.(f)

(a) Metal-organic agents are added to cyanide solutions to produce fine-grained deposits. The addition of excessive quantities of these agents should be avoided, because this will cause deposits to be of inferior quality and to have poor resistance to corrosion. The addition of these agents to solutions used for plating cast iron is not recommended.

(b) Sodium hydroxide produced by the cadmium oxide used. In barrel plating, 1 oz per gal is added for conductivity. (c) Sodium carbonate produced by decomposition of sodium cyanide and absorption of carbon dioxide, and by poor anode efficiency. Excess sodium carbonate causes anode polarization, rough coatings, and lower efficiency. Excess sodium carbonate may be reduced by freezing, or by treatment with calcium sulfate.

(d) For uniform deposits from cyanide solutions, the use of a current density of at least 20 amp per sq ft is recommended. Agitation and cooling of solution are required at high current densities. (e) Agitation and cooling are required when current density is high (above 20 amp per sq ft). (f) When used for still plating at high current density, air or mechanical agitation is desirable. Excellent for cast iron parts without deep recesses. Adaptable to plating of strip and wire.

6.1.4 **Equipment**

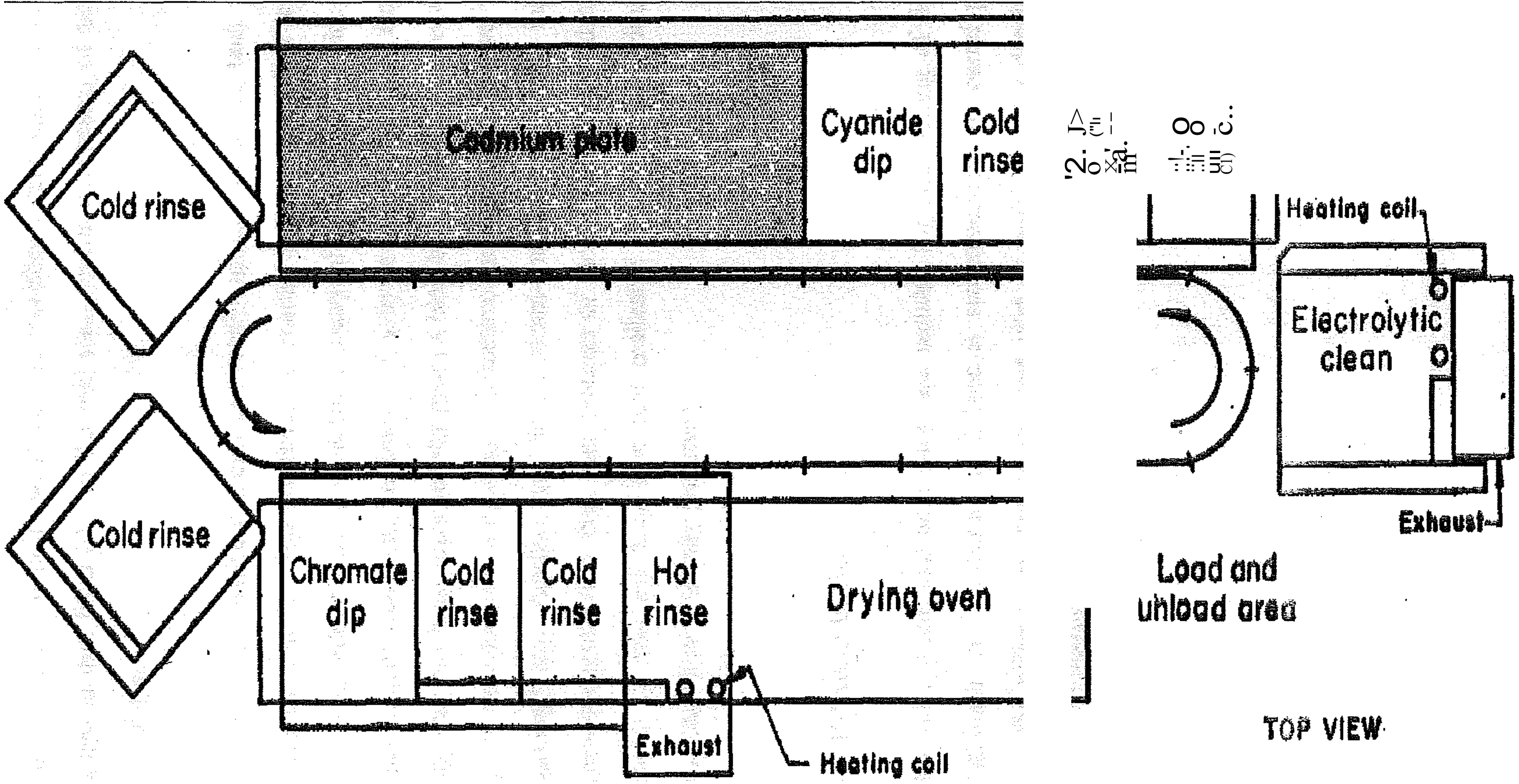
Considerations specific to the operation of cadmium cyanide baths in conventional plating equipment are discussed here; with attention, to the materials of construction employed.

Usually, unlined Steel tanks are used for Cadmiumplating; however, steel tanks with rubber linings are useful in preventing stray tank currents. Rubber and plastics used for tank linings should be tested for compatibility with the plating bath, to prevent contamination from constituents of the lining.

Filters and cooling coils also may be made of steel. Equipment for fume control is seldom used unless required by local ordinances; Typical tank arrangement is shown in Fig. 1.

Barrels may be made of hard rubber, polypropylene, acrylic resins, or phenol-formaldehyde or melamine-formable-hyde laminates; or of expanded or perforated sheet steel coated with vinyl plastisol, The plastisol coating is about 1/8 in. thick and is resistant to the standard barrelplating solutions and temperatures. Usually, doors and wall ends are of the same material.

Fig 11. Typical layout of installation for automatic [illegible]



6.2 Zinc Plating

Zinc is anodic to iron and steel, arid therefore offers more complete protection when applied in thin films (0.3 to 0.5 ı@)tlınn similar tlıickıi¢ss¢şğfp.iğlçelJınd other cathôdic coatings.

Because it is relatively cheap and readily applied in barrel, tank or continuous plating facilities, zinc is often preferred for coating ferrous park when protection from atmospheric and indoor corrosion is the prinıary objective. Normal electroplated zinc without subsequent treatment becomes duU gray in appearance after exposure to air. Bright zinc that has been subsequently given a bleached chromate conversion coating or a coatin_g of clear lacquer (or both) is sometimes used as a decorative finish. Such a finish,. although less durable than heavy .nickel-chromium, in many instances offers better corrosion protection than thin coatings of nickel-chromium, and at much lower cost. Plating of zinc on gray iron and malleable iron presents serious operational difficulties; cadmium is usually preferred.

6.2.1 Plating Baths

[illegible]

[illegible]

Several cyanide and acid baths are suitable for zinc ..-4-··=ı::
Darts.. Although the fluoborate acid bath., is recommended for uınıcı vı,~Lıı.ıg
superior to the other baths for plating cast iron, at higher f'.11rırPrıT .·.·..,,,~.,,.·.·.~..,.,
used also for automatic plating or for mill products.

[illegible]

[illegible]

[illegible]

Table 3. Cynide zinc plating baths **in which zinc cynide** is the sourece of zinc metal

Coııtltuent or condition		'lating method	
		Still tank or automatic	**Condult tubing and strip**
Composition Ranı,ı..O.z per Gal(ıı.)			
ZQıc °'yan19~(~)	.eU~ H	8 t.o 11	**8 to 12**
(Zinc metal equivalent)	(4.4 .to 6)	(4.4 *tb* 6)	**(4.4 to 6.8)**
Sodiuın cyanide	.5.2. tô8.8'	4.3'to 8.8	**2.1 to 6.5**
(Total sodium cyanide) (c)	(11.9tô18)	(11.0 to 18)	**(8.8 to 16.5)**
Sodiwn hydroxide	l~rlt.lı..	10 toJ2	.10to12
S0d1um polysultlde(d)	0.2	0.2	0.2
oııeıitını•conatttônı			
Ratio of total sodium eyanid~ to zinc.	2:7'"to••ıtô:3+f.ô'1	>2,5•t.ı,.•l t.o 3-to.-ı	2·to-1 *to* 2.&·to,,l;
Cıırrerıt. density,. amp per sq ft '.	3 tc> IQ	15 *tD* 60	40UJ100.
VoltaJe:	**12 til,,15**	**6**	6
Te?Qpe~tuı:e, F	68 t.o ~5	68 to 95	90to120

6.2.2 Process Control Variables

The operating characteristics of cyalnide zinc plating baths depen.d ön current density, on anode material and purity, and Qiı.füeyariables that affect cathodeefficiency [illegible], bath temperature, cyanid~-to-meta,,lJ~tio, and content of zinc metal and sodium **hydroxide. The s**odium carbonate and sodiüiiı ferrocyanide normally present cyanide **baths cause little or no trouble.** If nece. ssary, [illegible] te may b. e reduc. ed t [illegible] te l.y **6 oz per gal by chilling the bath** to 25 F, oritınay be precipitated by chemicaltreatment **with calcium or barium hydroxide**. Procedures for chemical analysis of cy~de zinc plating baths to determine zinc metal; total södiıım cyanide, sodium hydroxide, and sodium carbonate aredetailed in the Appendix'tôtlıis article.

Cyanide. zinc solutions are less efficiefütithan cyanide cadmium isolutions and produce a greater degree of hydrogen eınbitt:e:rınent.

6.2.3 Anodes

Zinc anodes are available as 4, balls and elliptical bars. Ball anodes may be spherical, flat-topped or bell-shaped; flat-topped are the most popular, being less readily confused with· spherical cadmium anodes, Zinc ball anodes are held in a spiral steel cage.

Three grades of zinc are used for an-odes, namely, Prime Western, Intermediate, and specialHigh Grade,·with.zinccontents·of98.5%, 99.50% and99.99%,tespectively. Best plating results are obtained with the use of the special High Grade,· which has a typical compositionof99;993 Zn, O.fl031 :Pb,0,0017 Cd, 0,0010 Feran.dar-traceÔlı.

Because zinc anodes dissolve chemicallY as. well as electtôchernicaJly'iiılhe bath, the effective anode efficiency is frequently higher than 100%. Cathode efficiencies are substantially lower than 100%, so that the zinc metal content of the bath will increase if dragout is not sufficient to ö:ffset>tfüs trend. To avoid buildup in metal content,. anodes should ·base· moved from the bath if operations are suspended for more than three or four days. The· zinc metal content in the bath caribe controlled by adjusting the ratio of zinc anode area to insoluble anode area. Proprietary anodes containing small aıtiounts of aluminum or magnesium are available tô decrease the solution rate of zinc and thus assist in coııtrôUing the metal content.

Because of the faster rate of chefili.calsôhitiôn of zinc and the lôwef cathode efficiency of the cyanide zinc bath, insoluble (steel) anodes are more widely used in cyanide zinc plating than in cyanide cadmium plating. Prolonged use of insoluble anodes;' however; increaşes the sodium carbonate content, which ultimately• nıust be reduced in order to maintain the composition balance of the bath.

6.2.4 B.ath Temperature.

For any given bath formulation, low operating temperatures decrease electrical efficiency and increase brightness of. deposit and throwing power, and high temperatures increase electrical efficiency and decrease throwing power and brightness. For most applications, bath temperature should be.below 95 .F. Higher temperatures result in excessive decomposition of sodium cyanide and organic brightening agent. Unless higher current densities and higher free-cyanide values are employed, the ·Use of temperatures above 95 F adversely affects throwing power of the bath and produces a frosty white, rather than a bright, deposit.

6.3 Cadmium and Zinc Compared

Except for differences in plating baths and in such operational details as current density and rates of deposition, cadmium and zinc plating are essentially similar processes. Reference should be made to the article on cadmium plating for a detailed discussion of:

1 selection of method (still tank, barrel, automatic)
2 Plating equipment for the three methods
3 Equipment maintenance
Pre-plating surface treatments
Processing steps
6 Rinsing and drying after plating
7 Post-plating treatments.

Exceptions with respect to equipment and processing are described below.

6.4 Chromium Plating

Chromium plating is a protective decorative coating "system" in which outermost layer is chromium layer usually is applied over combinations of plated coatings of copper and nickel. The function of this system is twofold: (a) to provide the basis metal with protection against corrosive environments; and (b) to maintain in service, an appearance conforming to an agreed-on standard.

Because it is difficult to obtain dense and pore-free electrodeposits of chromium, and because the plated deposits lack sufficient ductility to remain free of discontinuities during service, parts that are to be chromium plated must first be given a pore-free, continuous undercoat of a more ductile metal with good corrosion resistance. Nickel meets this need better than any other metal or alloy that is feasible to plate. However, when surfaces plated with chromiumovef\nickel are covered with an electrolyte (salt water, for example), the nickel slowly corrodes under discontinuities in the chromium. To protect tlıe' more anodic substrate ·metal from corrosion, thicknesses· for nickel ginif~lly i-a:tlğe from at least 0.3 mil (:r0f indoor service) to as much as 2(rriils (for outdoorseı-"Vi.te) Chromium thicknesses sf&ôrC)r 0.02 mil a:r~·11orliiairdPa~cÔfative finishes; minimum thicknesses of 0.03 to abô'ttt Ü.08 are apprôpriit~> <r0l-'' di.ı:tibi~ decorative coatings.

6.4.1 **Chromium Bath Compositi.():n.**

Sometimes referred to as the !19tğ~gry'.' pıth, the oldest type of chromium plating bath used for decorative plating consists of an aqueous solution of chromic anhydride (Cr03) that also contains a small airıôiliıt of soluble sulfate (SO_4), added as sulfuric acid or as a soluble sulfate salt such as>sodium sulfate. When dissolved in water, the chromic anhydride forms chro:trıiC icid, which is believed to exist in the following equilibrium:

$$H_2Cr_2O_7 + H_2O \rightarrow \leftarrow 2H_2CrO_4$$

'JJp.¢ t~ti<:> p:f'çJ:ıı-on:ri.c. acid to sulfate:}gıeµefallygiven as the weight ratio of CrO_3 to S04, gôve:fiis it]J.e .ctıtren.tie:fficiencyfori cJ:ıı-9:n:ıiµ:nı "metal .deposition{ at the cathode. The cathode current efficiency is affe~{ed > a.lso / by solution variables such as concentration of chromic acid, temperatµ:rıe;\1uıd .content of metallic impurities. The content of metallic impurities is an impgrtw:ıticonsideration from the standpoint of commercial operation, because excessively high content of metals such-as copper, iron, zinc and nickel will seriously affect bath. co1l;ductivity, cathode c;utr~ı-ıt efficiency, throwing power and covering power, even though the ratio of Cr03 to S04 as determined by solution analysis may be within optimum limits for the application.

6.4.2 Temperature of Chromium Baths

All chromium plating solutions require precise balance among temperature, currenfdei1sity, and solution composition. The exact temperature atWliirihbright, milky, frosty. or bµ.mt deposits occ.ur depends on. s.o.lutipn composition an.i:)d::.:···>.\urr. e.•.1lt.:•..density chromium plating is normally done at 100 to140°F; 115 to 125 °F:~t~eiı11~stc~Illl11on operating range At room temperature, the brightplating range is impracticablynarrow.

In a process set up to plate at 120 F, with all variables properly controlled, the temperature need vary only Sor 4 °F, up or down, to move the electrodeposits out ofthe clear, bright nıngt. .ponsequently, an. accur!!ejfli;perature controller and facilities for rapid cooling and heating of the bath are essential. Variation outside the ±3 °F range may cause an unacceptably high rejection rate or may necessitate costly stripping and replating operations.

6.5 **Nickel Plating**

Nickel plate, with or without an underlying copper strike, is 911<{ of the oldest protective-decorative electrodeposited metaj.1.ip (coatings for steel, 1:>r~~§arıd other basis metals. The first applications of nickelpla.t¢ w~re fô:f stove and bicycle côfupönents.

Unless polished occasionally, nickel plate will tarnish, takirig - a yellow color during long exposure to mildly corrosive atmospheres, or turning green on severe exposure. The introduction of cprömium plate in the late 1920's overcame the tarnishing problem, and led to a great increase in the use of nickel, as a component of protective-decorative coatings, in V?fious combinations.with copper and chromium..

The principal present uses for nickel plate without a subsequent chromium deposit are discussed here.

Electrodeposits of nickel possess a wide variety of properties, depending on plating-bath composition and operating conditions. They may be classified according to application or appearance as general-purpose, special purpose, black. and bright.

6.5.1 All-Chloride Bath.

The principal advantage of the all-chloride bath is its ability to operate effectively high cathode current densities. Other advantages Include high connectivity~ better throwing power, and less tendency to form nodular growths on edges, to pit, or to form nonadherent deposits if the current is interrupted. Deposits from this solution are harder and stronger than those from Watts's solutions. Compared to the Watts solution, the all-chloride bath has two major disadvantages: (a) the lower ductility and higher stress of its deposits! and (b) the rapid rise in solution pH- Lead cannot be used in contact with the all-chloride solution, and fumes from this solution are corrosive to the superstructure, vents and other plant equipment if not well protected .

Table 4. Composition and operation of three decorative nickel plating baths.

Constituent or condition	Type of bath Watts	Modified Watts	High-chloride
Basic Composition, oz per Gal			
Nickel sulfate	30-50	40-50	8-10
Nickel chloride	6-10	15-20	30-40
Boric acid	5-7	5-7	5-7
Operating Conditions			
Temperature, F ...	120-160	140-160	140-160
Current density, amp per sq ft:			
Anode	5-24	10-30	10-30
Cathode(a)	20-50	20-100	20-100
Agitation	(b)	(b)	(b)
pH (electrometric).	3.0-4.5	3.5-4.5	3.5-4.5

6.5.2 Anodes

TA chill cast anode containing 99% Ni came into acceptance with the widespread use of the Watts bath; subsequently, a rolled, depolarized anode was de"elope~ that contained small amounts ot~ckel .oxide but. reta~e~ a ~~~\~i content. Rollecl cl.epgJ~~edanodes are commonly used in high-pl.I baths, although they may be used throtıghöııtthe entire pH range of nickel plating solutions. avoid the formation of nodular deposits, these anodes usually are covered with cottoıı ör syn.tlıetıc~fiber anode bags while in use.

Cast or rolled "carbon" anodes (99% Ni anodes containing about 0.2% C) inay be used in baths with a pH of 4.5 or less. Although they are capable of forming an adherent carbon-silica mm that retains loose anode·particles, they are normally covered with atıôde bags during use, to prevent the forinatiôn of nodular deposits.

Virtually Ml nickel anodes made today are öf high purity and côntai:rla minimum of 99% Ni, the remainder consisting of variôüs elements added tö prevent anode passivity and to assure uniform solution into· the plating bath.

The selection of suitable material for insoluble anodes in nickeLplating depends primarily on the composition and operating<characteristics of the plating.bath. Lead, In wire, rod, or sheet form, Is a suitable anode ına.terial provided the solution does not contain chlorides. Under conditions requiring an alternative material, bothw:rought and electrolytic rıickeFhave perforrned satisfactorily. When chlorides are present in the bath, the most suitable anode materials are carbon or platinum; platinum may befüsölid form or may be clad over titanium or some other material. Because the use .of insoluble anodes depletes the nickel content of the bath, adequate provision must be made for replenishment of nickel.

Bath temperature variation in the operating temperature of a nickel plating bath can have a marked effect on the properties or electrodeposited nickel. To obtain consistent results, the temperature of a nickel plating bath should be maintained within i5 "F of the recommended temperature for a given application. In general, most industrial nickel electroplating baths are operated in the range of 100 to 140 F.

Electroplating bathsl such as the·stibllinate and fluoborate hıths that contain highly soluble nickel salts may be operated at temperatures as low as 100 F without adverse effects/ The higher nickel concentration obtainable with these salts makes it pössibleto produce S.ound~ ductile, fo"7-S~~SS<~~posits at lower oper,atin~ teı~ıp~r~tures than those required in plating baths corn-posed of nickel chloride. and nickel sulfate. Baths composed of the less soluble nickel salts must ordinarily be operated at higher temperature, usually from 120 to 140 t in ôfd.er.to yield sound deposits at rapid plating rates.

CHAPTER VII

VIL METALLIC COATING PRÖCESS

7.0 Introduction

Relatively thin coatings of metallic and inorganic materials can provide a satisfactory barrier between metal and its environment. The chief function of such coatings iş (aside :froın sacrificial coatings such as zinc) to provide effective barrier. Metal coatings are applied by electrodeposition, flame spraying, cadding, hot dipping, and vapor deposition. Inorganics are applied or formed by sp),"ayİiig, diffusion, chemical conversion. Spraying is usually f~llowed by baking or :firing at elevated te~~t:1,r>,fotal ~atings usually 0¥liibit ~~. formability, ~~.~ttr~anics are brittle. In b~th cases a complete barrier must be provided. Porosity or other defects can resulty in accelerated localized attack· on· the basic metal because of two-metal effects.

7.1 Aluminum Coating of Steel

Aluminum coated. steel products may be classified with respect to their intended service'as follows:

1. Products. for 'Yhich the prin.w'Ycpııp~11.1. isJftilization of the l:>e11.~:fipi<'lXJ:?ı-9p~ı-ties of aluminum namely, good corrosion resistance, bright metallic appearance, receptiveness to finishes, high re:tlet:.ti}ity, and good electrical co11dtfotivity
2. Products for whichJhe behavior of.the aluminum-iron I11t~rfa.pig]. c2ınpound is relied upon for resistance to oxidation, scale formation, and abrasion, and for high hardness.
3. Products for which the primary concern is to use the material as steel with a protective coating to obtain the mechanical properties, forrııa.bility··8Ad reliability of steel for .low-ccst nonrusting products to which :finishes peculiar to aluminum surfaces tan be applied.

Methods of applying aluminum coatings include hot dipping (batch or continuous), pack diffusion, th~ slurry prôcess, metal spraying, cladding, vacuum or chemical. vapor deposition, c4ld electroplating.; Choice of method is determined by composition of the basis metal, application of the coated pröduct, size .and shape of the product, production voltime, and cost.

Two important factors· iıı successfı.Ueda.ting by any nıethôcf are (a) ptbper 'ptepatatioı:ı of the steel surfa.ce;and -(b) côtifrôlof the formatiôri.'a:ı:ı.d ğfô-wt:Iıiôrllie intermetallic compound ·of alun.ı.ii;nıın and···ifonthat forms··at tlie>iıiterface>of füe aluminum coating and the steel substrate. Althoüğh there are many possible mefüods of preparing the surface, the method selected ınust remove the iron oxide/scale, either mechanically or chemically and also remove adsorbed moisture and gas :from the surface. Growth of the iron-ahıminıım ınterracial layer can be [illegible]rolled by silicon, berylliuiıi ôr c~oıni~ present e.ither.~ t~e\~t,,ı.or in the aluminum coating. Also, in some applications, a very thin phosphate mm will permit bonding and hinder growth of theııiteffatıaifayer.

7.1.1 Applications

Aluminum.coated steel products are•successfullyused in [illegible]:osive and oxidizing environments in which the temperature may range :fromthat of out door exposure to 2100

Atmospheric Exposure. Borne of the corrodents encountered in outdoor exposure are:

1. High-Sulfur-content industrial atniôsphetes
2. Nitrafe;.phosphate chemicals :froın fertilizers and manures in ru:raJ!atffiôsph.eres
3. Salt compounds used for ice-reniovaicın streets and roads
4. Organic acids in road Wastes

Alumirıum coated steel products exposed to severe industrial environments particularly products such as pole-line hardware, corrugated roofing and siding, and prefabricated steel buildings -have been found In excellent condition after ten years. Galvanized products in the same applications have "red rusted" in less than four years.

Examples of outdoor applications of aluminum çoated mild steel are given In Table 1; in general, these applications relate to designs requiring the l-p:ğh modulus and strength. of steel but· with the corrcsinncresistaııee of alumimını; Fôriparts made of fabricated sheet, the .design must allow·for/.the bare sheared edges:<.A.lsô;aluminum coated steel-fasteners should be used to maintain the appearance and structural integrity of an assembly, only heavy aluminum coatings (9 to 15 mils thick) are recommended fôr ııse ii:ı environments of continuous condensation or for immersion itı liquids: thinner coatings are subject to pitting attack, which perforates the coating and cerrodes the basis metal.

7.1.2 Procedures and Control.

Most commercial hot dipped aluminum c9ated steel strip is produced on continues, anneal-in-Line equipment s:irpilar to that used for galvanizing. The process consists essentially of three operations; surface preparation, heat treatment of the steel base, and aluminum coating.

Surface preparation is a two-phase opetatiô11: first all soil is remoVed.frôfü the surface by oxidizing at elevated teınperattı.re ör Hy chemical clea:umğ second, the surface oxides are reduced in a suitable atmôsphere•.to•prepare the strip:fôtcôatıng.

7.2 Hot Dip Tin Coating of Steel

Hot diptin>coatings are appliedto iron arıd steel for one or more of three main purposes: (a) fo p:rovide a nontoxic, :protective and decorative coating -for food-hand.ling, packaging, and çl,airy equipment: (b)to facilitate the soldering of a variety of compönenıs used in electronic and electridaj.)equipment; and (c) to assist in bonding another metal to the basis metal, as in the tinning of cast iron bearing .shells prior to lining with lead-base or tin-base alloy, The usual thickness range ofhofdip tin coatings is 0.3 to 1.5 mils.

7.2.1 Cleaning Before Hot Dip Tinning

Iron and steel parts must be free of oil, .grease, drawing lubricants, mil scale, and other sttrface\contaminants before fluxing and immersion in molten tin. Inadequate or improper surface preparation is a frequent cause of poor adhesion and other defects in hot dip tih<lSdatiiigs.

7.2.2 Fluxing

Fluxing·facilitates and speeds the: reaction of'molten tin with iron or stee4tthus promoting the formation ofa' continuous thin?laye:ç of tin-iron otöthetintermetfilli9 phase on which the.Iiquid tin coating can spread .inan even, smooth; corıtiıı.tıôusfilın. In hot. dip.tit:ı:ııing,>fluxes may be used in three different ways. (a) as aqueous solutions in which the work is dipped before it is immersed in the molten tin; (b) as a molten layer, or cover, on top of the niolten tin bath; and Cc)a.s.a solution or paste, or as an admixture to tin powder, that .is/applied to the surface .bfthe work prior to wipe tinning- The conıpôsitiôrıs offour aqueous flux solutions/arid of two molten flux·r>u'tü:>ɪx:ɹ are given In Tables I and 2;,respectively.

Table 5. Composition offln.xsolı:ttiôııs for use in hotdiptinning

Coıistıtuent	Solution A	Solution B	Solution C	Solution D
Zinc chlprl~	5	22~	24	40
Ammonium Chloride, lb	1	2~	3	2
Sodium. chloride, lb			6	
St.amıous. chloride, lb				2
!f4rochloric acid (Côml gra4eJ 28%), fi öz	4.8~	4.8	9,6	9.6
WR, gal	1.2max	12	12	12

7.2.3 Timımg Methods

Single-Pot 'finning

Single-pot tinning is frequently empfoye;:clto obtain a coating. preij.m:iı.ary Jo bonding or soldering, or to coat 'workpieces thı,ıt do not require tie higlıeştQμfl,ğtyof finish. The process involves a single iınmelısioıi of fluxed workpieces in a molten tin bath heated to 535 to 615 F. The average operating temperature of the bath is about 575 F. Upon withdrawal.from the bath the sur:ra8~\ofthe work may carry Spots of flux, which must be removed by suitable washing...

Two-Pot Tinning

Two-pot tinning COflSiStS Of dipping the W()fk first in a tin bath with a flux cover and second in a tin ba~ covered with oil<rR/ifOtt~n grease. Th~ process is used to develop high-quality heavy coatings and off~r~tij~.lollowing advan,tages over single-pot tinning:

1. Metal In the second tinning pot can be kept lower in Iron content than that in the first pot, .because no r~active tin:r:füjg. inyolving iron takes place during the second dip; thus, final coatings .areJo\\7 iıqontaminants.
2. The final dipping temperature can lı~ adjusted to suit the thickness or coating required and tile type of article process~d
3. Flux residues entrained on the work from the first dip are absorbed into the oil cover of the second dip.
4. The finished work retains a thin mm or oil that protects the coating during shipment and storage.

Three·Pot Tinning

In this process, after two-por.ainning .as previously described; the work is immediately transferred (while the coating is still molten) to a bath of hot tallow or palm oil. This promotes drainage of excess metal and encourages the formation of a uniform coating of economical thickness and :free from tears and drips. Three-pot tinfling is especially applicable when handling articles of complicated, recessed or reeiitranf shape, from which drainage of excess metal is difficult. It may also be employed for liğlit-g~ğework, on which the naturally rapid cooling would entail the production of too-heavy coatings in the two-pot ınethod.

Sal Ammoniac Tinning

This process is a. form of single-pgfl~Ş? in Which a high tinning temperature is used. It is particularly useful for light-gage steelarticles.

Grease Tinning

In the original method of grease tinniňgr}nolten tallow or palm oil is used in place of zinc chloride flux. This avoids any.risk• of the presence of corrosive flux residues on the :finished work and reduces the rate of accumulation of tin-iron cörripôuıιd in the tinning bath. Performed by. >skilled operators, the original process yields wôtk ôfve:ry high quality. However, it ha.s the disadvantage of being rather slow, because tallow or palıtı. oil alone is not a very fast-acting flux and the work must be immersed a relatively long time before it Is properly tinned. To [illegible] out-put, it is common practice to shorten the rough-tinning operation either by using a chloride flux in conjunction with the grease or by using molten grease dip after co1lventionally first tinning in a flux-covered pot.

7.2.4 Equipment

Hot dip tinning installation requires equipment for cleaning, pickling, fluxing, and tin dipping. An efficient ventilating system also is required, because fumes of some sari are produced at nearly every stage of the tinning process. Because the equipment requirements for cleaning and pickling operations, such as vapor degreasing, solvent cleaning, alkaline clearing, emulsion cleaning, abrasive blast cleaning, and acid pickling, are dealt with in separate articles-in this volume, the following paragraphs consider only the equipment required for fluxing and tinning.

7.3 Hot Dip Galvanizing

Hot dip coatings are applied to metals by immersing them in a molten metal bath of low-melting-point metals, chiefly zinc, tin, lead, and aluminum. Hot-dipping is one of the oldest methods for coating with metal, Galvanized steel is a popular example. Thickness of the coating is much greater than electroplates because very thin dip coatings are difficult to producte. Coated parts can be heat-treated to form an alloy bond between the coating and the substrate.

CHAPTifR VIII

VIIl NÖN--MtTALLit COATING PROCESS

8.0 Introduction

Non-met:ainccoating include phosphate coating, chromate conversion coating, painting of steel and cast iron, rust pteventive compounds, porcelain enamelin$, and ceramic coating.

8.1 Phosphate Coatlng

Phosphate c.oati:hg is the treatment of Iron or steel with a dilute solution of phosphoric acid and other chemicals whetepy the surface of the metal, reacting chemically with the phosphoric acid, is converted to an integral, mildly protective layer of insoluble crystalline phosphate.

The weight and crystalline structure *pf* tie gpating, and the extent of penetration of the coating into the basis metal, can be co11frôlled by the method of cleaning before treatment, the method of applying the solution, duration pf treatı:ııent, and by modification of the chemical composition of the phôsphating solution.

The .methôdiofiapplying phosphate coatings is usually detet1J.1111.ed\by the /size and shape of the article to be coated, small itelllŞ, such as nuts, bolts, sc:ı;e'\Vs .and sn:ıaJ.l stampings, are coated In tumbling barrels irrıı:tjersed in the phosphating solution, whereas large fabricated articles, such as refrigerator cabinets, which.are difficult to immerse, are usually spray coated with the solution while they are on. conveyors. Steel sheet and strip may be passed continuously through the phosphating solution or may be sprayed.

On the basis of pounds of chemicals consumed or tons of steel treated, the greatest use of phosphate coatings is as a base for paint Phosphate coatings are also used to provide. (a) a base for oil or other rust-preventive material; (b) lubricity and resistance to wear, galling or scoring of parts moving In contact, with or without oil (c) a surface that facilitates cold forming; (d) temporary. or short-time resistance to mild corrosion; and (e) as a base for adhesives In plastic-metal laminations.

8.1.1 Process Details

The application of. a phosphate coating normally comprises five successive operations: (a) cleaning, (b) rinsing,.(c) phosphating, (d) rinsing, and (e) chromic acid rinsing. Some of these operations may be omitted, or additional operations may be required, depending on the surface condition of parts to be phosphated or on the function of the phosphate coating. Parts exemplifying these exceptions are;

1. Heavily scaled parts, which may require pickling before cleaning
2. Parts with extremely heavy coatings of oil or drawing compounds, which may require rough cleaning before the normal cleaning operation
3. Parts that are tempered in air or a controlled atmosphere before being phosphated, may not require cleaning and rinsing before phosphating
4. Parts that are phosphated and later oiled for antifriction purposes; which may haw the chromic acid rinse omitted, because corrosion resistance is not required.

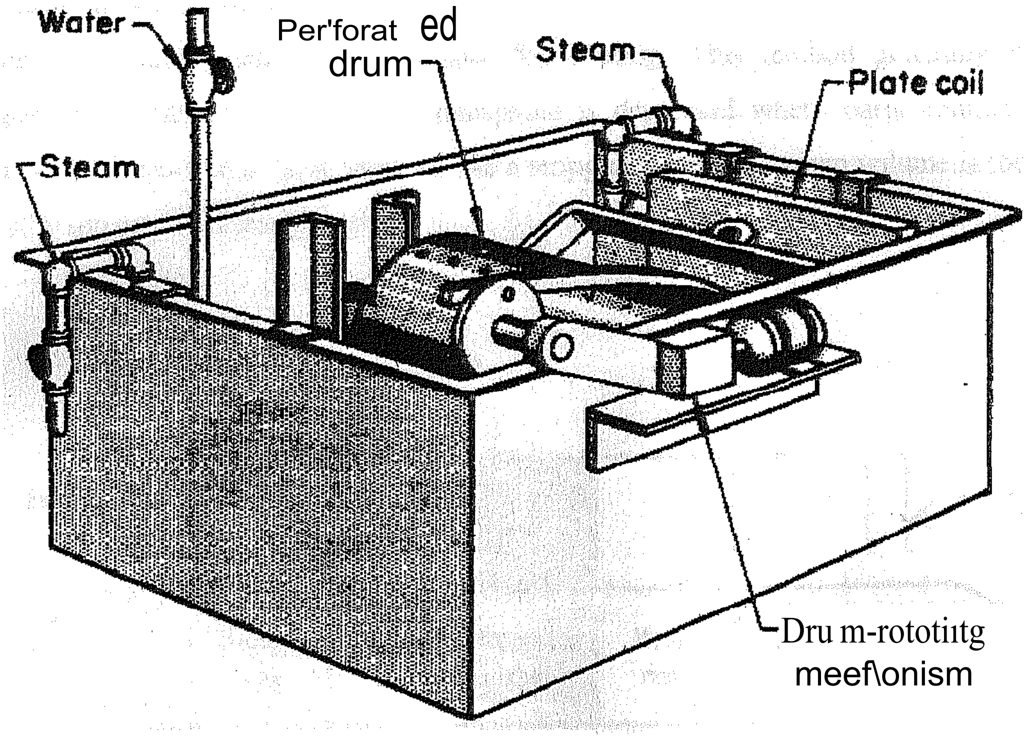


Fig.12
Typical immersion phosphating tank for foltch coating of which parts are loaded is shown. i~ immersion nosmon.

8.1.2 Phosphating Methods

Phosphate coatings may be applied a surface by either immersion or spray. Occasionally, a surface may be coated by brushing or wiping, but these methods are seldom used.

Immersion: All three types of phosphate .coatings zinc, iron and manganese can be deposited by immersion. Immersion is applicable to racked parts, barrel coating of small parts, and continuous coating of strip.

In general, smaller parts are more economically coated by immersion than by spraying; in fact, small parts (such as springs, clips! washers and screws that are produced in large volume can be coated efficiently only in ~ immersion system. Such parts are loaded into drums that are rotated at approximately 4 rpm after they are immersed in the· phosphating solıtion, (Small parts may. be plac.ed.in a basket and immersed, without rotation, in .the bath for coating. This method generally is not completely satisfactory, because· fiö phosphate is deposited where<.parts contact each other or the basket. It is.used, however, asa stopgap method orwhentvolumeisJooJow to justify the use ôftôfü.tıng.drums.)

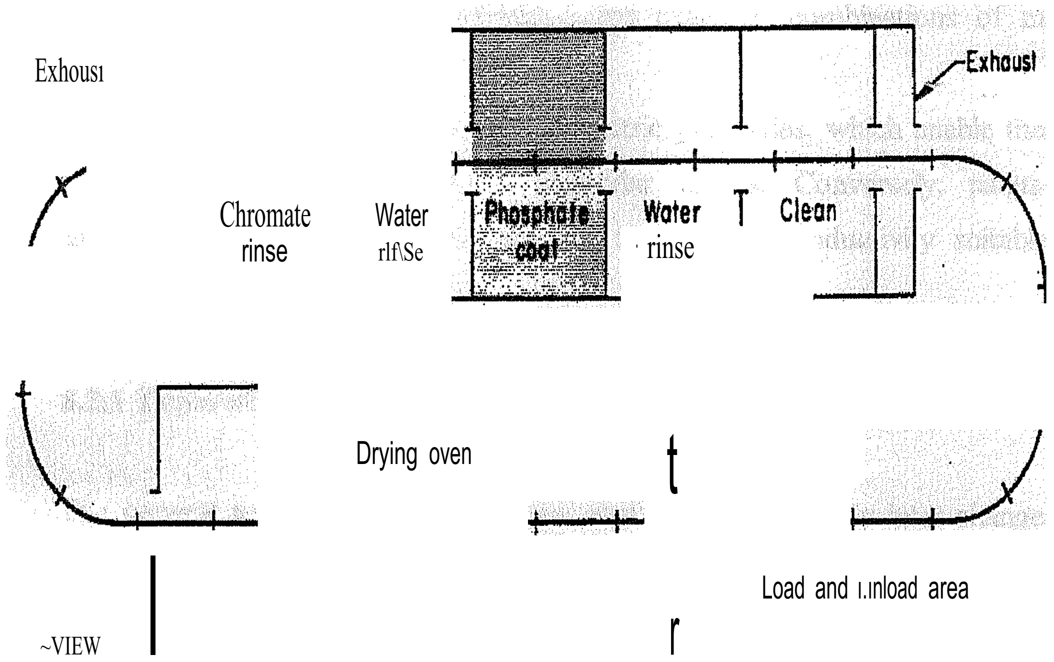


Fig. 13

Typical layout of a continuous conveyorized spray line for phosphating.

8.2 PaintlngğôfSteel and Iron

Painting is a generic term for the application of a thin organic coatingto the surface of a material for decorative and prot~ctive .purposes. Painting offers: the following advantages over other processes that are used for the protection or decôtation•of metal parts and assemblies.

1. The equipment required for applying paint is usually less expansive to buy and install, is simpler to operate, and requires less control.
2. Material and labor costs per square foot of surface coated o:fte;n are much lower,
3. Organic coatings art available in a wide range of pigments and vehicles. and can meet practically any requirement for .color, gloss, or degree of smoothness or roughness of coating surface.
4. Paints have•been developed that can withstand most corrosive conditions, and, unlike many metallic protective coatings, :organic films can simultaneouslyresist more than one corrosive condition - for example; combinations of rruμ:ine atmosphere and acid fumes.
5. Conventional paint films have good dielectric properties, which enable them to inhibit galvanic action between dissimilar metals. Conversely, paints are available that contain special pigments to provide conductivity suitable for grounding induced or static electricity.

8.2.1 Types of Paints

The general terms "paint" and orgru;tlc coating are essentially inter-changeable, and are used to designate certain coatings having an organic base.

Paint also is the term commonly applied to any of a specific class of materials consisting of pigme;nts dispersed in resins that are converted to relatively hard gels by oxidation, polymerization, or solvent evaporation;

Enamels are compositions of finely milled pigments (for coloring), inserts (most often for glOss control), and other additives, uniforınly disp~rsec;l in resins and solvehts. These compositions yield a relatively smooth, hard coating, which may range from highly glossy to matte (dead flat). Conversion from a liquid to a hard, tough film may be through oxidation or polymerization

8.2.2 Selection of Paint for Specific Requirements

The>selectfö1 bf the proper' pairiffor an application is irrfü:ı.encedprimarily·by appearance and fütıctional requirements; secondary considerations are surface condition, size of *parts* to be painted, and paint costs. Table 1 lists some of the resins commonly used in clear or pigmented organic coatings, and indicates their favorable characteristics and limitations as a guide to the selection of paint

Table 6. Organic coatings commonly selected for corrosion resistance in various environments

Types of coatings	Typical applications
Normal Outdoor Exposure	
Oil paints	Buildings, vehicles, bridges; maintenance
Alkyds	Trim paints, metal finishes, product finishes
Amino-resin-modified alkyds	Automotive, metal awnings, aluminum siding
Nitrocellulose lacquers	Automotive, product finishes
Acrylics	Automotive finishes
Marine Atmosphere	
Alkyds, chlorinated rubber, phenolics, vinyls, vinyl-alkyds	Superstructures and shore installations
[illegible]	Clear marine varnishes
Water Immersion	
Phenolics	Ship bottoms
Vinyls	Ship bottoms, docks
Chlorinated rubber	Ship bottoms, swimming pools
[illegible]	Clear marine varnishes
Chemical Fumes	
Epoxies, chlorinated rubber, vinyls, urethanes	Chemical-processing equipment
Extreme Sunlight	
Vinyls	Metal awnings
Acrylics	Automotive finishes
Silicone alkyds	Petroleum-industry processing equipment
High Humidity	
Amino-resin-modified alkyds	Refrigerators, washing machines
Epoxies	Air conditioners
Catalyzed epoxies, chlorinated rubber, phenolics	Maintenance; chemical and paper plants
High Temperature	
Alkyds	Motor blocks (200 F max)
Amino-resin-modified alkyds	Driers, stove parts (200 F max)
Epoxies	Motors, piping (260 F max)
Modified silicones	Stove parts, roasters (400 F max)
Silicones	Stove parts, roasters (550 F max); aluminum-pigmented paint (1200 F max)

8.2. Baking of Paint Films

If the organic base of paint occurs naturally as a hard, dry material (as does the base of pyroxylin lacquers, for example), the coating is dry when the solvent has completely evaporated. However, when the paint base is other than a hard material, a chemical action. must follow solvent evaporation, in order for the paint to dry completely. This chemical action may be either oxidation (for air-drying paints other than lacquerş) or<ipölymeriza.iion(föf baking erui:rn.els c6mınonJ_y used for product fin{ShingJ.

",.'",;ın·,,.. """·hnn-« are polymerized by a catalytic action within the paint the amine is the catalyst, is an example); these where a tough, hard film is required but heat cannot be tolerated. hr.ıDITPıtrPr polymerization is accomplished by the application of heat.

Heat is transferred by conduction, convection or radiation; Convection and radiation are employed in ovens for baking paint; conduction takes place (In shielded areas) only incidentally. Convection-type baking ovens usually are heated by gas; however, oil, electricity or steem also may be used. Radiation-type ovens may be heated by gas or electricity, although' electricity is more commonly used.

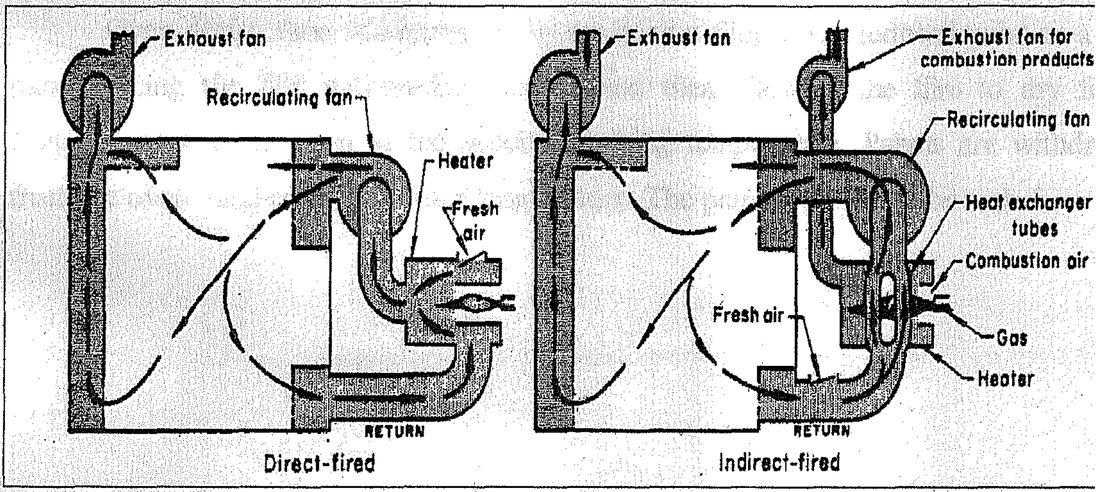


Fig.14

Direct~fi:ıred and indirect •.fired convection ovens, shown schematically to illustrate difference in principles employed for heating recirculated air in the baking of paint films.

s~2.s Quality• Control

After paint has been determined satisfactory by testing for ease of application, appearance; and _performance,and standards have been established, it is necessary to continue testing the paint, as often as required by the quality-control program established for the product, to determine its compliance with specifications, It is also essential that tests are conducted to determine the suitability of the dried or baked film.

Testing of paints in liquid form or of dry paint [illegible]
performed in accordance with methods described in ASTM [illegible]
number of properties of paints or paint films and indic~tes [illegible]
methods for determining them. [illegible]

Air drying time is determined [illegible]
a [illegible]

Oven drying time [illegible] of the reduced paint to a test
panel, letting the film [illegible] allowing the film to
specified time in an oven at the -specified baking temperature. [illegible]
from the oven -and cooled to room temperature. The paint should [illegible]

IX. CQNCLUSION

consı.aeı~aoıe ,,,,,'.. n,t1n1- of basic knowledge about the fundementals of corrosion against corrosion damage have been given in text of out that to prevent corrosion completely .in almost impossible. Howe the causes of corro.sion and methods to con

Electrochemical corrosion occurs continiously in ,..,.,''',..,,,,. presence every special solution, For example corrosion of valuable metal in the industry occurs in naturıµ.air ,..,u,1-,:nn,n (water vapor) without protection, Iron turns .into red powder

Procedure applied to protect metals against corrosion three groups. The first procedure is coating surface of metals coating by applying electroplating tecnique. Some of the metal """"+,,..,,... resp

may be cathodic against iron.
protecting. The scratched or torn coating the steel.

coating
dip common
or galvanizing.

Third type protectiçm procedures use non-m~tallic coating· materials such as paints and c.:,:;:rnmcs,

In the practice cadmium platingisextensively-used to projectsteeland cast iron products against corrosion. It is commonly used to the surfaces ofmachi:tied elements. Cadmium is relatively expensive, it has exeptienally high resistance ag~t corrosion but not ağaiıist chemicals. Chromium plating is hard and extremely high Corrosion resistance andhas decorative look.

Galvanizing in the oldest and most common and cheap method applied to steels to protect against envfronınental attacks. Galvanized sheets, profiles, plates and pipes are·used extensively for roofing, siding and water inshıttation,

Painting is less expensive, .decorative and -sin'ıple with steel most corrosıve condition unlike metallic evolting and acids...

References

ASM Handbook Committee, Metals Handbook, 8th edition, Vol.2, Ohio, 1981

A. Jones, D., Principles and Prevention of Corrosion Second Edition, Prentice Hall, NJ: 1996, pgs. 209-220.

Fontana Mars, Corrosion Engineering, McGraw Hill International Edition, New York, 1986

http://www.c3amulet.com/case%20studies/watercase6a.htm

http://www.corrosionsource.com/learningcenter/pitting.htm

http://www.corrosion-doctors.org

Jones, Denny. *Principles and Prevention of Corrosion*, Second Edition, pages 208-209. Prentice Hall, New Jersey. 1996.

L. Shrier, L., A. Jarman, R., T. Burstien, G., Corrosion Volume 1 Reactions third edition, T. Burstein, G., chapt. 1: L., chapt. 1: pgs. 179-183. Butterworth-Heinemann, Oxford: 1994.

W. Staehle, R. et.al.,