

INTRODUCTION

This manual is intended to briefly acquaint the reader with the principles of corrosion and the various methods available for corrosion control. It can prove useful as a handy reference guide. For your specific application(s), contact the product manufacturer(s) for specific detailed instructions regarding the particular product(s) suitability for the intended service.

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SECTION 1

PRINCIPLES OF CORROSION

(Updated: 02/2002)

The corrosion of valuable equipment and plant structures is going on all around us every day. Almost everywhere, ample evidence is available that a tremendous job of prevention and protection needs to be accomplished.

To effectively control corrosion, and make an intelligent selection and recommendation of protective coating systems, an individual needs to understand clearly the actual processes by which a clean, useful iron or steel structure can be eventually reduced to a collection of rusty scrap.

Fortunately, corrosion is a natural process and as such it is governed by and always follows natural laws. These laws are well known within the corrosion-engineering field, therefore it is possible to prevent or control corrosion by applying the appropriate counter measures.

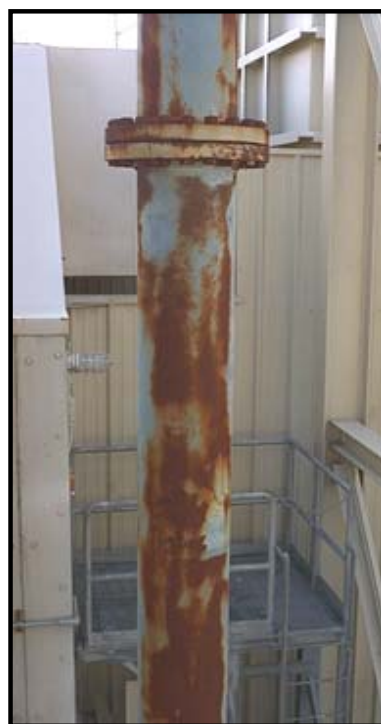
NOTE: This short section on corrosion theory is simplified for clarity purposes. It is not intended to train the reader with a mind to making him/her an expert in this area- but rather to give a sense of the depth and scope of the problem.

I. ECONOMIC IMPACT OF CORROSION

Corrosion is a major problem in the World today.

Corrosion results in lost revenues and diminished profits for businesses. Outside of the direct costs to replace and repair materials deteriorated by corrosion, companies lose money due to the “cost” of halting their manufacturing processes. Consider the following three situations where plant operations must stop due to corrosion.

- (1) Shutdowns caused when corrosion by-products from the interior of process vessels (tanks) contaminate the manufactured process
- (2) Unscheduled shutdowns to replace support steel and equipment in critical areas due to safety concerns



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- (3) Shutdowns caused by leaky tanks or pipes contaminating the ground

How much of the corrosion is preventable? The Battelle study, in the US, concluded that approximately 33% *"could be reduced by broader application of corrosion resistant materials and the application of best corrosion-related corrosion practices."*

The impact of corrosion extends well beyond just monetary terms. Corrosion can cause metal to swell to over 4 - 10 times its original size. This loss of metal weakens the structural integrity of supporting members potentially resulting in an unsafe working condition. Unfortunately, in some cases corrosion-related structural failures result in the loss of human life or serious permanent injuries.

The information in this manual is presented to you in the hope that by using it as a reference tool, you can help reduce or prevent corrosion and its costly effects.

II. DEFINITION OF CORROSION

"The deterioration of a material, usually a metal, that results from a reaction with its environment."



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This definition of corrosion consists of three distinct components:

1. An environment
2. A reaction
3. A material deterioration

The word "corrosion" actually comes from the Latin word "rodere" from which we derive the English word "rodent". "Rodere" means to gnaw away. Gerbils, rats and other rodents habitually chew or gnaw on objects to survive. In the same way, corrosion gnaws away or corrodes materials.

In the picture above, taken beneath a bridge on the island of Bermuda, it's obvious that corrosion gnawed away took a bite out of the steel. The moist, hot and salty environment in Bermuda promotes rapid corrosion unless structures are properly designed and adequately protected.

III. CORROSION OF IRON

The following reaction demonstrates that the rusting of iron oxide steel is a two-fold process involving:

- ◆ A chemical change of iron to iron to iron oxide, and
- ◆ An electrical process involving current flow.

This process is an electrochemical process, and, in fundamental principle, is identical to that occurring in such devices as vehicle storage batteries and flashlight dry cell batteries.

In fact, it is possible to construct a corrosion battery by supplying the following four necessary ingredients:

- ◆ An electrolyte
- ◆ An anode
- ◆ A cathode
- ◆ A metallic pathway



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THE CORROSION ELECTROLYTE

An electrolyte is a solution in water of salts or other chemical compounds, capable of conducting electrical current. The current carrying capacity of the electrolyte is due to the presence of tiny, electrically charged particles, called IONS, derived from the salt or other chemical dissolved in the water.

IONS

Ions are formed by the splitting (on mixing with water) of salts, acids, and caustic chemicals into electrically charged fragments of the original chemical. Both positive

and negative charges are created. These electrically charged chemical fragments are present in great number (56.7grams of table salt will split into 1023 ions, half (+) charge and half (-) charge) and are highly active and energetic. Their movement through the solution, under the influence of the corrosion chemical reaction, constitutes flow of electrical current through the electrolyte.

The presence of water is essential to the formation of the ions in the electrolyte. Ions cannot form under completely dry conditions. Therefore, water and ions are considered together as functional parts of the corrosion process.

The number of ions it contains largely determines the current-carrying efficiency of an electrolyte. Thus, a solution of table salt in water is an excellent conductor; whereas, pure water, containing very few ions, is a poor current conductor.

IV. THE CORROSION BATTERY

It's possible to demonstrate this process by using an electrolytic cell or corrosion battery to describe the type of rusting suffered by steel in normal atmospheric or marine environments (as distinguished from corrosion due to specific chemicals).

This corrosion battery exists whenever iron is exposed to a combination of oxygen, water and ions. This combination, the "big three" of corrosion, is not hard to find.

- A. Oxygen - All the oxygen needed is available in the atmosphere, and all exposed metal is constantly in contact with it.
- B. Water - The atmosphere, except for desert areas, is usually moisture laden. Either moisture vapour or dew droplets are in contact with the iron surface.
- C. Ions - Smog, salt spray, marine pollution, industrial soot and fumes, splash and spillage, soil contamination - all these sources can provide minerals, salts, acids or alkaline materials which dissolve in available moisture to produce ions.

In Figure 1 there is a diagram showing the "corrosion battery" which will produce rust when current flows. This drawing depicts a greatly magnified portion of the iron surface. Tiny adjacent areas (not visible to the eye) act as anode and cathode ions and just above the surface is moisture loaded with ions, to serve as an electrolyte. Gaseous oxygen is dissolved in the electrolyte, and is freely available to the surface of the metal.

Note that, in this case, the electrolyte provides the external circuit. The internal circuit provided by the metal part itself, since it is highly conductive from point to point.

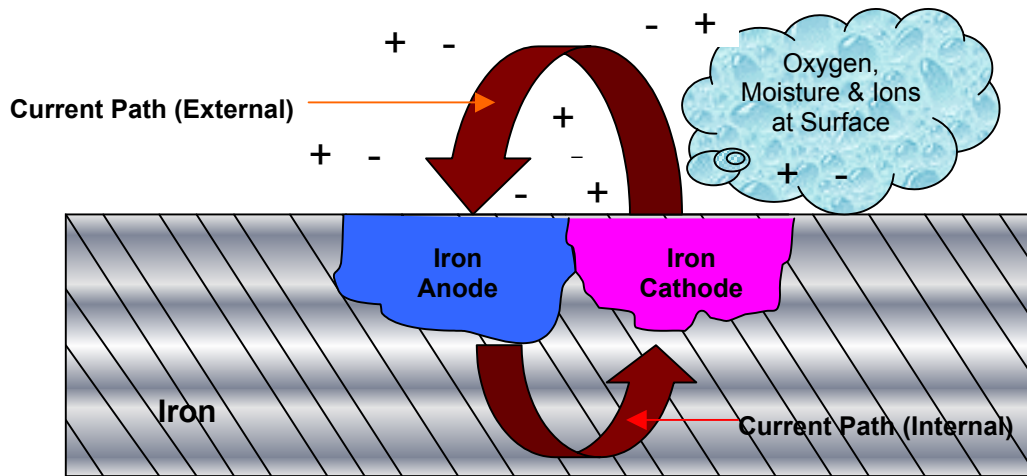
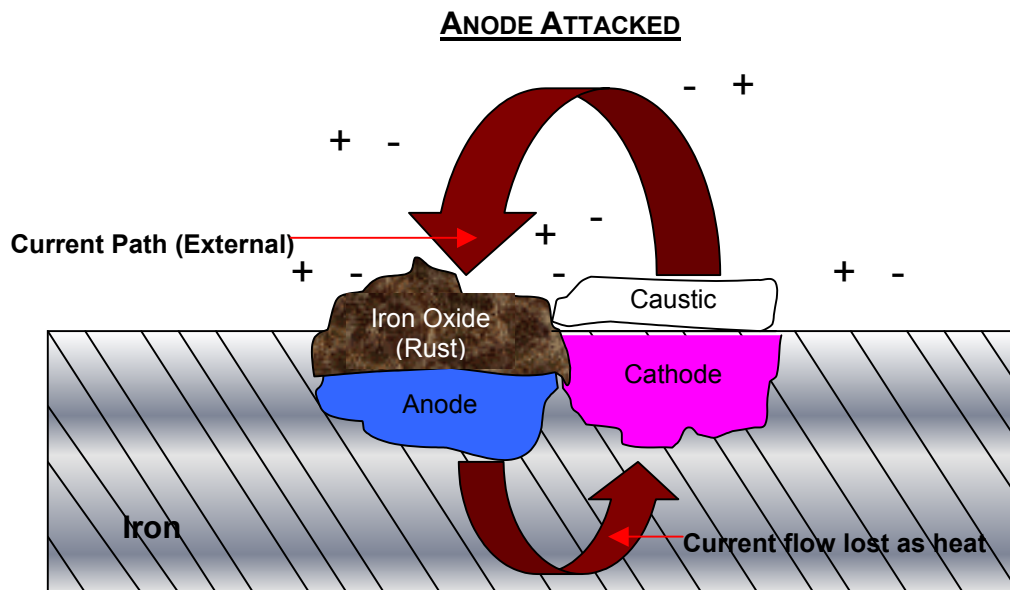


Figure 1: "The Corrosion Battery" (Ready to Discharge)

In Figure 2, (shown on the next page) the tiny battery is operating.

1. At the anode, an atom of metallic iron is converted to iron ion, and immediately reacts with water to form rust.
2. Current flow is set up between the anode and cathode.
3. The small currents generated here are dissipated as heat through the adjacent body of metal.
4. At the cathode, receipt of the current results in transformation of oxygen to caustic ion, resulting in a highly alkaline solution on the surface, as the caustic ion dissolves in the moisture on the surface.
5. At and above the surface, current is carried by the dissolved ions.
6. As the iron anode is eaten away, a growing deposit of rust forms.
7. This tiny battery is duplicated millions of times over a large iron surface, so that eventually the eye sees what appears to be a uniform layer of rust building up.
8. Note that the iron cathode is not attacked. However, it performed its function in providing a local at which oxygen could undergo its necessary change to caustic.



9. This process will continue until one of the following two conditions occurs: (a) all the iron is converted to rust or (b) something happens to weaken or break the circuit.

FORMATION OF CORROSION BATTERIES ON STEEL

At this point, let us consider a panel of mild steel, especially prepared to demonstrate the formation of corrosion batteries.

If we take a solution of gelatin and dissolve into it common table salt (sodium chloride) to provide ample oxygen and add two dye substances; one turns pink wherever caustic is formed at a cathode; the other turns blue wherever iron is attacked at an anode.

The steel panel is now embedded in the gelatin, and the solution chilled until gelled. We have trapped all elements of the corrosion battery, and we can observe specific reactions related to specific areas of the panel.

What do we observe?

- A. Pink cathode areas are randomly distributed on the face of the panel.
- B. Blue anode areas, where the steel is actually corroding, are formed on spots on the face of the panel, but are heavily concentrated along the edges and at the drilled holes of the panel.

NOTE: THE PANEL IS CORRODING ONLY IN THE BLUE AREAS.

Furthermore, we observe a very important characteristic of steel surfaces:

EDGES, AND OTHER AREAS SUBJECTED TO MECHANICAL WORK (SHEARED, DRILLED, SAWED, ETC.) ARE PRONE TO BE ANODES AND CORRODE PREFERENTIALLY.

STRONG ACID CORROSION BATTERY

The action of strongly acidic materials on iron or steel form a great corrosion battery in many industrial environments. (See Figure 3.)

Briefly, a vigorous reaction occurs to dissolve the metal into solution at the anode, and transforms hydrogen ion (H^+) into hydrogen gas bubbles (H_2) at the cathode.

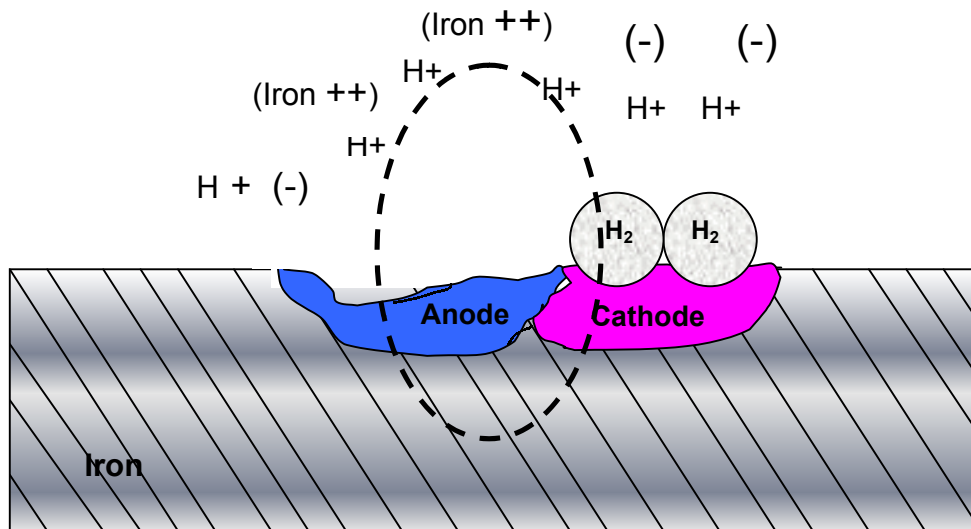


Figure 3: Acid Corrosion Battery

The reaction involved here is a vigorous one, and it continues until all of the available metal is consumed, or until all available acid is used up.

The dissolved metal in this battery will not form rust (at least not initially), but will remain dissolved in the acid electrolyte as an iron salt as long as sufficient moisture is present and as long as an excess of acid is present. When the available acid is consumed (for example, acid splash on steel), and the moisture evaporates somewhat, copious rust will then form and become deposited over the corroded areas of the metal surface.

V. GALVANIC CORROSION

Situations often arise where two or more different metals are electrically connected under conditions permitting the formation of a "corrosion battery". A situation then

exists where one metal will be corroded preferentially in relation to the other metal to which it is physically connected. This is referred to as "galvanic corrosion".

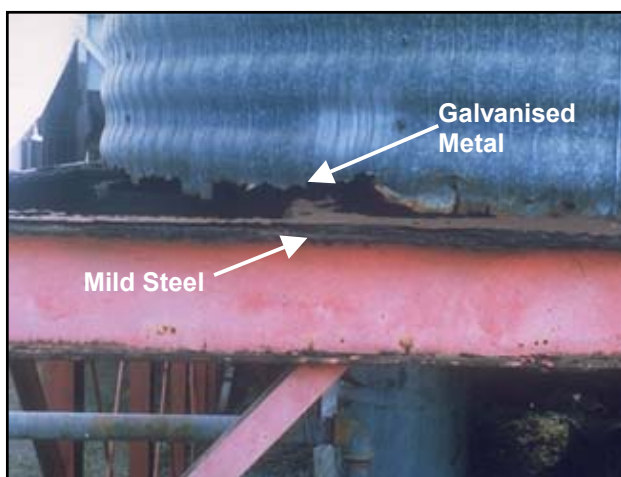
Galvanic corrosion is an extremely important corrosion process and one that is all too frequently encountered. Fortunately it is possible to use the principles of galvanic corrosion to our advantage in the cathodic protection of surfaces by using sacrificial metal anodes or inorganic protective coatings. The arrangement of many metals and alloys in a series known as the Galvanic Series of Metals and Alloys (Industrial) in Sea Water (see Figure 4), describes their relative tendency to corrode.

Bearing in mind that the metal located higher on the scale will corrode preferentially and thereby protect the metal lower on the scale from corrosion attack, the following example may be set up:

If copper and zinc are connected together, the zinc will dissolve and corrode preferentially, thus protecting the copper. Since the metal attacked is defined as the "anode", the zinc in this example serves as the anodic area. The copper will be the "cathodic" area or the metal protected. The function of each area is identical to that found in the "corrosion battery" set up for the rusting of iron. The intensity with which two metals will react in this preferential manner may be measured by the distance and the potential difference between the two metals in the Galvanic Scale (see Figure 4). Thus, between brass and copper there would be only a weak tendency for the brass to corrode; whereas, zinc or magnesium would dissolve very readily to protect silver. Since magnesium is at the top of the scale, it will corrode in preference to any other metal shown on the Galvanic Scale. Conversely, platinum, which is extremely inert, never corrodes preferentially,

While the tendency to corrode depends on the kinds of metal coupled together, the rate at which the corroding anode is attacked depends on the relative area of anodes and cathodes hooked together.

In the picture on the right, a macadamia nut tank in Hawaii constructed out of galvanised metal was connected to a support structure made out of mild steel. Although the steel was painted, the coverage on the edges proved insufficient to isolate the mild steel from the galvanised metal. Initially, the galvanised metal corroded to protect the mild steel; however after the metals were separated due to corrosion, the mild steel began to corrode very rapidly and the corrosion of the galvanised metal slowed down to a virtual standstill. This is an excellent example of the dissimilar



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metal corrosion problem that occurs when two different metals are connected together without a suitable insulator.

To avoid this problem several options were available to the design engineer including the following: (1) constructing the tank and support steel from the same type of metal, (2) including a gasket material between the galvanised metal and the mild steel to isolate the tank from the support steel, or (3) rounding the edges of the support steel and specifying a sufficient dry film thickness of a suitable high solids or 100% solids coating.

By looking at the Galvanic series shown in Figure 4 (below), we can see that the galvanised metal in the example above did exactly what we would predict it would do when it is connected with mild steel without a suitable insulator– it corroded to protect the mild steel.

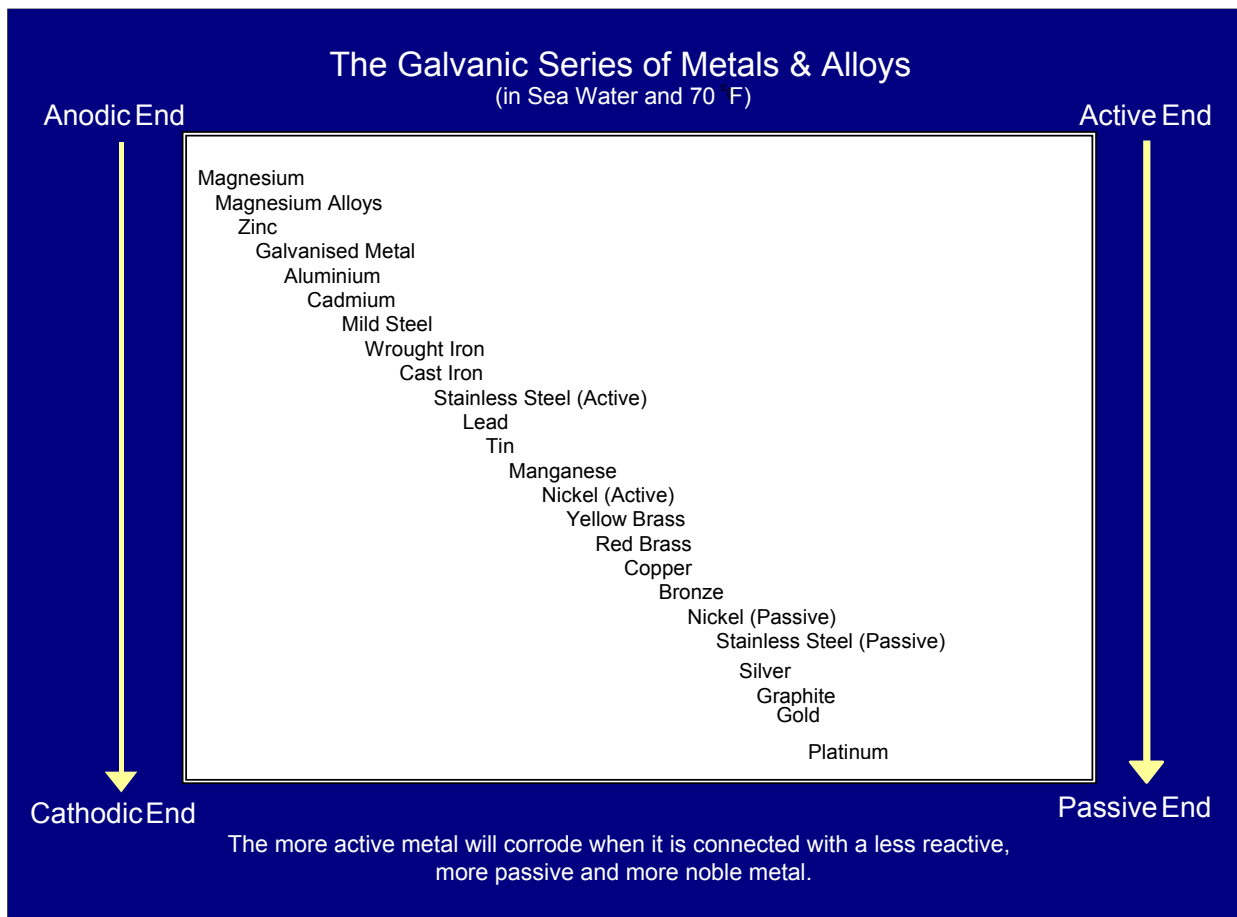


Figure 4: Galvanic Series of Metals and Alloys (Industrial) in sea water

The Galvanic Series (shown above)describes the electrode potential the metal assumes in sea water.

Figure 5 (shown below) lists the electrode potential series (EMF series) of metals and other substances according to potentials measured (or calculated) when in contact with their own standard ionic solutions. There are some noted differences between the two series.

Figure 5: STANDARD ELECTRODE POTENTIALS

Half Reaction	E^0 , volts	Formal Potential, volts
$F_2 + 2H^+ + 2e \rightleftharpoons 2HF$	3.06	
$O_3 + 2H^+ + 2e \rightleftharpoons O_2 + H_2O$	2.07	
S_2O	2.01	
$Co^{3+} + e \rightleftharpoons Co^{2+}$	1.842	
$H_2O_2 + 2H^+ + 2e \rightleftharpoons 2H_2O$	1.77	
$MnO_4^- + 4H^+ + 3e \rightleftharpoons MnO_2 + 2H_2O$	1.695	
$Ce^{4+} + e \rightleftharpoons Ce^{3+}$		1.70, 1 F $HClO_4$; 1.61, 1 F HNO_3 ; 1.44, 1 F H_2SO_4
$HClO + H^+ + e \rightleftharpoons \frac{1}{2} Cl_2 + H_2O$	1.63	
$H_5IO_6 + H^+ + 2e \rightleftharpoons IO_3^- + 3H_2O$	1.6	
$BrO_3^- + 6H^+ + 5e \rightleftharpoons \frac{1}{2} Br_2 + 3H_2O$	1.52	
$MnO_4^- + 8H^+ + 5e \rightleftharpoons Mn^{2+} + 4H_2O$	1.51	
$Mn^{3+} + e \rightleftharpoons Mn^{2+}$		1.51, aq. H_2SO_4
$ClO_3^- + 6H^+ + 5e \rightleftharpoons \frac{1}{2} Cl_2 + 3H_2O$	1.47	
$PbO_2 + 4H^+ + 2e \rightleftharpoons Pb^{2+} + 2H_2O$	1.455	
$Cl_2 + 2e \rightleftharpoons 2Cl^-$	1.359	
$Cr_2O_7^{2-} + 14H^+ + 6e \rightleftharpoons 2Cr^{3+} + 7H_2O$	1.33	
$Ti^{3+} + 2e \rightleftharpoons Ti^+$	1.25	0.77, 1 F HCl
$IO_3^- + 2Cl^- + 6H^+ + 4e \rightleftharpoons ICl_2^- + 3H_2O$	1.24	
$MnO_2 + 4H^+ + 2e \rightleftharpoons Mn^{2+} + 2H_2O$	1.23	1.24, 1 F $HClO_4$
$O_2 + 4H^+ + 4e \rightleftharpoons 2H_2O$	1.229	

Half Reaction	E ⁰ , volts	Formal Potential, volts
$\text{IO}_3^- + 6\text{H}^+ + 5\text{e}^- \rightleftharpoons \frac{1}{2}\text{I}_2 + 3\text{H}_2\text{O}$	1.195	
$\text{SeO}_4^{2-} + 4\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{H}_2\text{SeO}_3 + \text{H}_2\text{O}$	1.15	
$\text{Br}_2(\text{ag}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$	1.087 ^b	
$\text{Br}_2(\text{l}) + 2\text{e}^- \rightleftharpoons 2\text{Br}^-$	1.065	1.05, 4 F HCl
$\text{ICl}_2 + \text{e}^- \rightleftharpoons \frac{1}{2}\text{I}_2 + 2\text{Cl}^-$	1.06	
$\text{V}(\text{OH})_4^+ + 2\text{H}^+ + \text{e}^- \rightleftharpoons \text{VO}_2 + 3\text{H}_2\text{O}$	1.00	1.02, 1 F HCl, HClO ₄
$\text{HNO}_2 + \text{H}^+ + \text{e}^- \rightleftharpoons \text{NO} + \text{H}_2\text{O}$	1.00	
$\text{Pd}^{2+} + 2\text{e}^- \rightleftharpoons \text{Pd}$	0.987	
$\text{NO}_3^- + 3\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{HNO}_2 + \text{H}_2\text{O}$	0.94	0.92, 1 F HNO ₃
$2\text{Hg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg}_2^{2+}$	0.920	0.907, 1 F HClO ₄
$\text{H}_2\text{O}_2 + 2\text{e}^- \rightleftharpoons 2\text{OH}^-$	0.88	
$\text{Cu}^{2+} + \text{I}^- + \text{e}^- \rightleftharpoons \text{CuI}$	0.86	
$\text{Hg}^{2+} + 2\text{e}^- \rightleftharpoons \text{Hg}$	0.854	
$\text{Ag}^+ + \text{e}^- \rightleftharpoons \text{Ag}$	0.799	0.228, 1 F HCl; 0.792, 1 F HClO ₄ ; 0.77, 1 F H ₂ SO ₄
$\text{Hg}_2^{2+} + 2\text{e}^- \rightleftharpoons 2\text{Hg}$	0.789	0.274, 1 F HCl; 0.776, 1 F HClO ₄ ; 0.674, 1 F H ₂ SO ₄ ;
$\text{Fe}^{3+} + \text{e}^- \rightleftharpoons \text{Fe}^{2+}$	0.771	0.700, 1 F HCl; 0.732, 1 F HClO ₄ ; 0.68, 1 F H ₂ SO ₄
$\text{H}_2\text{SeO}_3 + 4\text{H}^+ + 4\text{e}^- \rightleftharpoons \text{Se} + 3\text{H}_2\text{O}$	0.740	
$\text{PtCl}_4^{2-} + 2\text{e}^- \rightleftharpoons \text{Pt} + 4\text{Cl}^-$	0.73	
$\text{C}_6\text{H}_4\text{O}_2 (\text{quinone}) + 2\text{H}^+ + 2\text{e}^- \rightleftharpoons \text{C}_6\text{H}_4(\text{OH})_2$	0.699	0.696, 1 F HCl, H ₂ SO ₄ , HClO ₄

Half Reaction	E ⁰ , volts	Formal Potential, volts
$\text{O}_2 + 2\text{H}^+ + 2\text{e} \rightleftharpoons \text{H}_2\text{O}_2$	0.682	
$\text{PtCl}_6^{2-} + 2\text{e} \rightleftharpoons \text{PtCl}_4^{2-} + 2\text{Cl}^-$	0.68	
$\text{I}_2(\text{aq}) + 2\text{e} \rightleftharpoons 2\text{I}^-$	0.620 ^b	
$\text{HgSO}_4 + 2\text{e} \rightleftharpoons 2\text{Hg} + \text{SO}_4^{2-}$	0.615	
$\text{Sb}_2\text{O}_5 + 6\text{H}^+ + 4\text{e} \rightleftharpoons 2\text{SbO}_4 + 3\text{H}_2\text{O}$	0.581	
$\text{MnO}_4^- + \text{e} \rightleftharpoons \text{MnO}_4^{2-}$	0.564	
$\text{H}_3\text{AsO}_4 + 2\text{H}^+ + 2\text{e} \rightleftharpoons \text{H}_3\text{AsO}_3 + \text{H}_2\text{O}$	0.559	0.577, 1 F HCl, HClO ₄
$\text{I}_3^- + 2\text{e} \rightleftharpoons 3\text{I}^-$	0.536	
$\text{I}_2(\text{s}) + 2\text{e} \rightleftharpoons 2\text{I}^-$	0.5355	
$\text{Cu}^+ + \text{e} \rightleftharpoons \text{Cu}$	0.521	
$\text{H}_2\text{SO}_3 + 4\text{H}^+ + 4\text{e} \rightleftharpoons \text{S} + 3\text{H}_2\text{O}$	0.45	
$\text{Ag}_2\text{CrO}_4 + 2\text{e} \rightleftharpoons 2\text{Ag} + \text{CrO}_4^{2-}$	0.446	
$\text{VO}^{2+} + 2\text{H}^+ + \text{e} \rightleftharpoons \text{V}^{3+} + \text{H}_2\text{O}$	0.361	
$\text{Fe}(\text{CN})_6^{3-} + \text{e} \rightleftharpoons \text{Fe}(\text{CN})_6^{4-}$	0.36	0.71, 1 F HCl; 0.72, 1 F HClO ₄ , H ₂ SO ₄
$\text{Cu}^{2+} + 2\text{e} \rightleftharpoons \text{Cu}$	0.337	
$\text{UO}_2^{2+} + 4\text{H}^+ + 2\text{e} \rightleftharpoons \text{U}^{4+} + 2\text{H}_2\text{O}$	0.334	
$\text{BiO}^+ + 2\text{H}^+ + 3\text{e} \rightleftharpoons \text{Bi} + \text{H}_2\text{O}$	0.32	
$\text{Hg}_2\text{Cl}_2(\text{s}) + 2\text{e} \rightleftharpoons 2\text{Hg} + 2\text{Cl}^-$	0.268	0.242, sat'd. KCl; 0.282, 1 F KCl
$\text{AgCl} + \text{e} \rightleftharpoons \text{Ag} + \text{Cl}^-$	0.222	0.228, 1 F KCl
$\text{SO}_4^{2-} + 4\text{H}^+ + 2\text{e} \rightleftharpoons \text{H}_2\text{SO}_3 + \text{H}_2\text{O}$	0.17	

Half Reaction	E^0 , volts	Formal Potential, volts
$\text{BiCl}_4 + 3e \rightleftharpoons \text{Bi} + 4\text{Cl}^-$	0.16	
$\text{Sn}^{4+} + 2e \rightleftharpoons \text{Sn}^{2+}$	0.154	0.14, 1 <i>F</i> HCl
$\text{Cu}^{2+} + e \rightleftharpoons \text{Cu}^+$	0.153	
$\text{S} + 2\text{H}^+ + 2e \rightleftharpoons \text{H}_2\text{S}$	0.141	
$\text{TiO}_2 + 2\text{H}^+ + e \rightleftharpoons \text{Ti}^{3+} + \text{H}_2\text{O}$	0.1	0.04, 1 <i>F</i> H_2SO_4
$\text{AgBr} + e \rightleftharpoons \text{Ag} + \text{Br}^-$	0.095	
$\text{S}_4\text{O}_6^{2-} + 2e \rightleftharpoons 2\text{S}_2\text{O}_3^{2-}$	0.08	
$\text{Ag}(\text{S}_2\text{O}_3)_3^{3-} + e \rightleftharpoons \text{Ag} + 2\text{S}_2\text{O}_3^{2-}$	0.01	
$2\text{H}^+ + 2e \rightleftharpoons \text{H}_2$	0.000	-0.005, 1 <i>F</i> HCl, HClO_4
$\text{Pb}_2 + 2e \rightleftharpoons \text{Pb}$	-0.126	-0.14, 1 <i>F</i> HClO_4 ; -0.29, 1 <i>F</i> H_2SO_4
$\text{Sn}^{2+} + 2e \rightleftharpoons \text{Sn}$	-0.136	-0.16, 1 <i>F</i> HClO_4
$\text{AgI} + e \rightleftharpoons \text{Ag} + \text{I}^-$	-0.151	
$\text{CuI} + e \rightleftharpoons \text{Cu} + \text{I}^-$	-0.185	
$\text{N}_2 + 5\text{H}^+ + 4e \rightleftharpoons \text{N}_2\text{H}_5^+$	-0.23	
$\text{Ni}^{2+} + 2e \rightleftharpoons \text{Ni}$	-0.250	
$\text{V}^{3+} + e \rightleftharpoons \text{V}^{2+}$	-0.255	-0.21, 1 <i>F</i> HClO_4
$\text{Co}^{2+} + 2e \rightleftharpoons \text{Co}$	-0.277	
$\text{Ag}(\text{CN})_2^- + e \rightleftharpoons \text{Ag} + 2\text{CN}^-$	-0.31	
$\text{Tl}^+ + e \rightleftharpoons \text{Tl}$	-0.336	-0.551, 1 <i>F</i> HCl ; -0.33, 1 <i>F</i> HClO_4 , H_2SO_4
$\text{PbSO}_4 + 2e \rightleftharpoons \text{Pb} + \text{SO}_4^{2-}$	-0.356	

Half Reaction	E^0 , volts	Formal Potential, volts
$\text{Ti}^{3+} + e \rightleftharpoons \text{Ti}^{2+}$	-0.37	
$\text{Cd}^{2+} + 2e \rightleftharpoons \text{Cd}$	-0.403	
$\text{Cr}^{3+} + e \rightleftharpoons \text{Cr}^{2+}$	-0.41	
$\text{Fe}^{2+} + 2e \rightleftharpoons \text{Fe}$	-0.440	
$2\text{CO}_2(\text{g}) + 2\text{H}^+ + 2e \rightleftharpoons \text{H}_2\text{C}_2\text{O}_4$	-0.49	
$\text{Cr}^{3+} + 3e \rightleftharpoons \text{Cr}$	-0.74	
$\text{Zn}^{2+} + 2e \rightleftharpoons \text{Zn}$	-0.763	
$\text{Mn}^{2+} + 2e \rightleftharpoons \text{Mn}$	-1.18	
$\text{Al}^{3+} + 3e \rightleftharpoons \text{Al}$	-1.66	
$\text{Mg}^{2+} + 2e \rightleftharpoons \text{Mg}$	-2.37	
$\text{Na}^+ + e \rightleftharpoons \text{Na}$	-2.714	
$\text{Ca}^{2+} + 2e \rightleftharpoons \text{Ca}$	-2.87	
$\text{Ba}^{2+} + 2e \rightleftharpoons \text{Ba}$	-2.90	
$\text{K}^+ + e \rightleftharpoons \text{K}$	-2.925	
$\text{Li}^+ + e \rightleftharpoons \text{Li}$	-3.045	

^a Source for the majority of E^0 values is Wendell M. Latimer, *The Oxidation Series of the Elements and Their Potentials in Aqueous Solutions*, 2nd ed. Englewood Cliffs, NJ: Prentice Hall, Inc. 1952. The formal potentials are from Ernest H. Swift, *Introductory Quantitative Analysis*, Englewood Cliffs, NJ: Prentice Hall, Inc. 1950. Used with permission.

^b These potentials are hypothetical, since they correspond to solutions that are 1.00 M in Br_2 or I_2 . The solubility's of these two compounds at 25°C are 0.21 M and 0.0133 M respectively. In saturated solutions containing an excess of $\text{Br}_2(\text{l})$ or $\text{I}_2(\text{s})$ the standard potentials for the half-reactions $\text{Br}_2(\text{l}) + 2e \rightleftharpoons 2\text{Br}^-$ or $\text{I}_2(\text{s}) + 2e \rightleftharpoons 2\text{I}^-$ should be used. On the other hand, at Br_2 and I_2 concentrations less than saturation, these hypothetical electrode potentials should be employed.

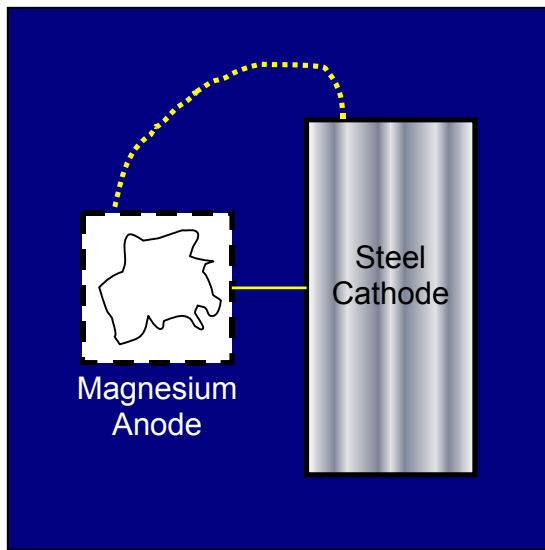


Figure 6:
Severe Galvanic Corrosion

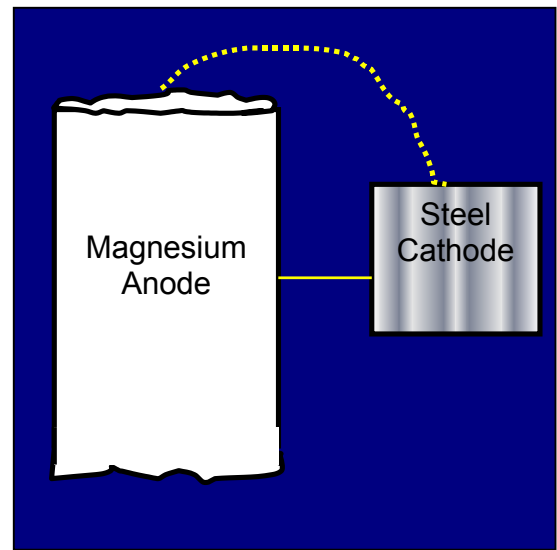


Figure 7:
Mild Galvanic Corrosion

In Figure 6, if a small magnesium anode is connected to a large area of steel (as in protection of a ship's hull), the anode area (being small as compared to the cathode area) will corrode very readily. This is due to the entire impact of the galvanic current being concentrated on a small area of active metal

Conversely, if the cathode area is small compared to the anode area (Figure 7), the corrosion of the anode will be relatively slow, since the demand on the anode is spread thin and any local spot loses little metal. It must be kept in mind that the areas of each metal involved are those in electrical contact and not just the areas of metal in physical contact. The area of metals in electrical contact will be determined by those areas which are in contact with an external conductive circuit (electrolyte).

For example, in the use of rivets of one metal to fasten together plates of a different metal, we find an excellent example of the possible effects of galvanic corrosion.

If steel plates (anodes) were bolted with copper rivets (cathodes) only a very slow corrosion of the steel would occur, since corrosive effect is spread out over a large area of steel.

On the other hand, if copper plates (cathodes) were bolted with steel rivets (anodes), rapid rusting of the rivets would occur. The small area of rivets would be attacked by all the galvanic current generated by the large copper plates and would corrode rapidly.

See Figure 8 (on the next page) for an illustration of this effect.

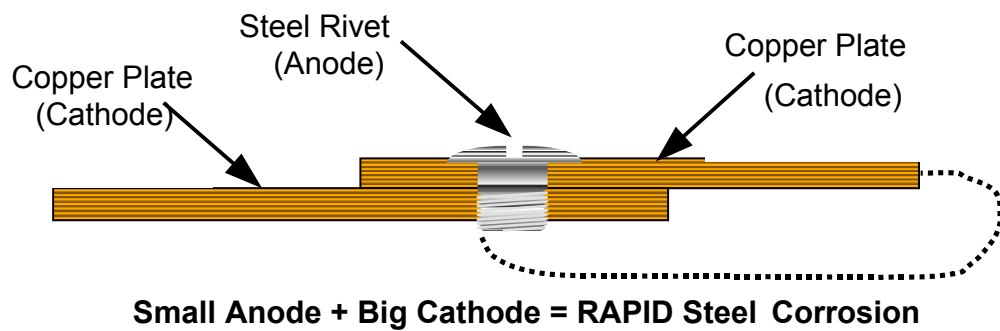
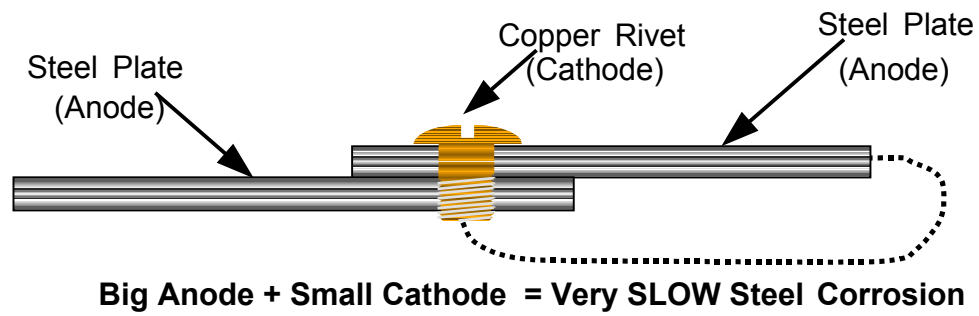


Figure 8: Relative Areas in Galvanic Corrosion

VI. CREVICE CORROSION

The presence of crevices or pockets in the design of a steel structure presents a special corrosion problem and one that is extremely difficult to combat successfully. Crevices have a tendency to corrode at a far greater rate than the adjacent flat metal areas.

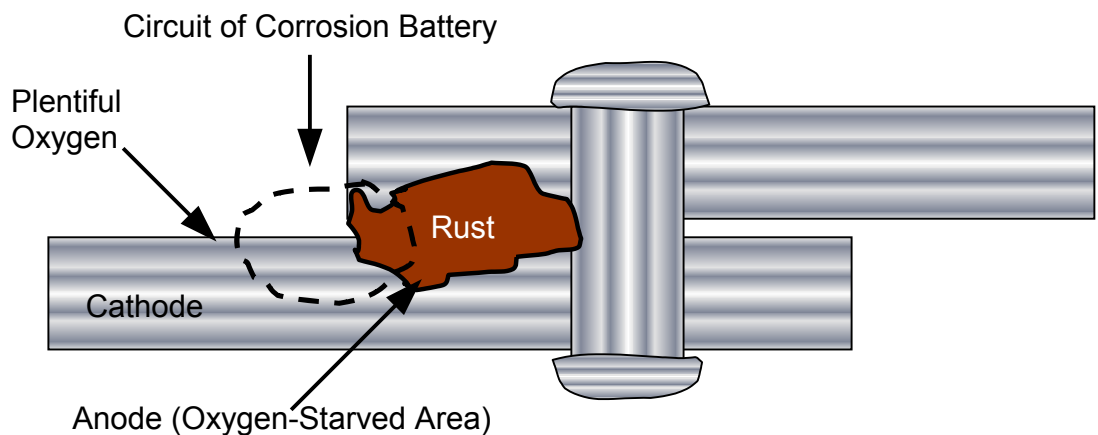


Figure 9: Crevice Corrosion

Again, it is possible to use a simplified version of the "corrosion battery" to examine crevice corrosion, as shown in Figure 9. Once again the essentials of the corrosion processes -- oxygen, water, and ions are present. Crevices certainly hold soluble salts and liquid solutions of these salts so more than enough water and ions are present to form an electrolyte. The remaining ingredient involved is oxygen. As we have observed in the iron "corrosion battery" and in the galvanic "corrosion battery", the change of oxygen to caustic is associated with the cathode area (the area protected). If the two areas of metal are involved in a "corrosion battery", such as in Figure 9, the area exposed to the most oxygen will become the cathode; thereby forcing the other area (oxygen starved area) to act as an anode and corroded. This is the situation that exists in crevice corrosion. The metal in the crevice is an oxygen starved area and is, therefore, subject to corrosion and acts as an anode.

It is known from wide field experience that it is very difficult to stop this type of corrosion. Application of a coating over the crevice is usually not satisfactory for two reasons:

1. Trapped salts and rust laden with corrosion and water will promote early blistering beneath the coating, leading to premature film failure.
2. The sharp edges of the crevice are likely to be inadequately covered with the coating so that edge rusting can start promptly. Film rupture along the edges, followed by progressive adhesion loss, will result in unsatisfactory coating performance.

The most practical way to eliminate crevice corrosion is to avoid structural design details that create crevice conditions (lap welds, lap sections riveted together, etc.). In existing structures, crevices should be filled with appropriate mastics or fillers and proper welding techniques should be observed. Weld spatter, pockets, cracks and other crevice type spots in the area to be coated should be eliminated.

VII. PITTING CORROSION

Pitting corrosion takes a very heavy toll on machinery and equipment due to the concentration of the electrical cycle on a very small anodic area. When protective films break down or pinholing occurs, local corrosion or pitting may follow. An anode is formed at the point where the film break occurs, and being in contact with the external electrolyte, it bears the full onslaught of any attack by a surrounding cathodic area. Generally the smaller the anodic area that is in contact with the electrolyte, the more rapid and severe the pitting.

VIII. CORROSION UNDER MILL SCALE

Mill scale is a form of iron oxide created during the fabrication of steel. Although it is a very hard, brittle film adhering to the steel surface, it is fragile and subject to cracking and spalling. Even worse, mill scale is cathodic with respect to steel; thus, it causes accelerated galvanic corrosion wherever a break in the scale exposes the underlying steel.

Obviously, painting over mill scale is a poor practice. Its complete removal, usually by abrasive blasting, is highly recommended before application of a protective coating to steel.

The inevitable failure resulting from painting over mill scale is illustrated in Figures 10 - 12. Since mill scale does not uniformly cover the steel surface, if a coating is applied over it, there will be small bare steel areas between the coating and the steel (see Figure 10). A coating cannot prevent cracking and spalling of the mill scale unless it is a perfect insulator. Since no coating is a perfect insulator, some corrosion batteries are set up. If a local break occurs, small bare steel areas are subject to the attack of large cathodic areas.

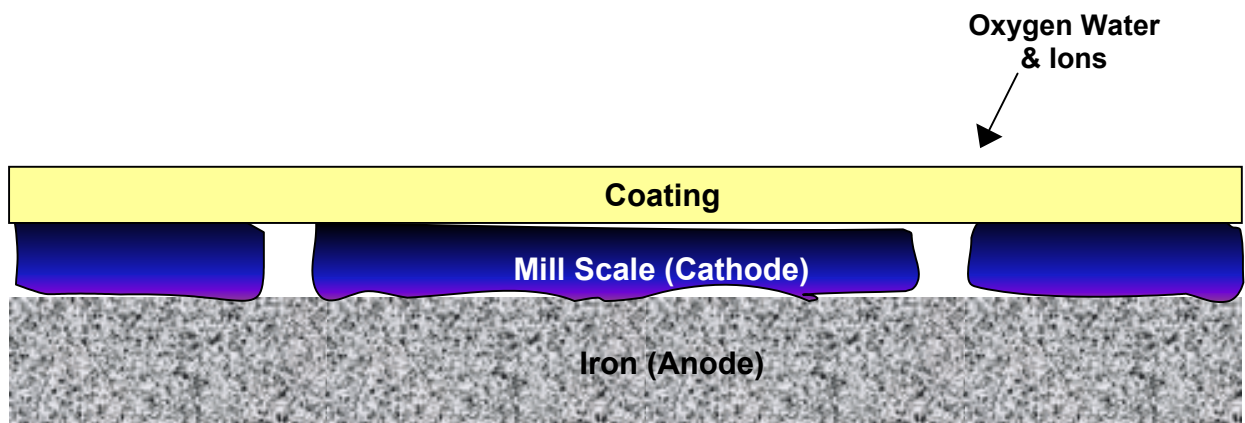


Figure 10: Coating over mill scale

As the pitting and rusting occur, as shown in Figures 11 & 12, the build-up of rust under the edge of the mill scale breaks and eventually cracks, loosening a small section of the mill scale. When the coating is applied directly over the mill scale, it possesses no direct adhesion to the steel itself. When the mill scale breaks away, normally a coating failure occurs.

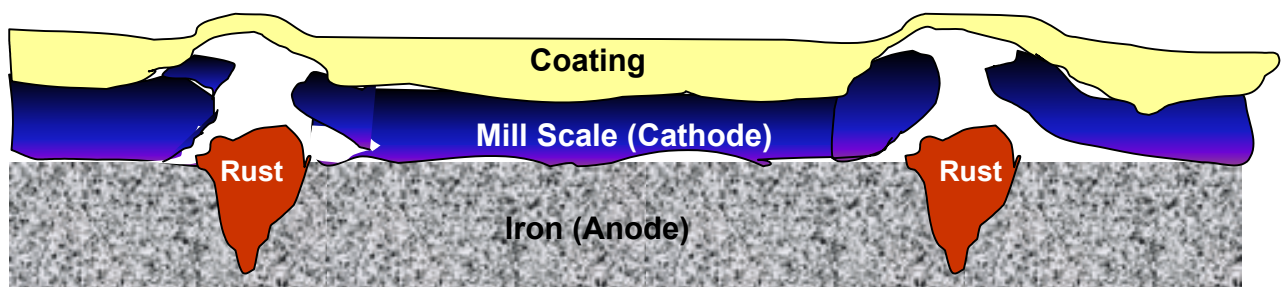


Figure 11: Rust forming- lifting coating and mill scale

As continued build-up of rust deposits persist a loosening of the coating will occur evidenced by peeling, blistering and rupturing, failure, and eventually loss of adhesion.

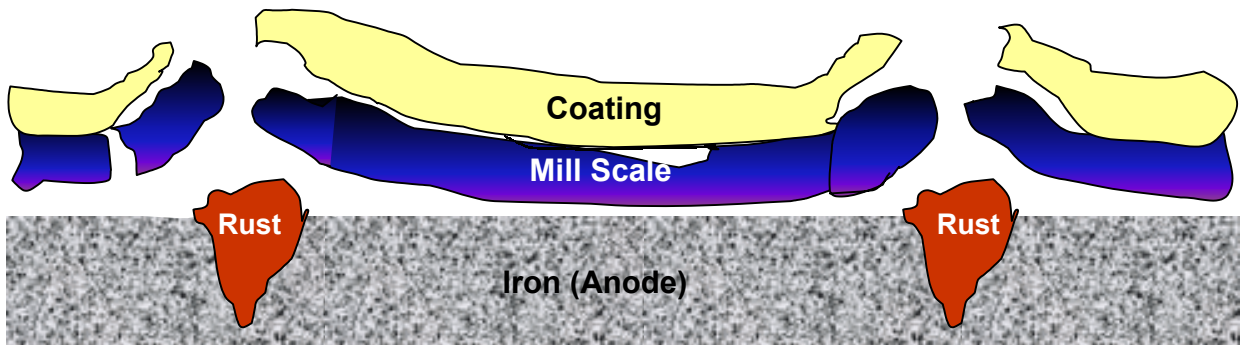


Figure 12: Coating film is ruptured & visible failure occurs

In this chapter, we have discussed the basic principles of how and why corrosion occurs. Knowing what causes corrosion provides a sound foundation for controlling and / or preventing it. Armed with this basic knowledge concerning the corrosion processes, in the next chapter we will begin to examine some common methods of combating and controlling corrosion.

SECTION 2

Revised: 02/2002

METHODS OF CORROSION CONTROL

The tendency of metals to corrode is a natural occurrence. It is inevitable. The corrosion engineer's job is to control these destructive effects at the minimum cost over the anticipated life of the structure. There are five principal methods in use today:

1. Placing a barrier between the material and its environment.
2. Using corrosion resistant materials of construction.
3. Installing cathodic protection
4. Over-designing the structure.
5. Altering the environment.

Complete textbook and courses exist that provide details on each of these methods. The purpose of this manual is to familiarise the reader with these methods of corrosion control by providing a brief overview of each method.

Each method possesses certain characteristic advantages and disadvantages and specific areas where their use is most economical. Since an industrial area is a composite of many and various types of corrosion areas, none of these methods function as a universal cure-all.

Each situation must be individually studied in order to reach a decision based upon such factors as the following:

- (1). Available down time
- (2). Equipment and plant obsolescence
- (3). Operating temperatures and cycles
- (4). Appearance
- (5). Environment
- (6). Anticipated life expectancy of the structure or vessel
- (7). Budgetary constraints

For each corrosion problem, it is necessary to weigh these individual factors and to pick the corrosion tool that provides the most economical means of protection over the life of the structure.

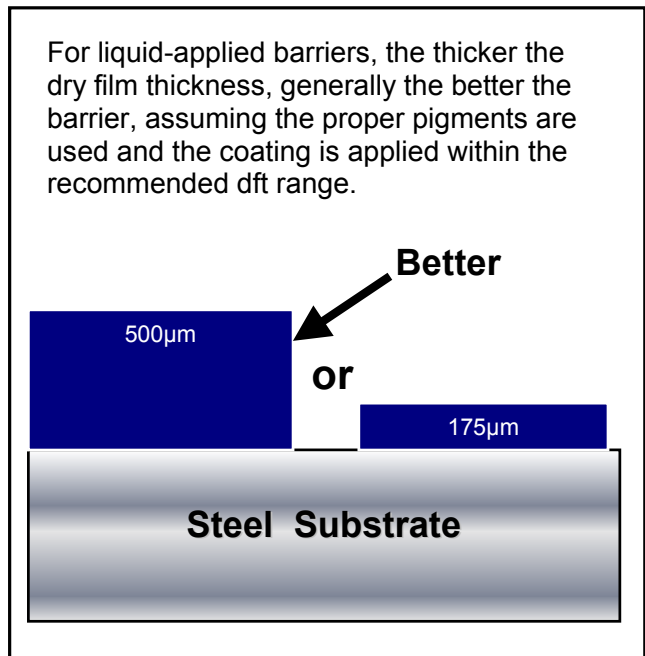
Often this choice is made in the design stage of a structure, so it is important to closely consult with the corrosion or maintenance engineer during the selection period. If this practice is not followed the specifying architect or engineer may overlook or even eliminate from their arsenal, viable economical weapons of corrosion control.

I. BARRIERS

Today, protective barriers, are by far the most commonly specified solution for controlling corrosion. Barriers function by isolating a construction material, such as steel or concrete, from a corrosive environment. Examples of barriers include liquid-applied protective coatings and linings, acid-proof brick or tile, plastic sheeting, and trowelled-on resinous membranes.

For years these barriers have served as the principle weapons in the corrosion engineers arsenal. Each barrier type listed above works best in certain kinds of environments, therefore careful analysis of a specific corrosion problem is necessary to choose the most effective and the most economical barrier system for a particular situation.

Barriers act primarily by stopping or slowing down electrolytes from reaching the metal substrate or by keeping chemicals from reaching concrete surfaces. To be effective, barriers should be uniformly applied at the proper dry film thickness and be properly and thoroughly cured before they are subject to in-service conditions.



One of the primary advantages of the barrier method of corrosion control is the wide degree of options that are available and their versatility. For many types of barriers, the materials are readily available and are installable by a large number of applicators. They can be installed on-site in an operating facility offering an advantage in many pre-existing plants or in maintenance situations.

Prior to selecting the proper type of barrier for a given application, a specifier should consider surface preparation and application issues. In some environments abrasive blasting and spray application of protective coatings is not permitted. In these situations, it is the design engineers responsibility to select a suitable material that complies with these restrictions. In other cases, the work must be performed during a

tightly scheduled shutdown that may not allow for the proper curing time that is necessary for some liquid protective coatings. Fortunately today, specifiers possess a wide variety of alternative surface preparation and application method options to select from.

The ultimate performance of any barrier system hinges on selecting the correct product, and following through to ensure that the surface is properly prepared and that the product is properly applied. Subsequent chapters in this manual examine barrier coatings, surface preparation methods and application techniques and methods in far greater detail.

II. CORROSION RESISTANT MATERIALS

Largely because of their price and structural qualities, steel and iron are the most widely used metals in industrial construction. Unfortunately, as discussed previously, these materials tend to corrode by reverting to their oxides more rapidly than other types of metal.

Therefore, in certain instances, the corrosion or design engineer turns to the more inert metals, alloys or even non-metallic materials to retard the corrosion process. Often, in extremely severe exposures, this is the only feasible answer. High temperature operations, combined with highly corrosive chemicals, may produce a situation too severe for any other type of structural material or protection. In such cases the relatively high initial cost of these metals is easily justified by their long life span.

Among the most common metals alloyed with steel or iron are chromium, copper, nickel, and molybdenum. Of the metals used in their natural state, aluminium is the most reasonable priced and widely used, while such rare metals as titanium and tantalum are only employed under the most severe conditions. The decision as to the use of this type of protection versus other means of control will depend to a great extent on the severity of exposure and the ultimate cost of the alternate methods. In the majority of plant maintenance, exposures are only mildly corrosive and the use of alloys and rare metals as construction materials is not economical.

In lieu of installing aluminium as the base metal at times through the use of arc spray or flame spray, aluminium and or zinc are used to “metallise” steel structures for additional corrosion and chemical resistance.

In addition to alloys, many corrosion resistant plastic materials are now available. Thermoplastic materials such as polyvinyl chloride and polyethylene are used in pipe and fume ducts. Glass reinforced epoxy and polyester compounds are employed in process piping with a higher temperature limit. They are also used in tanks or reaction vessels.



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In the picture at left, this residence constructed in a hot and humid, salt-spray rich, South Pacific Island is made of fibreglass material. Many other materials, including steel coated with various types of protective coatings, simply do not hold up for very long in this corrosive environment.

III. CATHODIC PROTECTION

A third tool available to the corrosion engineer is cathodic protection. In the preceding section of this manual, we discussed how two dissimilar metals coupled together produce galvanic corrosion. While we are often concerned with reducing the corrosion of the active metal, it is possible to take advantage of the fact that the cathode metal is protected while the anode corrodes. By deliberately coupling two dissimilar metals together, we can prevent corrosion of the less active (cathode) at the expense of the other metal.

Therefore, to protect a steel surface, we simply select a more active metal to serve as an anode. In other words we select a metal that is higher on the galvanic scale. Magnesium is commonly used for this purpose. When it is coupled electrically to the steel, a magnified corrosion battery is set up in which the magnesium, because of its greater activity, becomes the anode and the steel the cathode. In so doing, the magnesium anode corrodes preferentially, leaving the steel cathode intact.

The same results are achievable by providing an impressed current from an external source and applying it to the metal that we wish to protect. On such systems, generators, rectifiers, or batteries are used as the DC source. To prevent rapid disintegration of the anode, usually an inert metal is selected.

Today the greatest use of cathodic protection is found in the protection of marine equipment, hot water tanks, and underground or underwater pipelines. Simplicity is certainly one of its prime values and its effectiveness in the presence of a good electrolyte is unquestionable. However, in dry or damp areas, its usefulness is limited, and ordinarily in these environments, it is replaced or complimented by alternate methods of control, namely protective coatings.

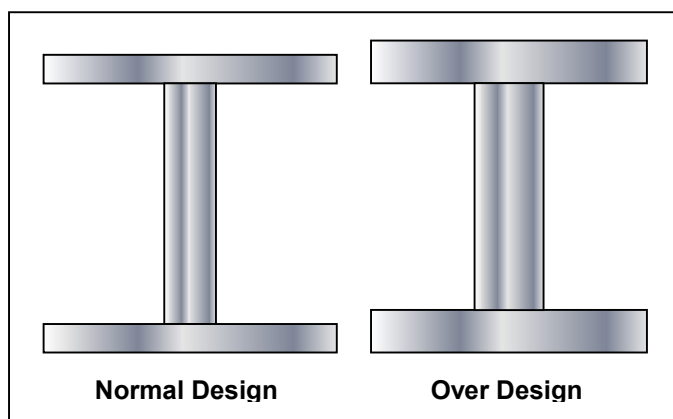
Like all corrosion control methods, cathodic protection systems require monitoring to ensure that they are working properly (i.e. that they remain connected). Failure to properly monitor cathodic protection systems can result in serious corrosion problems especially in tank bottoms.

IV. OVER-DESIGN

Over-design of structures refers to using heavier structural members or thicker plates in anticipation of corrosion losses. This method is sometimes used unwittingly; that is, excessive plate thickness is frequently specified as a matter of habit or custom, when lighter weight metals could be used if corrosion were prevented. Nowadays there is a trend toward utilising lighter structural members when suitable corrosion protection methods are employed.

The principal disadvantage of over-design, or built-in corrosion allowance, is that neither the exact length of life nor the replacement cost of a corroding material can be exactly predicted.

For example, it may be anticipated that an unprotected steel structure will have a life of X years and replacement cost of Y. But if X is less than anticipated, and if Y is more, the overall cost of the built-in corrosion allowance can be several times greater than expected. The cost and the effectiveness of other methods can be determined much more accurately.



V. ALTERING THE ENVIRONMENT

This procedure usually involves controlling accidental discharge of corrosion vapours, or adding inhibitors to liquids in a closed system. Environmental regulations regarding emissions of chemical vapours, especially from chemical plants and power plants, require the installation of expensive scrubber systems to maintain the emissions below the government mandated levels.

From a corrosion standpoint, the regulations actually serve a useful function in reducing the amount of sulphur and other chemicals available to serve as electrolytes in the corrosion process.

The use of chemical inhibitors is normally restricted to water supply, water circulating systems, steam and condensate lines, and brine systems. Since they are strictly an immersion solution, their usefulness in the maintenance field is definitely limited. In

addition, proper caution must be exercised in the selection of quantities and types of chemicals. Improper selection or maintenance of inhibitor systems can often accelerate rather than retard corrosion. However, if used properly within their limited open scope, they provide a simple and relatively low cost solution to corrosion control.

Another aspect of altering the environment is the elimination at the source of those contaminants causing corrosion. Today mandatory environmental controls are forcing design engineers to eliminate or greatly curtail discharge emissions from stacks. This has resulted in an alteration of the environment with positive benefits from a corrosion control standpoint. In the past, these chemical emissions often fell onto coated surfaces, sometimes after the surface had been blasted and before a barrier protected it. When combined with moisture from the air and rain, these emissions contributed to premature coating failures.

One of the benefits of the environmental regulations from a corrosion control standpoint is the reduction and in some cases the total elimination of the chemical fallout from power stations, paper mills, refineries and chemical plants. In the past these chemicals when combined with moisture from the air acted as electrolytes in the corrosion process.

SUMMARY

Regardless of the method of control that is employed to combat corrosion, proper selection of the method and proper installation of the system serve as the essential foundation for all credible corrosion control programs. The best system, if improperly installed or if installed to an improperly prepared surface, cannot and will not provide the desired protection over the life of the structure or substrate.

Since barrier protection is by far the most often utilised method of corrosion control, we will now focus on the proper selection of a barrier type, the proper methods of surface preparation and the proper application control techniques and methods.

COMPARISON OF CORROSION CONTROL METHODS			
METHOD	EXAMPLES	ADVANTAGES	DISADVANTAGES
Barriers	- Protective Coatings - Brick Linings - Plastic Sheeting - Monolithic Toppings	- Most user-friendly to apply compared to other methods - Very effective and more versatile than other methods - Reasonable cost	- Proper surface preparation and application required - Careful analysis of corrosion problem needed
Corrosion Resistant Materials	- Alloys - Copper - Nickel Chromium - Spray metallised Zinc or Al - Polyethylene - PVC - Stainless Steel - Thermoplastics	- Long life span - The only viable solution in some situations	- High initial cost - Aesthetic concerns - Some materials are limited in certain types of environments
Cathodic Protection	- Ship hulls - Underground pipelines - Tank bottoms - Underwater pipelines	- Simplicity - Effective in presence of good electrolyte	- Immersion required - Limited use in damp / dry areas - Monitoring
Over Design	- Heavier structural steel members or thicker plates than required to allow for corrosion loss.		- Higher initial cost - Exact length of life extension & replacement cost are not predictable - Increased weight
Altering the Environment	- Water supply and circulating systems - Using amines with acids - Inhibitors	- Simple to use - Low cost	- Limited to immersion solution - Quality & type of chemicals must be carefully controlled

SECTION 3

PROTECTIVE COATINGS

Revised: 02/2002

I. A BRIEF HISTORY

Modern protective coatings are an outgrowth of the paint that actually started out as an artist's material. From the early history of man, it was the artist who gathered the materials and developed the methods for making paint. Since early types of paint were made by artists, paint and varnish making was in itself an art for many centuries. Paint was primarily used for decorative purposes for most of recorded history.

Finally, with the industrial development that took place in the 18th and 19th centuries, paint began to emerge as a commercial material. However, the basic ingredients were still the natural resins and oils traditionally used by artists. These traditional materials have a certain value as protective coatings, but are limited in effectiveness, especially since lead was removed as a pigment due to health hazards.

At the turn of the 20th Century, industrial developments began to make heavier demands on coatings, and scientists began to investigate the traditional art of paint making with an eye toward improvement. During the last forty years, steadily increasing scientific effort has virtually revolutionised the manufacture of coatings. Today protective coatings are available which resist attack by nearly all chemicals and corrosive conditions. They often make it feasible to use steel structures, or other materials, in environments where it would not otherwise be economically possible. Using protective coatings actually saves billions a year in corrosion losses. Protective coatings are a valuable engineering material in the corrosion engineers arsenal.

II. DEFINITIONS OF PAINTS, COATINGS & LININGS

The "paint" materials used by the early cavemen differed in function and composition from the materials used today to protect against corrosion. In ancient times "painting" functioned primarily as a means of expression and a form of communication. Many millennia later however, "paint" transitioned into a highly developed art form designed to depict beauty. Now we use "paint" for communicative, decorative and protective purposes.

For ease of understanding, it's common nowadays to distinguish the types of liquid-applied materials by the functions for which each is formulated and designed. Typically the following three general classifications are used: (1) paint, (2) protective coating, or (3) lining. For clarification purposes, a definition for each of these terms is provided as follows:

- **Paint:** a film-forming, liquid material, usually oil, alkyd, acrylic or water-based in composition that is designed primarily to beautify through the use of colour. It is generally used in a non-hostile environment free of aggressive chemicals.
- **Coating:** a film-forming material, either liquid or non-liquid used to protect a material or substrate in a hostile environment from deterioration for a period of time. (This is also referred to as “protective coating” oftentimes.)
- **Lining:** a film-forming material, either liquid or non-liquid that is applied to a substrate in an immersion application such as a tank interior or a basin interior to protect the substrate and to protect the storage material from contamination. (This can present a very aggressive environment especially if the material being stored is kept at an elevated temperature.)

III. COMPONENTS OF COATINGS

Most protective coatings are comprised of only three components: (1) binders (also called “resins”), (2) pigments, and (3) solvents. (Note: There are some 100% solids coatings that do not contain any solvents, but the vast majority of the coatings sold today contain solvents.)

There are many different types of resins, pigments and solvents available for the paint chemist to select from when formulating a coating.

Each coating is designed with one or more of the following goals in view: (1) Cost competitiveness – easy to sell, (2) Application friendly – easy to apply, and (3) Long-term protection – lasts for a long time. To achieve the specific goal(s) the formulator selects the ratio of and types of resins, pigments and solvents that are required.

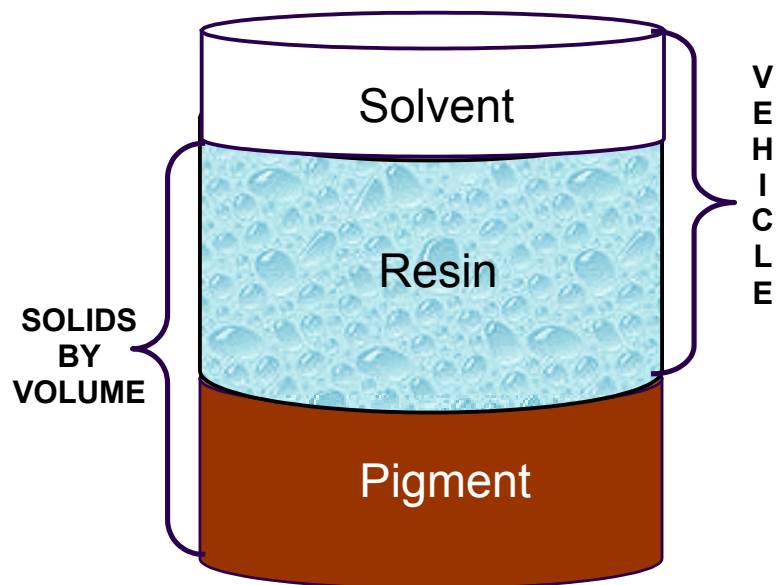


Figure 1: Coating components / ingredients for a pigmented coating that contains solvents (Note: This figure does not apply to a 100% solids coating)

A. PIGMENT FUNCTIONS

Pigments are defined as “discrete particulate solids that do not dissolve in the liquid”. They are ground into the coating and dispersed during the manufacturing process. They provide the following functions as depicted in the chart below:

PIGMENT FUNCTIONS	EXAMPLES
1. Colour pigments	Aesthetic or decorative effect, hide the substrate.
2. Protection of resin / binder	Absorb and reflects solar radiation which can cause breakdown of binder (chalking).
3. Corrosion inhibition	Zinc phosphate and barium metaborate and others act as inhibitors. Metallic zinc, when in high enough concentration, gives cathodic (sacrificial) protection.
4. Film reinforcement	Finely divided fibrous and platey particles which increase hardness and/or tensile strength of film.
5. Non-skid properties	Particles of silica or pumice which roughen film surface and increase abrasion resistance.
6. Sag control	So-called thixotropizing agents which prevent sagging of the wet film and also reduce tendency of other pigments to settle in container during storage.
7. Hide and gloss control	Increasing colour pigment concentration improves hide while an increase in either colour or other pigmentation decreases gloss.
8. Increased coverage	Properly selected "filler pigments*" sometimes called "inerts" can increase the volume solids (or coverage) of a coating without reducing its chemical resistance. (See note below)
* Note: There is a limitation on how much filler pigment can be used with a given resin composition. The constraint is termed the Critical Pigment Volume Concentration and indicates the volume of pigment which can be bound by the resin without leaving voids in the film. Pigments must be uniformly dispersed and completely "wetted" in the resinous binder to function properly.	

B. RESINOUS BINDER FUNCTIONS

The binder serves multiple functions. It essentially "glues" the pigments together in a homogeneous film. In addition the binder must also be capable of wetting out and adhering to the substrate, preventing penetration of aggressive chemicals, and maintaining its integrity in the corrosive environment. Since there is a wide variety of environments, it is not surprising that there is a wide variety of binders, each with its special niche within the coatings industry.

Most coatings are named after their binder. For example here's a list of several resins types that also refer to coating types in common coating circles: alkyds, acrylics, epoxies, novolacs, polyurethane's, polyesters, and vinyl esters. One notable exception to this rule is inorganic zinc, which is actually named after the zinc, its pigment.

C. THE VEHICLE OR FILM FORMERS

In order to apply an even, essentially void-free film that will wet and adhere to the substrate, the binder-pigment mixture must be in a highly fluid condition. The use of low molecular weight liquids (solvents) to dissolve or to increase the fluidity of the binder is often necessary. The combination of the solvents with the binder is referred to as the "vehicle".

Each type of binder has specific solvent combinations that are most efficient in producing the desired application and film-forming properties. Contrary to popular belief among painters, there is no universal solvent for protective coatings. For example, the best solvent for one type of coating may be water, while another coating might require a combination of expensive and toxic organic compounds. Using the wrong solvent, or "thinner", may cause any number of problems including but not limited to the precipitation of the binder. It may result in coating films with substandard properties both during application and in terms of long-term performance.

There are three different classifications of solvents commonly used in the coatings industry:

1. Primary solvents – used to dissolve the resin
2. Latent solvents – used controls the evaporation rate to aid in application
3. Diluent solvents - used to dilute the coating

Because of VOC (Volatile Organic Compound) regulations, the type and the amount of solvent that can be added by the contractor in the field may be limited. The VOC content is listed on the manufacturers product data sheets and is generally reported in grams / litre. The VOC is normally listed "as supplied" from the factory before any field thinning. (Note: Local VOC regulations should be referred to for compliance

Some of the common solvents used in the formulation and in the thinning of protective coatings are listed below:

SOLVENT	COMMENTS
Alcohol's	Good solvent for highly polar resins such as phenolics and acetals. Also used in solvent-based, self-curing silicates.
Aromatics	Compounds of the benzene family, including toluene, xylene, and high boiling homologues; major solvent for chlorinated rubber coal tar and certain alkyds; used in combination with other solvents in vinyl, epoxy and polyurethane vehicles.
Esters	Have distinctive, usually pleasant odour; commonly used in epoxy and polyurethane vehicles.
Ethers	High boiling solvents sometimes used to achieve vehicles with high flash points.
Ketones	Compounds of the acetone family including methyl ethyl ketone (MEK), methylisobutyl ketone (MIBK) and cyclohexanone; most effective solvent for vinyl's but often used in epoxy and other formulations.
Mineral Spirits	Often called painter's naphtha; high boiling petroleum product used for oil and alkyd vehicles.
Water	Only thinner for latex and emulsion coatings, as well as for certain water-based inorganic zinc silicate primers.

IV. BINDER (RESIN) TYPES & PROPERTIES

In order to produce a film that performs satisfactorily in a given environment, the coating, after application, must convert to a dense, solid membrane. Some materials can accomplish this simply by releasing their solvents while others must go through a series of complicated chemical reactions, sometimes requiring the application of heat after evaporation of the solvent.

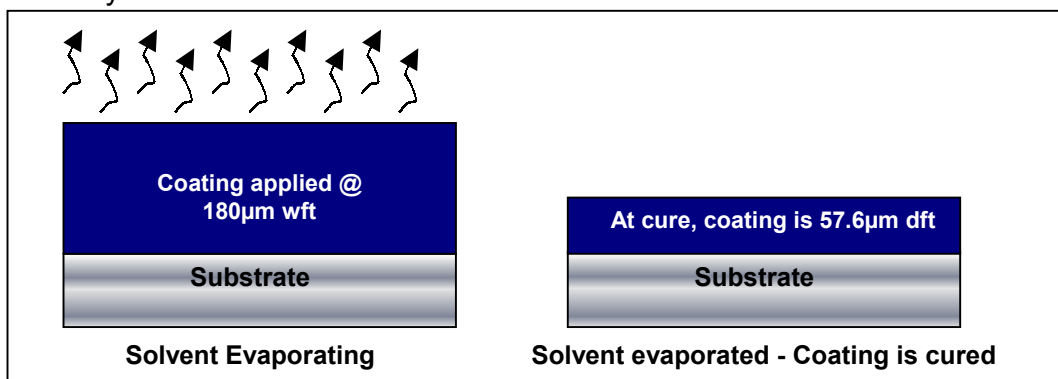
The ability of a resin to form a dense, tight film is directly related to its molecular size and complexity. The polymers that are capable of forming such films simply by the evaporation of solvent are initially of very high molecular weight and are not capable

of further chemical reaction. Because of their large size, these polymers must be kept in a dilute solution, and coatings based on them, have a low volume solids. Resins of low molecular weight, although requiring chemical conversion to attain polymer structures of suitable size, have the advantage of being able to produce higher solids combinations.

Five general types of binders or film formers are used to formulate protective coatings for the chemical processing and marine industries. The four organic binders include solvent evaporation, drying oil or oxidation, co-reacting or polymerisation and condensation type coatings. Inorganic vehicles are the fifth class of binders. A brief description of these film formers follows:

A. SOLVENT EVAPORATION - based on high molecular weight, chemically resistant polymers which form films by evaporation of solvents; low volume solids which sometimes are increased by the addition of lower molecular weight resins or plasticizers. See Table on Page 47. Examples of solvent evaporation cured coatings include:

1. **Polyvinyl Chloride Copolymers** - range from low film build materials (25 to 50 microns per coat) to high build tank linings (125-250 microns per coat) and for maintenance coatings.
2. **Chlorinated Rubbers** - formulated in a variety of combinations with modifying resins to attain higher solids; chemical and water resistance varies with type and amount of modifier used; usually limited to applications at 50 to 75 microns (μm) per coat, although some newer materials are capable of building at 100 to 150 dry microns



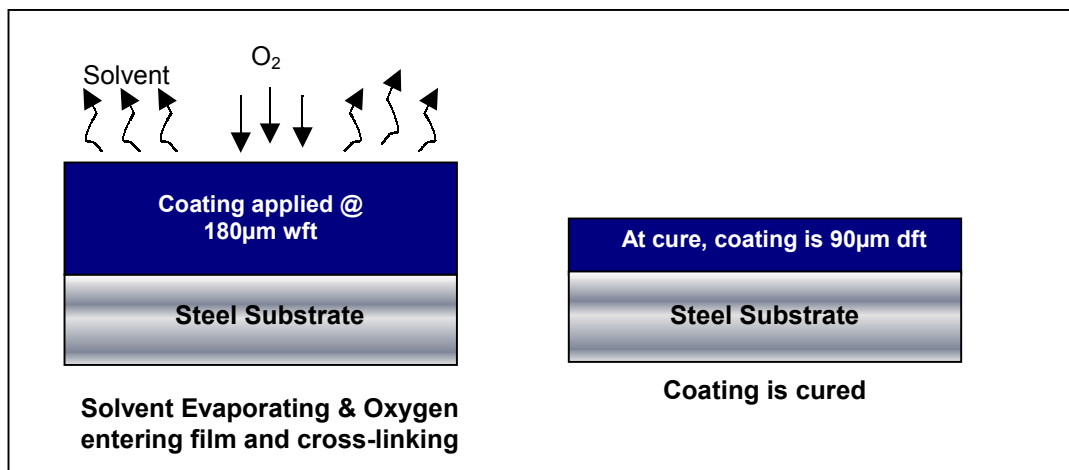
One Step Solvent Evaporation Curing Process for 32% SBV Product

3. **Polyacrylics** - have excellent colour and gloss stability in outdoor weathering; chemical resistances are not as high as for vinyl copolymers or chlorinated rubbers; often used in mixture with polyvinyl chloride copolymer or as final coat.

Two of the primary limitations of the solvent evaporation cure type coatings are their limited dft range per coat and their sensitivity to strong solvents.

B. OXIDATION OR DRYING OIL TYPES - low molecular weight resins capable of converting to tough films through intermolecular reactions with oxygen catalysed by the presence of metal soaps, such as cobalt octoate. See Table on Page 48. Examples:

1. **Natural oils**, such as linseed, tung and soya oils which contain reactive sites which are activated by oxygen in their molecules; very slow in converting to cured films.
2. **Alkyds** - natural oils which are chemically modified by reactions with synthetic acids or alcohol's to improve rate of cure, chemical resistance or ultimate hardness; degree of modification is designated by one of the following terms: "long oil" (relatively minor modification), "medium oil" (moderate modification), or "short oil" (considerable modification).



Two-step Oxygen Induced Curing Process for 50% SBV Alkyd Product

3. **Varnishes** - natural oils or alkyds containing dissolved or reacted resins such as chlorinated rubber or phenolic to increase hardness and chemical resistance.
4. **Epoxy Esters** - a type of alkyd in which a high molecular weight epoxy resin is used in the chemical modification; usually have a higher degree of chemical resistance than normal alkyds, but have poor exterior weathering properties.
5. **Uralkyds (Urethane oils)** - a type of alkyd modified by reaction with tolylene diisocyanate which imparts excellent abrasion resistance, but also detracts from exterior weathering properties.

NOTE: The drying oil types convert to their cured state by taking up atmospheric oxygen; consequently, the rate of cure is most rapid at the air surface and slowest at the substrate interface. Because of the difference in cure rate through the thickness of the film, care must be taken to avoid wrinkling resulting from excessive film thickness or too rapid recoating.

C. POLYMERISATION OR CO-REACTING TYPES - unlike the solvent and drying oil type film formers, these materials have two or more separately packaged components which are combined just before application. Reaction rates between the components are modified somewhat by the presence of solvents. However, the co-reacting coatings, after mixing of the components, have limited pot life which is reduced by increased application temperatures and usually extended by lower ones. See Table on Pages 49 - 50. Examples:

1. Epoxy coatings - which cure at ambient temperatures are based on low molecular weight resins containing the reactive epoxy group at each end of the molecule. This group has a particular affinity for ammonia derivatives called amines. The amine group may be strung along a short molecule, the polyamine, or may be more widely scattered on a long chain, the polyamide. In both cases, the amine containing chain ties the epoxy resin molecules together in a dense cross-linked structure. The film obtained with the polyamine is usually more dense, having better solvent and chemical resistance, but decreased flexibility and of a more brittle character than that of the polyamide. Modification of these curing agents by prereacting them with a portion of the epoxy or other resins is sometimes undertaken by coatings manufacturers to improve the cure properties. These modified amines are called amine adducts.

The water resistance and, to a degree, the acid resistance of the various room temperature epoxy coatings can be improved by the incorporation of high concentrations of selected coal tar resins into the formulas. These epoxy coal tar coatings are often used in areas where a high order of water resistance is required without the need of the solvent resistance or appearance of the base epoxy system.

Epoxy coatings are characterised by hard films of limited flexibility with a high order of chemical and, except for the coal tar modifications, solvent resistance. They are, however, much more susceptible to attack by oxidising agents such as chlorine gas, peroxides and nitric acid than are coatings based on vinyl copolymers or chlorinated rubber. A major weakness is their high rate of chalking in exterior exposures.

With the enactment of the VOC regulations, there are now several different types of high-build **100% solids epoxy coatings** based on Bisphenol A and Bisphenol F (novolacs) resins. These coatings are generally used in tank lining applications although they can be used for non-immersion applications

on structural steel and concrete. Most of them react very quickly and therefore possess a very short pot life. In addition, the novolacs tend to blush in many situations, so extra care and preparation is required to remove any amine blush when applying multiple coats of 100% solids novolacs in order to avoid massive delamination problems.

Special plural component spray equipment with heat traced lines is required to apply some of these 100% solids epoxy coatings, whereas other formulations are sprayable with 65:1 or 73:1 ratio airless pumps but the hose length may be the limiting factor due to the short pot life. Special training and equipment is required to apply many of these coatings. Generally the dft ranges from 250 to 625 microns per coat.

In addition, there are some 100% solids, low-film build penetrating sealers that are used in special applications. The dft ranges on these products normally range from 25 – 50 microns. (Note: if these thin-film products are applied too thick they will run and sag.)

- 2. Polyurethane coatings** are based on the reaction of a group of chemicals, the diisocyanates with resins or chemicals containing alcohol or amine substituents in their structures. The diisocyanates have a high order of toxicity and must be chemically modified to permit their use in protective coatings. The most common practice is to make polyurethane prepolymer by reacting two molecules of the diisocyanate with one molecule of a resin or chemical compound containing two alcohol groups in their structures.

The polyurethane prepolymer is capable of further reaction with resins or chemical compounds containing amine groups (a very rapid reaction) or alcohol groups (much slower).

A third possible reaction that is sometimes useful but often a nuisance is with water. If a free isocyanate group comes in contact with water, it will decompose to form an amine and simultaneously release carbon dioxide gas. Neighbouring isocyanate groups will react immediately with the amine of initiate the promotion of a complex polymer structure. This reaction with moisture is the basis for the **one package moisture-curing polyurethane**.

Another approach to polyurethane coatings is to mix the prepolymer with a resin containing alcohol groups at the time of application to form a **two-package polyurethane**. The choice of the second resin will determine, to a large degree, physical properties such as hardness and flexibility in the cured film.

When properly formulated, applied and cured, polyurethane coatings have outstanding toughness and abrasion resistance with chemical properties

similar to the epoxies. Unlike the epoxies, they do not have good adhesive properties to steel and concrete without a suitable primer.

- D. CONDENSATION COATINGS (HEAT CONDENSING)** - are based on resins which interact to form cross-linked polymers when subjected to temperatures of 175⁰ C to 205⁰ C. The use of such materials is limited to tank linings and objects, or structures which can be handled in an oven. Many of the so-called "powder coatings", as well as high temperature silicones and baked phenolics, fall into this category. See Table on Pages 49 - 50.

The oldest of the condensation coatings is the pure phenolic. Applied in several coats to a thickness of 150 microns and baked to a temperature of 190⁰C, the phenolic film becomes extremely hard and chemically resistant. It is, however, extremely brittle and is rapidly attacked by caustic solutions.

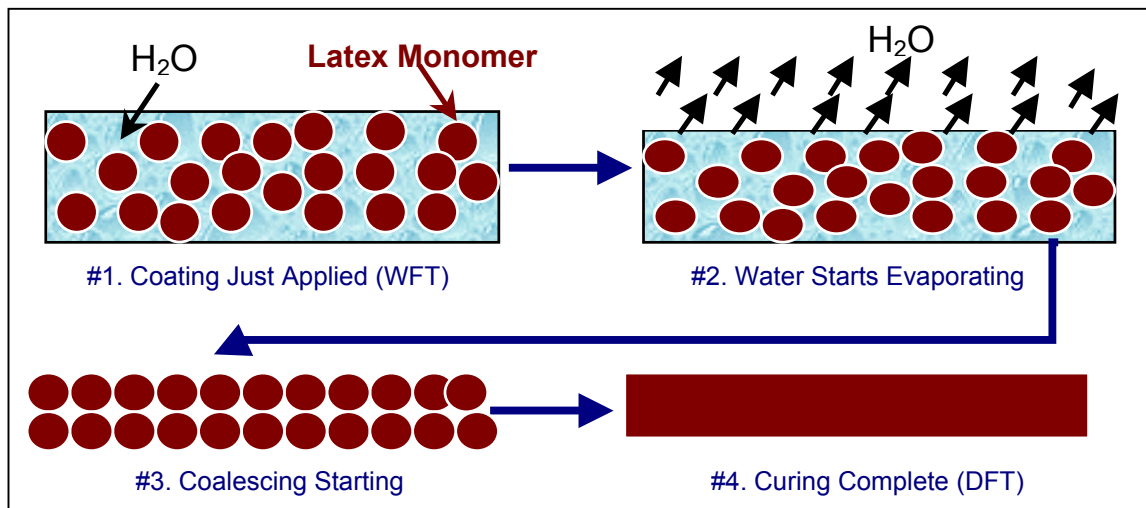
- E. INORGANIC SILICATES** are binders which do not contain organic (carbon) structures in their composition. For this reason they are non-combustible and are unaffected by sunlight or organic solvents. Their outstanding use is to serve as a matrix for metallic zinc dust in zinc inorganic primers. There are several approaches to silicate binders, but each appears to depend on the development of an extremely adhesive form of silica during its cure. Examples follow. See Table on Page 51.

- 1. Post-cured inorganic silicates** are based on water solutions of alkali silicates pigmented with zinc dust or zinc dust and a metal oxide. The dust or powder is mixed into the liquid at the time of application. A 62.5 to 75 micron film spray applied, dries very rapidly, usually within one hour. At this point, it is very hard, but remains water-soluble. Application of an acid curing solution is necessary to achieve the conversion of the silicate to the insoluble silica.
- 2. Self-curing, water based silicates** are mixtures of alkali silicates and colloidal silica pigmented with zinc dust or zinc and a metal oxide. As with the post-cured materials, the separately packaged powder is dispersed in the vehicle at the time of application. The development water insolubilisation for this type of film is dependent on the absorption of carbon dioxide from the atmosphere during the curing process.
- 3. Self-curing based silicates** are organic esters which gradually hydrolyse upon exposure to moisture produce a binder which appears to be essentially identical to those of the water-based types. A major advantage of this type of film is its almost instant resistance to rain or flowing water. Although most of the commercially available inorganic coatings in this category are sold as two separately packaged components, "one package" products are proving to be practical.

The inorganic zinc primers are recognised as having many of the benefits of galvanising, while providing a much more suitable surface for top coating than the latter. They should not be confused with the so-called zinc-rich organic primers. See Table on Page 51.

- 4. Organic zinc rich primers** - The use of metallic zinc as the pigmentation in a variety of vehicles, most notable in epoxy-polyamide combinations, does result in primers having outstanding anticorrosive properties. However, field experience has demonstrated that coating systems employing these zinc-rich organic primers do not have the longevity of those based on the inorganic zinc silicates.

- I. **COALESCENCE CURED COATINGS** – Some coatings, primarily one-component water based acrylics cured by a special process referred to as coalescence. In this process the water is the primary solvent. As the water evaporates from the film,



the individual monomers move closer together and if the temperature is warm enough (as a rule above 10°C) special coalescent solvents on the outer portion of the monomers allow the monomers to join together to form a more complex and stronger polymer. A graphic example of the process of coalescence is shown above.

Products that cure by coalescence are sensitive to moisture (in the form of high relative humidity or rain) and to freezing temperatures during their curing process. In high humidity conditions it may take several weeks for the product to achieve full cure even though it will appear dry. During this time, if adhesion tests are performed prematurely, they will often produce invalid results. Care should be taken to ensure that these products are applied and allowed to cure within the proper environmental conditions as stated on the manufacturers product data sheet.

- II. PATENTED PROPRIETARY ENGINEERED SILOXANE COATINGS – These coatings consisting of a group of several Ameron coatings represents state-of-the-art breakthroughs in coatings technology. The technology used to formulate these coatings is proprietary and patented. A brief discussion of the benefits and unique advantages of each of these coatings is listed below. For further information regarding the suitability of these products to your particular application contact your local Ameron representative and consult the latest product data sheets.

PSX 700 – The world's first weatherable epoxy. It combines the properties of both a high-performance epoxy and an acrylic polyurethane in ONE coat. This multi-purpose coating which can be applied directly over inorganic zinc and coated steel. Its adhesive strength of 2700 psi is far above traditional epoxies. In accelerated weathering QUV testing, the PSX 700 significantly surpassed the gloss and colour retention offered by typical aliphatic polyurethane topcoats. It is highly resistant to graffiti, stains and dirt accumulation. It is user-friendly to apply and is able to be sprayed, brushed or rolled without the need for thinning in most cases. The PSX 700 can be applied to structural steel, tank exteriors, concrete walls and floors, piping, offshore platforms, marine topsides and superstructures.

PSX 1001- A single-pack, high-gloss, acrylic polysiloxane topcoat that provides a polyurethane-like finish in one component without the isocyanate. The PSX 1001 is compatible with epoxy, alkyd and other types of primers and can be applied by brush, roll or spray. The PSX 1001 possesses an unlimited recoat time and exhibits excellent gloss retention.

V. COATING SYSTEMS – CONCEPT & FUNCTION OF EACH COAT

There is no perfect coating formulation that will satisfy the demands of every environment or set of application conditions. Usually a system approach consisting of a properly selected primer, intermediate, and finish coat provides the best answer to the requirements of a specific coating problem.

Sometimes the system approach involves selecting three different generic types of coatings from the same manufacturer. A common example of this approach is the system used on many highway bridges consisting of an IOZ primer (inorganic zinc), epoxy intermediate, and an acrylic polyurethane topcoat. In this coating system each coat provides distinctly different functions.

In other situations, all the coats may be based on the same or similar resin composition, but each coat may be formulated with a binder that contributes specific benefits to the overall system. For example the primer may contain a “wetter” resin than the intermediate or topcoat.

Let's briefly look at the functions and properties required for each of the coats in a conventional three coat coating system.

A. PRIMER COAT

A primer should meet most, if not all, of the following requirements:

1. Good adhesion to the surface to be protected when the latter has been cleaned or prepared according to specification
2. Provide a satisfactory bonding surface for the next coat
3. Possess the ability to stifle or retard the spread of corrosion from discontinuities such as pinholes, holidays, or breaks in the coating film
4. Contain enough chemical and weather resistance by itself to protect the surface for a time period in excess of that anticipated before application of the next coating in the system
5. Under certain conditions, notably tank linings, chemical resistance equivalent to the remainder of the system

Four types of primers that are commonly used over steel may be compared in their abilities to meet these requirements. (See Primer Comparison Table on Page 52.)

B. INTERMEDIATE COAT

Intermediate coats may be required in a system to provide one or more of the following properties:

1. Adequate film thickness of the system (body coat).
2. A uniform bond between the primer and the topcoat (tie coat).
3. A superior barrier with respect to aggressive chemicals in the environment. (May be too deficient with respect to appearance or physical properties to be a satisfactory finish coat.)

C. FINISH COAT

Finish coats are the initial barriers to the environment, but are also the surfaces that are seen by management and the public.

However, there are situations where the barrier to the environment will primarily be a function of the body or primer coat, while the finish coat serves to provide a pleasing appearance, a non-skid surface, a matrix for antifouling agents or other specialised purposes. Obviously, the chemical resistance of the finish coat in one of these situations must be sufficient to ensure its remaining intact in the environment.

VI. FORMULAS TO CALCULATE M² COVERAGE / LITRE & WFT TO DFT CONVERSIONS

With only two pieces of information you can calculate the theoretical M² coverage of any litre of paint no matter who manufactures it. If you know the solids by volume (as manufactured) and the dry film thickness (dft) you want to achieve, you can determine the coverage rate.

Here's how it's done:

$$\text{Theoretical coverage per M}^2/\text{Litre} = \frac{(10 \times \% \text{ Solids by Volume})}{\text{dry film thickness in microns}}$$

The above is the theoretical coverage of one litre and not the practical coverage as it was necessary to hold all terms constant which is not the case with actual applications of coatings. The theoretical coverage is based upon making the following three “variables” constants:

1. Solids by volume
2. Coating is applied at exactly the set dry film thickness (Few coatings are applied at a uniform dft.)
3. There is no waste (Assumes every drop of paint is used.)

Most protective coatings contain solvents that evaporate from the film so this loss must be factored out of the coverage. Although protective coatings are applied at many different film thicknesses depending upon the coating type and the environment, they are rarely applied at uniform dft (as we assumed to determine our theoretical coverage) and they are not applied at 100% efficiency without any waste.

If every drop in the container is applied to a surface without any loss, the litre of material will cover the “theoretical” area. In most instances, the liquid contains a volatile solvent, which upon evaporating reduces the thickness of the film. For instance, if the wet coating that contains 50% volume of solvent is applied at 50 microns wet film thickness (WFT); the film, after drying, will be 25 microns dry film thickness (DFT). Since ½ of the wet film thickness is solvent, it evaporates.

Example: What is the theoretical m² coverage of a coating containing 30.0% solids by volume solids that is applied at a dry film thickness of 25 microns?

$$\text{Theoretical coverage} = \frac{(10 \times 30)}{25} = 12 \text{ m}^2 / \text{litre}$$

Obviously no applicator can get every drop of material out of the container, nor can he avoid leaving some of it in or on the application equipment. More importantly, there will be considerable losses, particularly in spray painting, due to the configuration of the piece being painted, wind or air movement and overspray or missing the target. The magnitude of these losses will vary depending on the object being coated, the type of application equipment, and the wind movement.

With the same coating, "Painter A", spraying a flat wall indoors with a spray pump in good condition will get considerable more microns per pass than "Painter B" spraying 5cm channel steel in a 20 mph wind and with a badly maintained spray gun that clogs up every 10 minutes. (Note: Some contractors figure on a 20 - 30% loss factor for normal airless spraying and 10 – 15 % for rolling.)

Example: What is the practical m² coverage at 25 microns DFT of the 30% solids by volume coating of material from the previous example if we anticipate a spray losses of 20% and 30%?

$$\text{Practical coverage} = (\text{Theoretical Coverage}) - \frac{\text{Theoretical Coverage} \times \% \text{ Loss}}{100}$$

For a 20% loss factor the answer is:

$$(12) - \frac{12 \times 20}{100} = 12 - 2.4 = 9.6 \text{ m}^2 / \text{litre}$$

For a 30% loss factor the answer is:

$$(12) - \frac{12 \times 30}{100} = 12 - 3.6 = 8.4 \text{ m}^2 / \text{litre}$$

Dry Film Thickness Calculation from wet film thickness

To determine the dry film thickness of a coating use the following formula:

$$\text{Dry Film Thickness (dft)} = \frac{(\text{Wet film thickness} \times \% \text{ Solids by Volume})}{100}$$

For instance, using our same 30% solids by volume gallon from the previous example, if we apply the product at 150 microns wft (wet film thickness), we calculate the dry film thickness as follows:

$$\frac{(150 \times 30)}{100} = 45 \text{ microns dft}$$

Wet Film Thickness Calculation from dry film thickness

Conversely, if we know the dft that we want to achieve and we know the solids by volume, we calculate the wft (wet film thickness) as follows:

$$\text{Wet Film Thickness (wft)} = \frac{\text{Dry film thickness}}{\% \text{ Solids by Volume} \times 100}$$

Therefore, if we want to obtain a 50 microns dft for a 30% solids coating how many wet mils do we need to apply to achieve the 50 microns dft?

$$\text{Wet Film Thickness (wft)} = \frac{(50 \times 100)}{30} = 166.67 \text{ microns wft (wet film thickness)}$$

It is important to recognise that these calculations assume that there is no additional thinning by the contractor. If the material is thinned, it reduces the dft achieved by the same wft.

Wet Film Thickness Calculation (when thinner is added)

We calculate the wft of a product when additional thinner is added as follows

$$\text{Wet Film Thickness (wft)} = \frac{\text{Dry film thickness} [1 + (\% \text{ Thinner by Volume} / 100)]}{(\% \text{ Solids by Volume} / 100)}$$

For example, let's say the contractor thinned the 30% solids material above by adding 1 litre (**20%**) of thinner to 5 litres of paint. We still want to achieve 50 microns dft, so how much wft do we need to obtain 50 microns dft?

$$\text{Wet Film Thickness (wft)} = \frac{50 [1 + (20 / 100)]}{(30 / 100)} = 200 \text{ microns wft}$$

As you can see by adding 1 litre of thinner per 5 litres the contractor now needs to apply 200 microns wft instead of 166.67 microns wft to achieve the same 50 microns dft.

Table 1: Solvent Evaporation or Coalescent Type Coatings

Generic Coating Type	Chlorinated Rubber, Oil Chlorinated Rubber	Water-based Acrylic
Cure Type	Solvent Evaporation	Solvent evaporation & Coalescence
Effect of Sunlight	Slow Surface Chalk	Prolonged chalk resistance
Wet or Humid Environments	Excellent	Fair
Industrial Atmospheric Contaminants a. Acid b. Alkali c. Oxidising d. Solvents	Excellent Excellent Excellent Limited	Good Good Good Limited
Splash & Spillage of Industrial Compounds a. Acids b. Alkali c. Oxidising Agents d. Solvents	Very Good Very Good Good NR	Poor Poor Poor NR
Water Immersion	Ship hulls	N/R
Tank Linings	Swimming pools	Not used
Physical Properties a. Abrasion resistance b. Heat Stability c. Hardness d. Gloss e. Colour availability	Good Limited Good Semi gloss to matt Wide range	Fair Limited Good Wide Range Full Range
Additional notes	Traditionally low solids and low film build. New high-build types becoming available.	Use as primer and finish coat on metal, concrete and drywall
Product Examples		Amercoat 148, Amercoat 220

Table 2: Oxidation or Drying Oil Types

Generic Coating Type	Silicone Alkyd	Epoxy Ester	Alkyd	Uralkyd
Cure Type	Oil type	Drying oil	Drying Oil	Oil type
Effect of Sunlight	Slow surface chalk	Rapid surface chalk	Yellowing & surface chalk	Slow surface chalk
Wet or Humid Environments	Fair to good	Fair to good, will yellow	Poor to good, will yellow	Fair
Industrial Atmospheric Contaminants a. Acid b. Alkali c. Oxidising d. Solvents	Fair to good Fair Fair Limited	Fair Fair Poor Limited	Fair to good Poor Fair Limited	Poor to fair Fair Poor Good
Splash & Spillage of Industrial Compounds a. Acids b. Alkali c. Oxidising Agents d. Solvents	Not recommended	Not recommended	Not recommended	Not recommended
Water Immersion	Not recommended	Not recommended	Not recommended	Not recommended
Tank Linings	Not used	Not used	Not used	Not used
Physical Properties a. Abrasion resistance b. Heat Stability c. Hardness d. Gloss e. Colour availability	Fair Good Fair Good Full range	Fair Fair Good Wide range Full range	Fair Fair Fair Wide range Full range	Excellent Good Excellent High gloss Limited range
Additional notes	Good colour and gloss retention. Dry heat resistance to 120°C.			
Product Examples			Amercoat 5105, Amercoat 5401, Amercoat 5405	

Table 3a: Polymerisation or Co-reacting & Condensation

Generic Coating Type	Coal Tar Epoxy	Epoxy, Amine Cure	Epoxy, Polyamide Cure	Epoxy Phenolic
Cure Type	Co-reacting	Co-reacting	Co-reacting	Condensation
Effect of Sunlight	Surface chalking	Yellowing & surface chalking	Yellowing & surface chalking	Tank lining
Wet or Humid Environments	Excellent	Very good, may yellow	Very good, may yellow	Tank lining
Industrial Atmospheric Contaminants a. Acid b. Alkali c. Oxidising d. Solvents	Excellent Excellent Limited Limited	Good Excellent Limited Excellent	Good Excellent Limited Excellent	Tank lining
Splash & Spillage of Industrial Compounds a. Acids b. Alkali c. Oxidising Agents d. Solvents	Good Good N/R N/R	Fair Excellent N/R Excellent	Poor – fair Excellent N/R Very good	<u>As Tank Lining</u> Cer. Fatty acid Very good N/R Outstanding
Water Immersion	Marine pilings Sewage basins	Tanks, Sewage basins	Ship hulls	As tank lining
Tank Linings	Marine ballast tanks & crude oil tanks	Marine cargo / ballast tanks; fuel storage tanks	Marine cargo / ballast tanks: fuel storage tanks	Wide range solvents & foods: caustic cartage
Physical Properties a. Abrasion resistance b. Heat Stability c. Hardness d. Gloss e. Colour availability	Limited Excellent Very hard None Black, red	Good Good Very hard Wide range Full range	Good Good Hard Wide range Full range	Outstanding Very hard Limited
Additional notes	Timing between coats is critical to obtain intercoat adhesion	Cure rate and pot life affected by temperature (true of all epoxies). Appearance and weathering problems solved by use of acrylic polyurethane finish coats		Usually high-bake coating. Low-bake type has decreased flexibility.
Product Examples	Amercoat 78HBB	Amercoat 235, Amercoat 90S	Amercoat 385, Amercoat 370, Amerlock 400	

Table 3b: Polymerisation or Co-reacting & Condensation

Generic Coating Type	Phenolic	Moisture-cured Polyurethane	Polyurethane (two package)
Cure Type	Condensation	Co-reacting	Co-reacting
Effect of Sunlight	Tank lining	Aliphatic – Minimal chalking	Aliphatic – Minimal chalking
Wet or Humid Environments	Tank lining	Very good	Very good
Industrial Atmospheric Contaminants a. Acid b. Alkali c. Oxidising d. Solvents	Tank lining	Good Good Poor Excellent	Very good Excellent Limited Excellent
Splash & Spillage of Industrial Compounds a. Acids b. Alkali c. Oxidising Agents d. Solvents	As Tank lining Ltd. min. acid N/R N/R Outstanding	 Fair Fair N/R Good	 Good Good N/R Excellent
Water Immersion	As tank lining	N/R	Ship hulls
Tank Linings	Outstanding for solvents, aqueous solution & food products	Not used	Marine cargo / ballast tanks. Fuel storage tanks
Physical Properties a. Abrasion resistance b. Heat Stability c. Hardness d. Gloss e. Colour availability	Good Excellent Excellent Excellent Clear or dark shades	Excellent Good Excellent Range Limited	Outstanding Good Excellent Range Full range
Additional notes	High-bake coating. Lining should not be cleaned with alkali solution.	Have ability of curing at low temperatures. Aromatic urethanes discolour and chalk rapidly in sunlight. Acrylics have prolonged resistance to yellowing & chalking. Care must be taken to avoid moisture contact before cure.	
Product Examples		Amercoat 462	Amercoat 450 S

Table 4: Zinc-Rich & Other Primers

Generic Coating Type	Inorganic Zinc Post Cured	Inorganic Zinc Self-Cure Solvent-Based	Inorganic Zinc Self-Cure Water-Based	Organic Zinc Two Package	Moisture Cured Organic Zinc-rich
Cure Type	Co-reaction	Hydrolysis	Carbon dioxide	Co-reacting	Hydrolysis
Effect of Sunlight	Unaffected	Unaffected	Unaffected	Surface chalking	Discoloration
Wet or Humid Environments	Outstanding	Outstanding	Outstanding	Very good	Outstanding
Industrial Atmospheric Contaminants a. Acid b. Alkali c. Oxidising d. Solvents	Must topcoat Must topcoat Must topcoat Outstanding	Must topcoat Must topcoat Must topcoat Outstanding	Must topcoat Must topcoat Must topcoat Outstanding	Must topcoat Must topcoat Must topcoat Excellent	Satisfactory Satisfactory Satisfactory Very good
Splash & Spillage of Industrial Compounds a. Acids b. Alkali c. Oxidising Agents d. Solvents	N/R N/R N/R Outstanding	N/R N/R N/R Outstanding	N/R N/R N/R Outstanding	N/R N/R N/R Very good	N/R N/R N/R Very good
Water Immersion	With suitable topcoat on ship hulls and other marine structures.				N/R
Tank Linings	Marine cargo / ballast tanks. Fuel storage, including floating roof tanks.				Not used
Physical Properties a. Abrasion resistance b. Heat Stability c. Hardness d. Gloss e. Colour availability	Outstanding Outstanding Outstanding None Grey or tints of grey	Outstanding Outstanding Outstanding None Grey or tints of grey	Outstanding Outstanding Outstanding None Grey or tints of grey	Good Good Good Flat Grey or tints of grey	Very good Good Good Flat Grey
Additional notes	As primers for organic systems, provide greatly extended service life. Special application technique or use of tie coat may be required to avoid solvent bubbling in organic topcoat. Alkyds always require topcoat.				
Product Examples	Dimetcote 3A	Dimetcote 21-5	Dimetcote 9,	Dimetcote 302, Amercoat 68	Amercoat 460

Table 5: Primer Comparison Table

Primer Type/ → Requirement ↓	Alkyd or Oil	Mixed Resin	Resin Identical to Topcoats	Inorganic Zinc
Bonding to Surface	Usually have the ability to wet and bond to most surfaces and are somewhat tolerant of substandard preparation.	Adhesive properties are major considerations of formulation. Not quite as tolerant of substandard surface preparation as oil types.	Adequate for proposed use when surface is properly prepared.	Outstanding adhesion to properly cleaned and blasted, roughened surfaces.
Adhesion of Topcoats	Satisfactory for oil types. Usually unsatisfactory for vinyl's, epoxies and other synthetic polymers. Are softened and lose integrity by attack from solvent systems of these topcoats.	Formulated for special range of topcoats.	Usually part of specific generic system. Maximum permitted dry time before application of second coat must be observed.	Fits into a wide range of systems. "Tie Coat" may be required. Specific recommendation should be obtained for immersion systems.
Corrosion Suppression	Limited. Alkali produced at cathode and corrosion battery attacks film (saponification) and causes disbonding. Results in spread of undercut corrosion.	Usually formulated with good resistance to alkali undercut and may contain inhibitive pigments for a degree of corrosion inhibition.	Often contain inhibitive pigments for degree of corrosion inhibition. Resistance to "alkali undercut" is variable.	Outstanding in ability to resist disbonding and under film corrosion. Anodic property of metallic zinc protects minor film discontinuities.
Protection as a single coat	Limited by severity of exposure	Limited by severity of exposure	Limited by severity of exposure	With very few exceptions will protect without topcoat
Chemical Resistance	Typical of alkyds	Usually of lower order of resistance than that of topcoats.	Typical of system.	Not resistant to strong acids and alkalis. Has outstanding solvent resistance.

SECTION 4

CHARACTERISTICS OF CHEMICAL COMPOUNDS

Updated: 02/2002

I. WATER, THE MOST IMPORTANT CHEMICAL IN CORROSION

In the first section of this manual entitled, "*Principles of Corrosion*", we stressed the role of water in electrolytes. We have seen very clearly that corrosion is an electrochemical process involving ions. Water is the necessary solvent envelope for these ions. Therefore, at this point we wish to reemphasize that water is, with some exceptions, always involved in chemical corrosion processes.

Water is called the "universal solvent" because of its unique ability to dissolve or mix with a great number of substances. With time, it is capable of migrating into and through the most impervious of organic films. Since water is such a strong solvent, the pure chemical can only be obtained by successive distillations or by chemical treatment (deionized water). Although pure water has high penetration properties with respect to organic coatings, it is a poor electrolyte. Substances that dissolve in water decrease its penetrating power. They do this by lowering the vapour pressure of the water. At the same time these substances increase the corrosivity of the water by making it into a strong electrolyte.

A. BLISTERING OF PROTECTIVE COATINGS IN AQUEOUS IMMERSION AND HIGH HUMIDITY

Since the protective coatings sold for corrosion are represented as barriers, an explanation of water-filled blisters developing on ship bottoms and water tank linings is in order.

Water, probably as a vapour, does penetrate organic films. Although a coating will hold out liquid water, it will allow the smaller molecules of water vapour to pass. The rate at which this transmission occurs, varies with the chemical nature of the film, its thickness, the difference in pressure between its wet and dry sides, the temperature and purity of the water and the electrical potential of the steel.



Blisters on interior of water tank due to osmotic blistering

Photo Courtesy of AEC Engineering, Inc.

For optimum performance in aqueous immersion a protective coating must:

1. Be formulated with resins having low rates of moisture vapour transmission (MVT),
2. Not contain water soluble additives,
3. Be bonded to the steel and between coats by mechanisms that are not sensitive to the very small concentration of moisture,
4. Not contain voids in the film or between the film and the substrate,
5. Not be applied over surfaces which are contaminated with moisture sensitive substances, and
6. Not be applied over cathodically protected surfaces capable of potentials in excess of 0.85 volt, unless system has been designed for this application.

The first three precepts in the above list are the coatings formulator's problem. The 4th and 5th items are the responsibility of the applicator, while the designer, specification writer or owner/operator must accept responsibility for the 6th item.

For a protective coating formulated for a specific immersion condition to develop blisters in that service, there must be a decreasing pressure gradient running from the solution side of the film to a void in or behind the film. Under these conditions water vapour will pass through the film on each side of the film. The driving force is the vapour pressure of the solution. However, traditionally it is described in terms of the **osmotic pressure**.

Osmotic pressure describes the ability of a solution to dilute itself by pulling water from the atmosphere, other solutions and some solid materials. Highly concentrated salt solutions have high osmotic pressures while that of absolutely pure water is zero. Conversely, pure water has a high vapour pressure while the vapour pressure of the concentrated salt solution is low. Furthermore, raising the temperature of a solution increases its osmotic pressure, thus increasing its ability to penetrate the coating film. The equation which describes the osmotic pressure of dilute solutions is as follows:

$$\pi V = n RT$$

Where the π is the osmotic pressure, V the volume of solution n the number of moles of dissolved substance, T the absolute temperature in degrees Kelvin and R is a constant.

In a typical example of immersion blistering, a small amount of moisture vapour migrates through the coating and condenses in a void between the film and

substrate. Usually, it finds some water soluble substance with which to form a concentrated solution having a high osmotic pressure. Water is then pulled through the film to dilute this solution and an osmotic blister is formed.

At times, blistering results from misuse of a coating. For example:

A tank lined with a 250 micron epoxy film has performed satisfactorily in a hot, very concentrated brine solution. Because of a change in plant operations, the tank is switched to ambient temperature and deionized water service. After one month blisters appear in the lining.

In this example, the mistake was made of changing to a solution of higher water vapour pressure. The hot, concentrated brine was a solution of much lower water vapour pressure. In neither instance was the coating formulated with respect to its moisture vapour transmission rate or bonding ability to hold up in the new service. The higher moisture pressure in the new service increased the penetration of water into the film where osmotic blistering could take place.

B. DISBONDING WITHOUT BLISTERING

Some coating systems, particularly those of a relatively brittle nature, will lose adhesion without exhibiting blistering. The mechanism of a failure is identical to that in the previous section. However, the adhesive strength between the coating and the substrate is less than that required to distort the film into a blister. As a result the condensing water takes the path of least resistance and spreads under the film.

C. IMPRESSED CURRENTS AND BLISTERS

Structures immersed in seawater or buried in the ground are sometimes protected by impressed currents or sacrificial anodes. Protective coatings are used in conjunction with these modes of cathodic protection to decrease current demands. If through malfunction or poor design of the system, the potential of the steel becomes more negative than -0.85V (relative to a copper/copper sulphate reference cell) hydrogen gas is likely to be generated between the film and the steel. Here the pressure of the forming gas may easily be greater than the adhesive strength of coating to substrate. The coating becomes disbonded and osmosis takes over.

D. BLISTERING IN NON-IMMERSION

Protective coating systems for non-immersion do not ordinarily require the same degree of resistance to moisture vapour transmission and quality of bonding as those used for immersion. However, some exposures where heat and extremely high humidities, or where splash, spill or spray prevail, are as aggressive as immersion. In fact some areas, because of the high availability of oxygen from the

atmosphere, can be even more troublesome. The selection and application of coatings for these conditions require as much concern as for immersion service. The Cleveland Humidity Cabinet develops just such a test condition. As such, it is a severe test for the rapid testing of coatings in the laboratory.

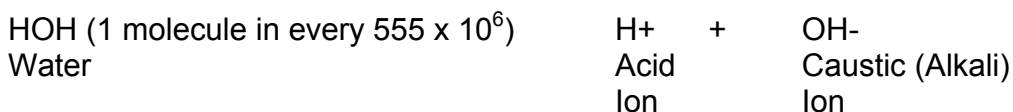
In addition, when coatings are applied over porous primers, such as inorganic zinc's most coating manufacturers recommend that a "mist" coat of the subsequent coat be applied before applying a full coat at normal thickness. Since the zinc is porous, this "mist" coat (usually @ 15 – 20 micron dft) allows air or gasses in the pores to escape through the thin film. If the intermediate or topcoat is applied too thickly over the inorganic zinc (IOZ), the air in the pores is compressed and tries to escape. Depending upon the thickness of the overcoat and the speed at which it sets up, either blistering, cratering or pinholing are the common end results.



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E. ACIDS, ALKALIS & NEUTRAL SALTS

In discussing electrolytes in the section on corrosion batteries we pointed out that many substances which dissolve in water split into ions, some carrying a positive charge, and others a negative. However, pure water itself does split into ions. The degree of this splitting is very low, about one molecule in every five hundred and fifty-five million, and is not sufficient for carrying an electrical current.



The H⁺, proton or acid ion, is numerically equal to the OH⁻, hydroxide or caustic ion. In very simplified terms, chemical compounds that liberate H⁺ in solution are acids. Those that liberate OH⁻ are called alkalis, caustics or bases. These compounds which do not change the equal balance of H⁺ and OH⁻ of pure water are called neutral salts. NaCl is a good example of a neutral salt.

The concentrations of H⁺ and OH⁻ in a solution may conveniently be described by a scale called pH. If we use the symbolism (H⁺) and (OH⁻) to signify that we mean the concentration of the ion inside the parentheses, then the mathematical expression for pH definition is:

$$\text{pH} = -\log_{10} (\text{H}^+) \text{ or expressed differently as } (\text{H}^+) = 10^{-\text{pH}}.$$

pH measurements are conveniently and accurately made by a pH meter or less accurately by pH paper. The paper is impregnated with coloured indicators set to change from one colour to another at a preset but approximate pH.

The midpoint of the pH scale, 7, indicates an equal balance of H^+ and OH^- , or neutrality. This does not necessarily mean that the solution is not corrosive. Although pure water has a pH of 7, many strong electrolytes have the same value. pHs lower than 7 signify an acid condition while those above 7 indicate alkalinity. The pH of the strongest acids is 0, and the strongest alkalis 14.

The pH Comparison Chart on the next page shows the values for some common solutions. Each unit indicates a tenfold increase in H^+ or OH^- over the preceding number. Thus, a pH 3 mixture has 100 times the H^+ concentration of pH 5, while the concentration of OH^- at pH 12 is 1000 times that at pH 9. Note the relatively low concentrations of hydrochloric and sulphuric acids required to approach pH 0; also observe that a 10% caustic soda solution has a pH 14. Does this mean that a 20% hydrochloric acid solution can only be slightly stronger than a 4% one or that a 10% soda caustic solution is the strongest alkali attainable? The answer to both questions is "No". It is true that the ability of an acid or alkali to ionise is limited by its concentration in water. However, the unionised molecules serve as a reservoir for either H^+ or OH^- ions as they are used up in a reaction. In other words, a 20% hydrochloric acid solution will do a great deal more damage to a concrete or steel surface than will a 4% solution.

II. ACIDS AND CORROSION

As the concentration of H^+ increases, electrolytes become more corrosive and have a greater ability to penetrate protective coatings. Increasing the temperature of an acid solution makes it extremely aggressive.

Much of the acid corrosion which is experienced in industrial complexes is the work of weakly acid solutions resulting from condensed atmospheric moisture which has taken up fumes, solids or aerosols of an acidic nature. Usually these agents are combustion products that have been dispersed over a wide area by prevailing winds. Coating systems based on organic primers and topcoats are to be preferred over inorganic zinc primed systems in this acid vapour environment.

Many industrial operations manufacture or use acids of a considerable higher order of activity. Ordinarily, both industrial hygiene and economic considerations limit the extent of atmospheric contamination from splash, spills and fumes of these materials. Vinyl copolymer systems are used and provide excellent protection in many such areas, but for some areas, such as frequent splash or spillage, vinyl chloride coatings are used since they are much more durable.

In the past, spray applied coatings were not reliable linings for strong acid tanks because of the potential for pinholes. Although the film, itself, might not evidence attack, H^+ ions would often get to the substrate through pinholes or by migration

through the film. Nowadays, with the advent of 100% solids coating technology, it is possible to effectively spray apply 625 - 1000+ microns per coat of 100% solids coatings with the proper equipment and technique with virtually no pinholes. (Note: For lining applications, it is always a good practice to conduct holiday tests prior to placing the lining into service.

pH	Strength / Type	Examples
0	Very strong acids	4% Hydrochloric (0.1), 10% Sulphuric (0.3)
1	Strong acids	0.4% Hydrochloric, 1% Sulphuric (1.2), 1% Phosphoric (1.5), Human stomach (1.0 - 3.0)
2	Strong acids	0.04% Hydrochloric, 0.1% Sulphuric (2.1), water from acid thermal springs, 6% Acetic (2.4), lemon juice (2.2 - 2.4), soft drinks (2.0 - 4.0)
3	Weak acids	0.6% Acetic (2.0), pickles (.30 - 3.4) wine (2.8 - 3.8), mine water, 0.06% Acetic (3.4), orange juice (3-4)
4	Mild acids	Carbonated water (3.8), peat water
5	Mild acids	Drinking water (5.0- 8.0), human urine (4.8 - 8.4)
6	Very mild acids	Rain water
7	Neutral	Pure water, river water, neutral brines
8	Very mild alkaline	Sea water, 1 to 10% baking soda (8.4)
9	Mild alkalis	10% Borax Solution (9.4)
10	Mild alkalis	0.02% ammonia (10.6), 5% liquid toilet soap (10.2)
11	Weak alkalis	10% washing soda (11.6), 2% ammonia (11.6) 0.2% ammonia (11.1)
12	Weak alkalis	0.1% caustic soda (12.4), 10% 7SP (12.6)
13	Strong alkalis	1% caustic soda (13.2)
14	Very strong alkalis	10% caustic soda

III. ALKALIS AND CORROSION

Weak aqueous alkalis are essentially identical to neutral salt solutions in their corrosivity. They accelerate corrosion because of their qualities as electrolytes. Stronger alkalis may actually exhibit a measure of corrosion inhibition.

Atmospheric contamination by alkalis is usually in the form of wind dispersed dusts. High-performance water-borne acrylics or catalysed acrylic aliphatic polyurethane topcoats, and epoxy intermediate coats with inorganic zinc primers provide excellent protection to the solutions that develop from atmospheric condensation.

Storage and transportation vessels for a wide range of concentrations and temperatures of alkali solutions are a large part of the tank lining market. This is one instance of the product being protected from the substrate, and not because the former attacks the steel. Corrosion occurs when the tanks are empty after cleaning, and must be prevented to avoid product contamination. In addition to normal barrier properties, the coating often must be capable of retaining its integrity at high temperatures, sometimes even at steam temperatures. Specially formulated epoxy linings have had a high degree of success for this service.

For areas where considerable splash of alkaline solutions is encountered, epoxy systems are very durable. Alkyd or oil paints should never be used in these areas.

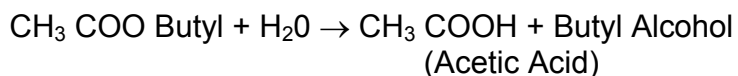
IV. OXIDISING COMPOUNDS

Oxidising compounds are chemicals that react vigorously with a number of organic materials. The recommendation for coatings where contact with these materials is possible must be made on a specific case-by-case basis. Although such chemicals are normally not corrosive to steel, they can cause rapid degradation of protective coatings. Examples are nitric acid, chromic acid, hypochlorites, perchlorates, nitrogen tetroxide (the oxidiser used in space fuel systems), chlorine gas and concentrated sulphuric acid. Hot, concentrated sulphuric acid can reduce some coatings to a charcoal residue in a few minutes.

Vinyl chloride and vinyl chloride copolymer systems are useful in many of the less severe exposures to oxidising agents.

V. ORGANIC SOLVENTS

Most organic solvents are not corrosive to metals or concrete. However, certain classes, the esters and the chlorinated compounds respectively, are capable of producing acids after prolonged contact with water. Consider a tank containing an ester like butyl acetate. Keep in mind that not only is it difficult to obtain and maintain such solvents in a truly anhydrous condition, but also the tank may contain water from a previous cleaning or another product. Therefore:



Acetic acid is capable of releasing H+. Similarly, but even more potentially corrosive is: chlorinated compound + H₂O - HCl + neutral by-products. The HCl is a strong acid and electrolyte and goes to work on the tank.

The need for a coating to possess solvent resistance is usually restricted to immersion and splash or occasional spill situations. In these applications, the film must maintain its integrity after contact with the solvent in order to be a satisfactory barrier to other more corrosive environments. In this respect, the requirements are similar to those for caustic tank linings.

Although one tends to think of solvents in terms of chemicals which are normal components of protective coatings, we must point out that a number of organic compounds are capable of softening and sometimes dissolving resinous binders. These include animal and vegetable oils, crude petroleum, fuels, lube oils, alcohol's, glycol's and many low molecular weight chemical intermediates. Many of the effects are highly specific. For example, a coating may not be suitably resistant to methanol but be perfectly acceptable to the higher homologous alcohol, ethanol, propanol, etc. If you have any doubt contact the Technical Service Department of a reputable coating manufacturer for a recommendation. Do not try to guess or extrapolate.

Coatings that have demonstrated excellent performance in the widest range of solvents include inorganic zinc's, phenolic-epoxies and high bake phenolics. Epoxy-polyamine and epoxy-polyamide formulations can be quite satisfactory for splash and spill of most solvents and are a good tank linings for some of the less potent ones.

VI. ORGANIC ACIDS

Many of the organic compounds that have solvent properties are also capable of liberating ions. Acetic acid, tall oil fatty acids, and certain vegetable and animal oils are representative of this group.

High bake phenolics and phenolic epoxies are often used as linings for tanks carrying some of these products. Specific recommendations should be obtained from a reputable coating's manufacturers Technical Service Department.

Many chemical resistant epoxy coatings are satisfactory for occasional spills of organic acids, but check with a reputable coating manufacturer for specific recommendations before proceeding.

VII. LIMITATIONS OF PROTECTIVE COATINGS

Although spray applied protective coatings provide a wide range of protection against corrosive environments in the past most of them were only capable of being applied at relatively thin films. This limited thickness excluded their use in some areas of severe chemical exposure or physical abuse. However, with the advent of the new generation of 100% solids novolacs, novolac epoxies and epoxies and special application equipment, it is now possible to apply some liquid protective coatings at 1000+ microns per coat using a multi-pass spray technique or by applying multiple coats. There are even some liquid-applied coatings that can be applied at 3125+ microns per coat. Nevertheless there are situations where liquid-applied protective coatings are not the best or the most viable solution to the corrosion problem for various reasons.

For these special applications, thicker barriers such as sheet linings, plastic sheets, monolithic toppings or corrosion-resistant brick are used.

SECTION 5

PROTECTIVE THICK BARRIER SYSTEMS

Revised: 02/2002

I. BENEFITS OF & ROUTES TO PROTECT

Thick barriers are those protective systems having a thickness of 750 microns and greater. The following benefits are achieved with thick barriers:

1. Increased time to penetration by aggressive chemicals
2. Thermal insulation of the bond to the substrate
3. Ability to tolerate erosion under conditions of very severe chemical or abrasive attack without losing integrity immediately.

As with coatings applied at 750 microns or less, cracks, pinholes or other defects in the barrier can still result in catastrophic failure since corrosive activity would be hidden until there is a failure of the structure.

Approaches to thick barriers include:

1. Sheet materials that can be adhesive or mechanically bonded to the substrate,
2. Composites of resinous binders with glass mat,
3. Hot melt applied resins,
4. Ceramics such as brick or tile,
5. Highly filled co-reactive resin mixtures that can be applied by trowelling or by special spray techniques
6. 100% Solids Protective Coatings
7. Sacrificial materials
8. A combination of two or more of the preceding.

Thick barriers find their major applications as linings for processing stacks, interior tanks, and tank like structures and as floor coverings.

II. SHEET LININGS

Many chemically resistant high polymers can be press moulded or extruded as sheets. However, to permit installation as a tank lining the sheet must be:

1. Flexible enough to permit rolling for shipment and for moulding to the contours of the structure being protected,
2. Capable of being attached to the substrate by a method which is relatively simple, and
3. Thermoplastic enough to permit joining butted or lapped edges by heat welding.

Plasticised polyvinyl chloride at a thickness of about 2250 microns is a very satisfactory lining for a wide range of acid storage and plating tanks. Although increasing the thickness of the sheet adds to its barrier properties, a subsequent reduction in pliability and the higher weight make application more difficult. However, 4500 micron sheets are customarily used on the bottoms of plating tanks to provide better impact resistance when heavy or sharp objects are accidentally dropped in the tank.

Smooth sheets are bonded to the substrate by a spray-applied primer adhesive system. Steel surfaces must be abrasive blasted to clean to White Metal (Sa 3 ISO 8501-1) before application of the primer. Concrete surfaces should be smooth, free of protrusions or pits and thoroughly dried with removal of any by centrifugal blasting, abrasive blasting or some other satisfactory and agreed upon method.

Ribbed vinyl sheets are often employed to protect concrete structures, particularly sewer pipe. In this type of construction, the sheet, with the rib side out is first mechanically held to the inner form. The concrete is poured and tamped into the form around the T-ribs, producing an integrally bonded lining capable of resisting back pressures up to the tensile strength of the sheet. Industrial sewer piping carrying effluent corrosive to concrete is completely lined while sanitary pipe requires only a partial lining to protect the upper areas of the pipe. The practice of protecting the surfaces that are usually not in immersion rather than those which are immersed requires some explanation.

In sanitary sewers the source of corrosion is sulphuric acid produced by bacteria on the more aerated surfaces of the pipe. These so-called aerobic bacteria require oxygen to convert hydrogen sulphide to sulphuric acid. The gaseous hydrogen sulphide that rises to feed these bacteria is produced by another group of micro-organisms that proliferate on the immersed surfaces. These anaerobic bacteria do not require oxygen and give off hydrogen sulphide as a waste product of their metabolism. This gas has a very low order of corrosivity. The sulphuric acid

produced at the most aerated surface is extremely corrosive to concrete and will gradually eat away any unprotected, non-immersed surfaces. When the acid drips into the effluent, it becomes highly diluted and is carried off without damaging the bare concrete.

The most important factor in obtaining successful linings with plasticised polyvinyl chloride sheets is the fusion of joints. Strips of the same or similar composition are fused to butted or overlapped edges of the sheet by a heat welding technique employing hot air guns designed for this work. The welds must be continuous and should be thoroughly tested both mechanically and with a high voltage pinhole detector before the structure is put in service.

Manufacturers of vinyl sheet linings publish chemical resistance tables showing the maximum concentration/temperature limitations for their products: Where a proposed use exceeds the temperature limitation, a course of acid bricks may be used between the solution and the sheet to reduce the service temperature to the acceptable limit.

III. LIQUID APPLIED THICK BARRIERS

A. 100% SOLIDS BY VOLUME LIQUID APPLIED BARRIER COATS

Although very high-build 100% solids coating formulations have been around and installed on concrete surfaces since the mid 1980's, it's only with the stricter environmental regulations that they have gained in popularity for steel surfaces.

The early 100% solids applications were primarily used on concrete surfaces for wastewater applications especially in sewer lines, digesters and clarifiers. They were used primarily to combat the corrosive effects of H_2SO_4 . Most of these materials were elastomeric polyurethane's and many were applied at 2500 – 3125 microns dft using specially designed plural component spray equipment with heat-traced lines and heated 205 litre drums.

The 100% solids elastomeric polyurethane's are still around today. They possess limited chemical resistance properties and cannot be used in many acids or in tanks containing aromatic hydrocarbons, Ketones, or chlorinated solvents. They do perform well with deionized, distilled and raw water. Some formulas are approved for potable water tanks and vessels. (Note: In addition to their narrow chemical resistance range, they also do not perform well at in-service temperatures above 50°C.)

In the late 1980's, 100% solids epoxies and novolac epoxies began to be used on concrete. These products were often used in combination with reinforcement as secondary containment lining systems. They possessed a much broader chemical resistance range than the elastomerics. Most of the early applications

consisted of trowel down applications, but in the mid 1990's the same resin systems were formulated for successful spray applications. The 100% solids epoxy and epoxy novolac barriers are now being used successfully in steel tank lining applications. Generally they are applied at 1000+ microns dft for lining applications in one or two coats using a multi-pass application technique.

There are several potential problems associated with 100% solids coatings that are worth noting. First, most of them require very expensive special equipment. If a contractor attempts to apply these coatings with improper equipment the application will be unsuccessful.

Second, some of these products, especially the novolac epoxies, tend to "amine" blush when exposed to moisture. This blush is not necessarily visible to the eye, but it must be removed by soapy water and rinsed thoroughly prior to the application of any subsequent coat(s) or delamination may occur once the tank is placed into service.

Third, since the 100% solids materials set up quickly. This is an advantage in many situations since many of the 100% solids coatings DO NOT require the traditional 7-day cure time before being placed into service. However, the fast set-up time can also turn into a disadvantage. If the maximum recoat window is exceeded special surface preparation will be required prior to the application of subsequent coats or massive delamination can occur.

Like all protective coatings, 100% solids barriers work well in some applications and don't perform well in others. Specifying engineers are encouraged to request laboratory or field immersion testing using Atlas cell testing or some other test protocol prior to specifying liquid applied coatings for severe chemical immersion exposure.

B. SOLVENT BASED BARRIERS

Although some of the more highly thixotropised, solvent containing protective coatings are capable of being spray applied to thicknesses of 1250 dry microns and higher, the practice is not recommended for the following reasons:

1. High concentrations of solvent may remain in the coating, degrading its chemical or water vapour resistance.
2. Delayed escape of solvents may set up stresses that can cause film cracking and disbonding from the substrate.
3. Pinholing becomes more prevalent as solvent containing films are applied at very heavy thicknesses.

4. Severe "orange peeling" of the surface is often encountered due to its inability to flow and level. The "hills and valleys" effect causes point-to-point thickness to vary extremely in such films.

Filled liquid epoxy formulations, styrene reactive polyesters and hot melt applied bitumen's have proved to be much more reliable thick barriers. These materials, because of their high viscosity, do not lend themselves to conventional or airless spray application. Trowelling, squeegeeing, daubing and mopping are the commonly used procedures for applying these barriers. In some instances spray applications with special equipment is possible.

C. HOT MELT BITUMEN'S

Hot melt applied bitumen's such as coal tars and asphalt's at about 2250 microns are excellent vapour barriers and, with the exclusion of solvents, have a high order of chemical resistance. They are extremely thermoplastic, however, and must be shielded from temperatures above their softening point.

D. SURFACERS

Mortars prepared by mixing high concentrations of mineral aggregates into solventless, liquid resins can be applied to concrete by similar techniques used for Portland Cement Mortars. These mixtures set up through chemical reactions of the resin component form hard, dense, chemically resistant barriers in thicknesses of 3.2mm to 6.4mm. The former thickness is standard for vertical surfaces while the latter is normal for floors.

The reactive binders used in these surfacing compounds are liquid epoxy systems or, in some instances, styrene-reactive polyesters. For services where there is no exposure to caustic, hydrofluoric acid or other fluorides, the aggregate is a mixture of sized silica's. When these silica destroying chemicals are encountered, a carbon aggregate is used. Epoxy surfacers are generally superior to the polyesters for contact with solvents or alkalis. Polyesters have the edge for resistance to oxidising agents.

The concrete must be clean and free of glaze or laitence before the application of a surfacing system. Where polyester is the binder, the concrete must be cured and dry. Epoxies are much more tolerant to moisture in the concrete. A primer coat is used to achieve good bonding and also to prevent binder deficient zones in the topcoat due to absorption of resin into porous concrete area. The surfacer can be applied by trowel, by screed and trowel (floors only) or by a spray and then trowelled smooth.

Many surfacers are supplied as three separately packaged components: liquid, curing agent and powder. However, some epoxy surfacers are available with the curing agent mixed with the aggregate and require only two separate packages.

One of the developments in epoxy surfacers is a product that can be readily sprayed by a gunite technique and does not require trowelling to finish.

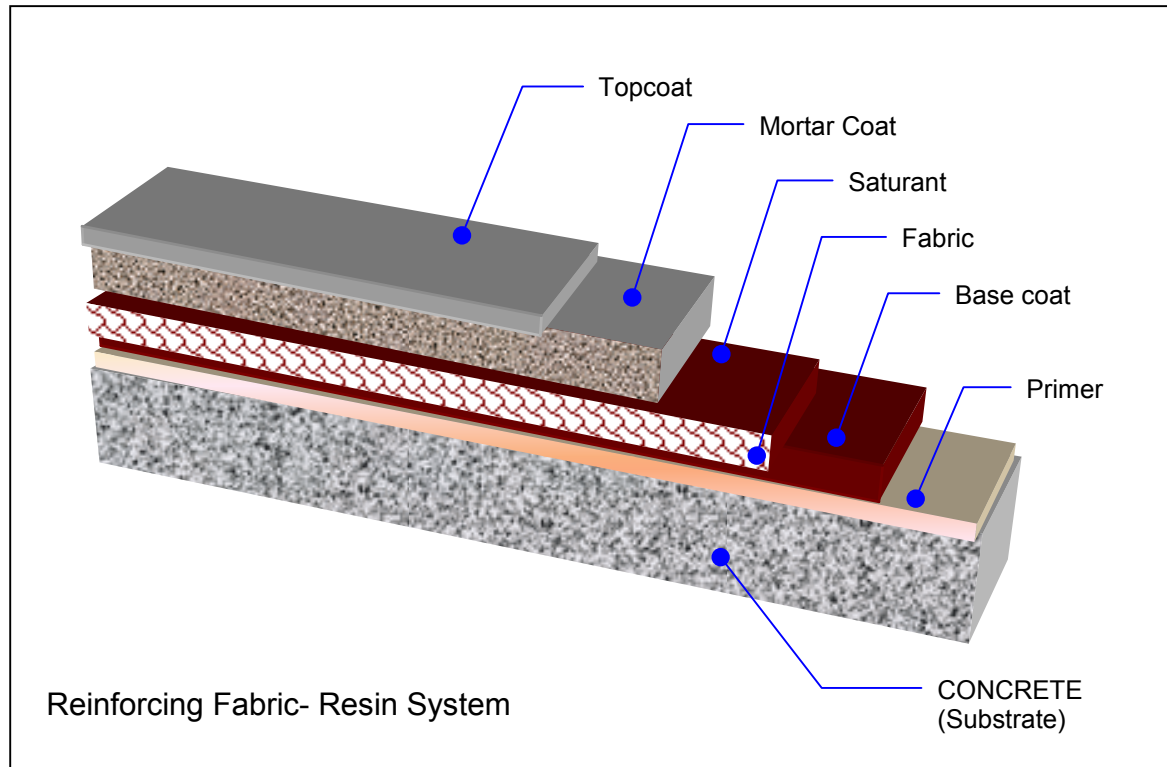
Surfacers are very effective chemical and abrasion resistant barriers when applied with care to properly prepared concrete surfaces. Where poor performance has been experienced with these materials, one of the following is likely to have been the cause:

1. Poor substrate - concrete softened and degraded by prior contact with chemicals.
2. Concrete uncured - usually only a problem with polyesters.
3. Surface contaminated by dirt, grease or oil.
4. Failure to remove dirt from surface after acid etching or sandblasting
5. Primer applied over glaze or tence.
6. Failure to use primer.
7. Pinholes in surfacer resulting from air entrained in compound during application - most severe when surface curing temperatures are too high during application. (Note: it's best to apply when the surface temperature is falling.)
8. Poor cure due to low application temperatures.
9. Prolonged steam cleaning
10. Exposure to chemical/temperature conditions in excess of those recommended by the manufacturer
11. Cracking of concrete substrate.

E. REINFORCING FABRIC-RESIN COMPOSITES

One route to obtaining thick, liquid applied barriers is the employment of glass cloth or other fabrics that provide support, reinforcement and bulk. Usually, a thin primer coat is applied to attain a good bond to the substrate. This is followed by a heavy resinous base coat into which the fabric is pressed with overlaps of at least 2.54cm. The third coat is normally applied with a special roller or is brushed in to saturate the fabric. Finally, a heavy finish coat is trowelled or squeegeed on to provide a smooth, uniform surface. Variations in this general procedure are used to employ two or more layers of fabric.

Solventless, 100% solids liquid resins are used as the resins. These 100% solids materials have the advantage of less shrinkage during cure and the probability of fewer voids in the barrier.



Styrene-polyester/glass cloth composite have been successful linings for steel tanks holding acid solutions while epoxy/glass has been employed in preventing product contamination in both steel and concrete tanks. These barriers are usually in the thickness range of 2.4mm to 3.2mm and are essentially tanks within tanks. Both systems have been used with varied success to repair pitted bottoms in steel storage tanks for fuels.

Hot melt bitumen's also are often reinforced with glass cloth or other fabrics to improve their physical properties. These barriers may be as thick as 9.5mm.

The effectiveness and longevity of composite liners depend, for the most part, on the skill and experience of the fabricators. Two common causes of failure are stress cracking due to insufficient reinforcement and pinholing due to air entrapment in the resin during application.

SECTION 6

SURFACE PREPARATION

Revised: 02/2002

I. INTRODUCTION

A. PURPOSE OF SURFACE PREPARATION

Prior to the application of any coating, the surface must be properly prepared to receive the coating material. Good surface preparation is perhaps the most important part of the entire coating job.

If contaminants such as oil, grease, dirt, chemicals, salts, chlorides etc. are not removed from the surface to be coated, they will prevent the adhesion of the first coat. In the past the primary focus concerned removal of visible contaminants. Several studies on the detrimental and corrosive effects of non-visible contaminants indicate that these must also be detected and removed prior to coating to obtain the anticipated coating life. Some of the more common non-visible contaminants include chlorides and sulphates

Rust left on the surface will continue causing a loosening of the coating and eventual loss of adhesion. If mill scale is not completely removed, it will cause accelerated corrosion resulting in inevitable failure (see Section 1, Principles of Corrosion.).

In addition to removing contaminants, good surface preparation also roughens the surface to assist in obtaining a mechanical bond or profile by increasing the surface area of bondable sites.

Any soluble foreign matter such as salts can cause osmotic blistering in the coating.

Good surface preparation enhances coating performance, allows the coating system to perform better under adverse conditions and provides increased years of service.

This section is divided into the following two parts: (1) surface preparation of steel, and (2) surface preparation of concrete.

II. PREPARING STEEL FOR PAINTING

The SSPC: The Society for Protective Coatings, through its specifications, recognises eleven methods of preparing steel for painting. Of these, five are abrasive blasting

procedures that are jointly issued by SSPC and NACE International. The ISO 8501-0 (used primarily internationally) correlate with several of these standards.

Table 6: Cross Reference Guide to Surface Preparation Specifications

SSPC Standard	NACE Standard	ISO 8501-1	Brief Description
SP 1	-----	-----	Solvent Cleaning
SP 2	-----	St 2 or St 3	Hand Tool Cleaning
SP3	-----	St 2 or St 3	Power Tool Cleaning
SP 5	No. 1	Sa 3	White Metal Blast Cleaning
SP 6	No. 3	Sa 2	Commercial Blast Cleaning
SP 7	No. 4	Sa 1	Brush Off Blast Cleaning
SP 8	-----	-----	Pickling
SP 10	No. 2	Sa 2 ½	Near-White Blast Cleaning
SP 11	-----	-----	Power Tool Clean to Bare Metal
SP 12	No. 5	-----	Surface Preparation & Cleaning by High & UHP Water Jetting
SP 13	No. 6	-----	Surface Preparation of Concrete
SP 14	NO. 8	-----	Industrial Blast Cleaning

Note: The ISO 8501-1 are not an exact crossover to the SSPC / NACE standards.

Table 7: Visual Standards Available from SSPC

Description	Standard Names
Visual Standard for Abrasive Blast Cleaned Surfaces	ISO 8501-1, SSPC VIS1-89
Visual Standard for Evaluating Degree of Rusting on Painted Steel Surfaces	ISO 4628-3, SSPC VIS 2
Visual Standard for Power and Hand-Tool Cleaned Surfaces	ISO 8501-1, SSPC VIS 3
Interim Guide & Visual Reference Photographs for Steel Cleaned by Water jetting	SSPC VIS 4(I)

Note: In most instances, the written standards take precedence over the visual standards in any dispute, unless otherwise stated in the specification documents. The visual standards or comparators are used to supplement the written standards.

For steel, proper surface preparation means steel is cleaned to specified surface cleanliness requirements and the surface roughness range (or anchor profile) that is correct for the coating being applied.

NOTICE: Listed below is a brief description of each of the surface preparation standards. This is not a complete or official description of these standards and the readers are advised to obtain complete official copies of the standards.

- A. **SOLVENT CLEANING (SSPC-SP-1)** - A process used to remove all visible oil, grease and other visible, soluble contaminants by use of solvents, emulsions, cleaning compounds or other materials which involve a solvent action. It is generally used as a pre-cleaning procedure prior to blasting and other types of surface preparation. It is not a satisfactory method by itself because it does not remove rust, scale or old coating residue. However, solvent cleaning is often a necessary first step in the preparation of steel since it is the most effective method of removing heavy deposits of lubricants.

Solvent emulsion cleaning followed by water rinsing is a preferred method since the oil or grease contamination is removed rather than spread around. (Note: There are strict environmental regulations that govern the discharge of chemical

cleaners and in some cases even discharge water from cleaning operations over waterways.)

- B. **HAND TOOL CLEANING (SSPC-SP-2, ISO 8501-1 St2/3)** - Cleaning with hand tools is the slowest and usually least satisfactory method, frequently producing a result that may be as bad or worse than the surface before it was cleaned. Wire Brushes, scrapers, chipping hammers or chisels are used to remove loose, non-adherent paint, rust or scale. It is mostly used indoors where blast cleaning is impractical or for spot touch and repair. Hand tool cleaning, with chipping hammers or chisels is very effective in removing weld spatter prior to blasting since abrasive blasting alone will generally not remove weld spatter. Prior to and after performing SSPC SP2, it is necessary that the surface be free of all visible contaminants as listed in SSPC SP 1, Solvent Cleaning.



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- C. **POWER TOOL CLEANING (SSPC-SP-3, ISO 8501-1 St2/3)**



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The advantage of the power tool is that it does little better cleaning job than hand tools and it does it at a much higher rate per man-hour. Cleaning with pneumatic or electrically driven rotary or impact devices is more efficient; however, power tool cleaning with a wire brush tends to polish the surface. In some cases, the profile of such surfaces is such that good adhesion is not obtained. Prior to performing Power Tool Cleaning, it is necessary to remove visible oil, grease, soluble welding residues and salts by the methods outlined in SSPC SP 1 (Solvent Cleaning). In addition, after using these tools it is necessary to re-perform SSPC SP 1 Solvent Wiping if the surface does not conform to the SSPC SP 1 specification. Dust, dirt or similar contaminants must also be removed before painting.

There are several power tools that have found practical use for cleaning:

- ☑ Grinders
- ☑ Roto-Peen

- ☑ Disc Sanders
- ☑ Clean-n-Strip

- ☑ Needle Guns
- ☑ Wire Brushes

Although these devices may be superior to hand tools, power tool cleaning is normally used only for touch-up and repair. On occasions, special shrouded power tools vacuum attachments are used.

Table 8: Overview of SSPC Hand & Power Tool Cleaning Specifications

Requirements of Specification	SP2	SP 3	SP 11
Remove all visible oil, grease, soluble welding residues and salts by the methods outlined in SSPC SP 1	✓	✓	NA
Remove all loose mill scale	✓	✓	NA
Remove all loose rust	✓	✓	NA
Remove all loose paint	✓	✓	NA
Remove all loose detrimental foreign matter	✓	✓	NA
Remove all visible grease, dirt, dust, mill scale, rust, paint, oxide, corrosion products, and other foreign matter	NA	NA	✓
Slight residues may be left in lower portion of pits if original surface is pitted	NA	NA	✓
Surface profile / anchor pattern must be 25 microns or >	NA	NA	✓

- D. **ACID PICKLING (SSPC-SP-8)** - Frequently used to clean steel objects which are small enough to be immersed in a tank of pickling solution or larger objects that will be galvanised. The process starts with degreasing to remove oil, grease or other contaminants. The steel is then immersed in hot (85°C) acid, usually sulphuric. This will remove mill scale and rust and etch the surface of the metal. The steel is then rinsed with warm water and a dilute solution (5%) of phosphoric acid to reduce the rate of rusting by forming a layer or barrier of iron phosphate on the surface of the metal. This method is often preferred to blast cleaning because less labour is required and no dust is created.

Pickling is often used prior to applying hot-dipped galvanising to steel. It is important to keep the solutions and rinsing baths from becoming contaminated. If

insufficient care is taken, contaminants will collect on the surface of the liquids and be re-deposited on the steel when it is withdrawn.

For best results, the coating should be applied before the steel starts to rust, and as soon as it is dry. Normally, the steel should not stand un-coated for more than four hours; however in certain high-humidity conditions the time between cleaning and coating may be a matter of minutes not hours.

E. POWER TOOL CLEANING TO BARE METAL (SSPC-SP-11)

This standard is one of the newer SSPC surface preparation standards. It is intended for smaller maintenance tasks where all existing rust scale, old coating, etc. must be removed or where abrasive blasting or chemical treatment is not allowed. All visible oil, grease, dust, dirt, mill scale, rust, paint, oxides and other corrosion products must be removed and the surface must have a minimum anchor profile of 25 microns. Slight residues of rust and paint are allowed to remain in the bottom of the pits only if the original surface is pitted.

The final appearance of the surface can vary considerably depending upon the particular type of power tool(s) that were used in the process. It is important to note that most power tools produce a profile without sufficient angularity for the application of certain coatings, such as inorganic zinc's that require an angular profile. (Readers are advised to consult the coating manufacturer of the primer to make sure that SSPC SP 11 is suitable for the specific coatings prior to performing the SSPC SP 11.)

Productivity rates for SSPC SP 11 are low; cost can be high and cleanliness is usually not as good as delivered by abrasive blasting.

F. ABRASIVE BLAST CLEANING OF STEEL SURFACES

Abrasive blast cleaning is the best method for preparing steel for the application of protective coatings. It effectively removes rust, mill scale, old paint and some other contaminants. Certain contaminants, especially the non-visible ones mentioned previously, must be removed prior to blasting. By roughening the surface, abrasive blasting increases the surface area and therefore the bondable sites.

The following two elements are necessary for effective abrasive blasting: (1) a hard, clean abrasive, and (2) a device which will propel the abrasive against the steel with a speed sufficient to cut into the metal.

The two primary methods employed in this form of surface cleaning are centrifugal blasting and compressed air abrasive blasting.

1. **CENTRIFUGAL BLASTING**, also called automatic blasting, is an airless method of abrasive blasting. Sometimes this process is also referred to by the names of one of the early centrifugal blasting equipment manufacturers (for example, “Wheelabrating” for steel and “Blast tracking” for concrete).

Steel fabricators use large centrifugal blast machines prior to painting to remove mill scale, to obtain the specified surface profile and to achieve the specified surface cleanliness. Depending upon the design and configuration of the steel, it is sometimes necessary to send the steel back through the “wheelabrator” or blasting machine two or three times.

Basically the machine propels recyclable abrasives against the surface to be cleaned by imparting velocity to them by means of a rapidly rotating wheel. The propelling process is very similar to the action performed by a pitching machine used in a batting cage. The degree of cleaning is in direct proportion to the following factors:

1. the speed of the conveyor
2. the distance from the workpiece
3. the condition and type of the abrasive mixture,
4. the care and maintenance of the wheels

8-Wheel Vertical Car Type Structural Cleaning Machine.

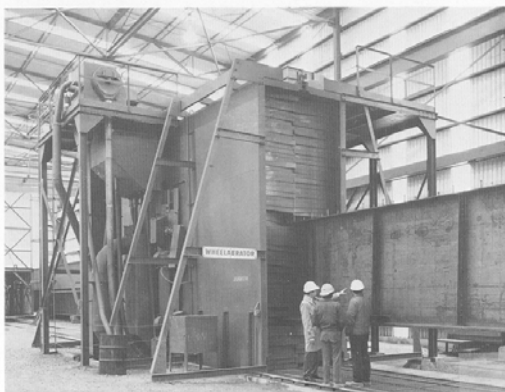
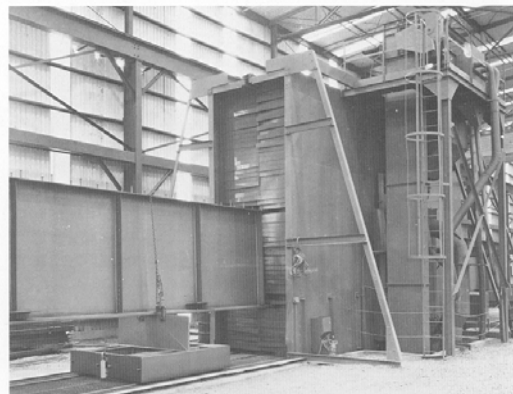


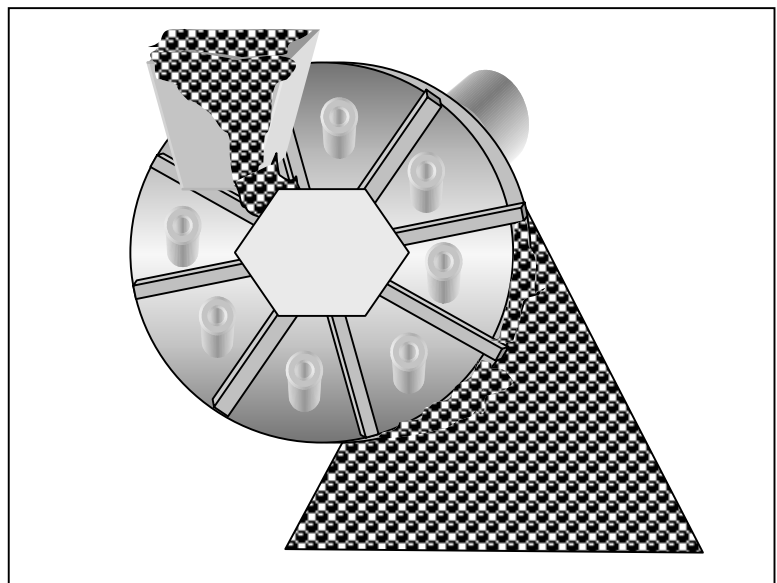
Photo courtesy of USF Surface Preparation Group, Wheelabrator – BCP Products

The abrasive material, usually steel shot or steel grit (designed for good fracture resistance) impinges against the surface removing rust and mill scale. The abrasives are continually collected, fines and dust removed, and reused. They are carried back to the wheels by a conveyor system. As the abrasive strikes the workpiece, they are constantly reduced in size until they are finally too small.

Fresh abrasive must be added at regular intervals to maintain the efficiency of the mix. Additionally, the mixture should be checked daily for oil pickup from the surfaces that it has contacted. Contaminated abrasive must be discarded or it will pass the contaminant onto the steel target or workpiece.

The quantity of abrasive pellet thrown onto the steel surface is determined by the size of the wheel motor. Several wheels are usually mounted on a blast machine so that all surfaces of the steel to be cleaned are exposed to the direct blast from one or more operative wheels. Changing the speeds at which the conveyor is operated can produce different degrees of cleaning. Also, higher horsepower wheels are designed to produce any given degree of cleaning at faster line speeds.

Careful maintenance of centrifugal blasting units is essential to their satisfactory performance. The high-speed wheels can malfunction for a number of reasons. The dust collectors occasionally fail to remove "fines", and the latter cushion or dilute the good abrasive. Finally, the vacuuming component to remove the abrasive from the shape before it



Schematic of a centrifugal blast wheel in operation using steel shot

leaves the chamber must be functioning to avoid abrasive being coated by primer. Centrifugal blast cleaning is a widely accepted shop method of preparing new structural steel and plate to receive protective coatings.

In addition to the stationary machines, there are **portable centrifugal blast machines** that are used on concrete floors. These machines are often referred to as "blastrac" machines, the name of one of the primary manufacturers of the equipment. The portable units used on concrete come as

walk behind units or as riding units. They work on the same basis as the large stationary units, using recyclable steel shot or grit abrasives.

Concrete pours can vary considerably in their hardness from one slab to another within the same floor. For this reason it is necessary to adjust the working mix of abrasive in order to provide the proper profile for coatings. Inexperienced operators often do not adjust the abrasive mix as needed and they subsequently cut too deeply into the floor and sometimes even create grooves. This can significantly increase the amount of coatings that are required to cover over the excessive profile and deep grooves. The 100% solids epoxies that are often used on interior floors are expensive, so an increase of 25% – 35% in coating consumption for a large project is costly. To avoid this problem, some coating applicators sub-contract the “blastracking” to a contractor who specialises in centrifugal cleaning of concrete floors.

One of the limitations with the portable “blastrac-type” units is their restricted accessibility in tight areas, around equipment and in the area up against the wall due to the shrouds on the equipment. To prepare these inaccessible areas, contractors must use less efficient and more labour intensive tools and equipment, such as needle guns.

The most recent addition to the portable centrifugal blasting equipment world are the **remote control units** that are used to blast the sides of tanks, vessels, ships and other large flat surfaces. Early reports appear to indicate that for certain applications, these remote controlled centrifugal blast units provide substantial savings compared to conventional blasting equipment.

2. **COMPRESSED AIR ABRASIVE BLASTING** - Air abrasive blasting or sandblasting involves injecting a supply of abrasive into a rapidly moving air stream and propelling it at high velocity through a nozzle of the proper configuration so that the solid particles impinge against the surface to be cleaned. In the past sand was the most commonly used abrasive for blast cleaning, thus the term sandblasting is often used to describe abrasive blasting even when another type of abrasive is utilised.

Important considerations in good and efficient air blasting include.

- (1). The skill of the workman
- (2). The distance and angle from the workpiece
- (3). Maintaining equipment in good working order to producing the proper volume of abrasive at the proper velocity
- (4). Using the proper size compressor and air nozzle
- (5). The quality of the abrasive

When proper skill is employed and equipment is maintained and used correctly, achieving a given degree of cleanliness is a function of time. The five degrees of surface cleanliness defined below:

SSPC-SP-5, NACE No. 1, ISO 8501-1 Sa3 - White Metal Blast Cleaning

This finish is defined as a surface with a grey-white, uniform metallic colour, slightly roughened to form a suitable profile for coatings. This surface shall be free of all visible oil, grease, dirt, dust, mill scale, rust, corrosion products, oxides, coatings, or any other foreign matter.

The type of abrasive used impacts the colour of the blasted surface. Pictorial representations are given in the standards.

SSPC-SP-10, NACE No. 2, ISO 8501-1 Sa 2 1/2 - Near White Blast Cleaning

This finish is defined as one from which all visible oil, grease, dirt, mill scale, rust, corrosion products, oxides, coating or other foreign matter have been removed from the surface except for very light shadows, very light streaks or slight discoloration's. At least 95% of each 76.2mm x 76.2mm surface area shall have the appearance of a surface blast cleaned to a white metal surface finish and the remainder shall be limited to the light discoloration mentioned above.

SSPC-SP- 6, NACE No. 3, ISO 8501-1 Sa 2 – Commercial Blast Cleaning

This finish is defined as one from which all visible oil, grease, dirt, dust, rust, mill scale, coatings, oxides, corrosion products and foreign matter have been completely removed from the surface except for slight stains, shadows, streaks or discoloration's of rust, stains of mill scale, or stains of previously applied coatings. At least 67% of each 76.2mm x 76.2mm surface area shall be free of all stains as noted above.

SSPC-SP- 14, NACE No. 8– Industrial Blast Cleaning

This surface is defined as a surface free of all visible oil, grease, dust and dirt. Traces of rust, mill scale and coating residues can remain on 10% of each unit area of the surface. The traces of mill scale, rust and coating are considered tightly adherent if they cannot be lifted with a dull putty knife. Shadows, stains of mill scale and stains of previously applied coating may be present on the remainder of the surface.

SSPC-SP-7, NACE No. 4, ISO 8501-1 Sa 1 - Brush Off Blast Cleaned Surface.

This finish is defined as one that is free of all visible oil, grease, dirt, loose mill scale loose rust and loose coatings. Tight mill scale and tightly adhered rust, paint and coatings are permitted to remain, provided they have been exposed to the abrasive blast pattern. Mill scale, rust and coating are considered tightly adherent if they cannot be lifted with a dull putty knife.

Important Notice – Please Read: The brief descriptions of the joint surface preparation standards provided above are not the actual SSPC / NACE specifications. Consult the actual specifications if you are responsible for writing specifications or performing work in accordance with these specifications.

Table 9: Overview of the SSPC / NACE Joint Blasting Standards

REQUIREMENTS ↓	SP 5 NACE No.1 Sa 3	SP 10 NACE No. 2 Sa 2½	SP 6 NACE No. 3 Sa 2	SP 14 NACE No. 8	SP 7 NACE No. 4 Sa 1
Remove all visible* oil, grease, dirt, dust	✓	✓	✓	✓	✓
Remove all visible* mill scale	✓	✓	✓	NA	NA
Removal of all visible* rust	✓	✓	✓	NA	NA
Removal of all visible* coating	✓	✓	✓	NA	✓
Removal of all visible* oxides, corrosion products, and other foreign matter	✓	✓	✓	NA	NA
Degree of staining allowed to remain	0%	5%	33%	NA	NA
Traces of tightly adherent mill scale, rust and coating residues are allowed to remain on 10% of each unit area of the surface	NA	NA	NA	✓	NA
Remove all loose** mill scale, loose** rust, loose** paint, and other loose** detrimental foreign matter	NA	NA	NA	✓ (***)	✓
Notes: • * Visible means “when viewed without magnification” • ** Loose means “it cannot be removed by lifting with a dull putty knife” • *** Subject to a maximum amount allowed to remain as listed in the specification. Consult the written specification for further details.					

a. BLASTING ABRASIVES

The selection of abrasive is usually determined by availability, cost, work location, the type and depth of profile required, regulations and the specifications. Steel grit and shot are normally used in automatic equipment or in shop situations with air abrasive blasting equipment where the material is cleaned and recycled. In recent

years, primarily due to major lead-removal projects on large bridges, automatic recyclable abrasive blasting equipment has become practical and mobile for site locations and field use.

Field blasting normally uses coal slags or synthetic grits which are used only once and not recycled, although some synthetic grits have sufficient resistance to breakdown and allow for cleaning and recycling.

The various types of abrasive that are used perform differently and produce characteristically different types and depths of surface profile. The profile, resulting from blasting is extremely important in its effect on coating performance. If the surface is too smooth or not angular enough, some coatings adhere poorly. On the other hand, if the surface is too deep, sharp pinnacles of metal are likely to project through the coating and remain unprotected.

Some of the most frequently used abrasives and their characteristics are listed in the following page. There are four general types of abrasives, categorised as follows: (1) natural minerals, (2) mineral slags, and (3) manufactured media, and (4) organic media.

The most commonly used natural mineral abrasives are garnet and staurolite / zircon.

Mineral abrasives are basically the waste products from smelting and combustion operations. The most commonly used mineral abrasives is Coal Slag (often called by its trade name e.g. "Black Beauty" or "Black Blast"). This manufactured abrasive is efficient and a by-product of ore reductions or other manufacturing processes. Other mineral abrasives include copper slag, lead slag, or utility slag, which is produced by coke burning furnaces and mineral shot. Of the mineral abrasive group, Coal Slag is preferred to sand by many contractors because it does not create as much dust upon impact with the steel target and it often produces an excellent profile for many high-performance coatings.

Due to health concerns with silica sand, alternative media such as Black Beauty, Starblast, and Alumina have been gaining more acceptance in the United States. These media are all non-metallic abrasives very similar to sand in the type of surface texture that they can produce. Surfaces blasted with Black Beauty or Starblast have more smoothly cut single impact craters, but the bulk of the surface is choppy and distributed like a typical sandblasted surface. Alumina and sand produce virtually identical profiles.

Table 10: Abrasive Characteristics Comparison

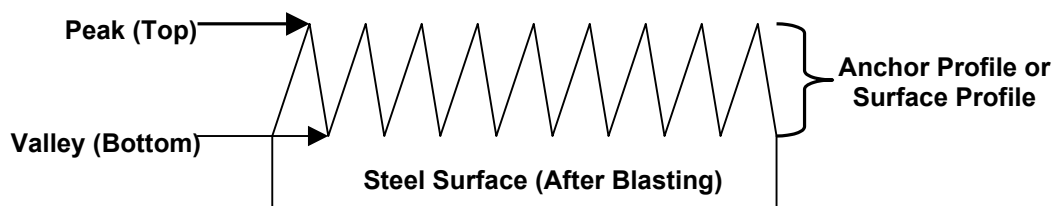
Material	Mesh Size	Shape	Density lbs / ft ³	Initial Cost	# of Cycles	Per Use Cost	Typical Uses
Mineral Slag	8-80	☆	85-112	Med.	1 - 2	Med.	Outdoor Blasting
Steel Grit	10-325	☆	230	High	200+	Med.	Removing Heavy Scale
Steel Shot	8-200	●	280	High	200+	Low	Cleaning, Peening
Aluminium Oxide	12-325	☆	125	High	6 – 8	Med.	Cleaning, Finishing, Debarring, Etching
Glass Bead	10-400	●	85-90	Med.	8 – 10	Low	Cleaning, Finishing

The third general class of abrasives is referred to as “manufactured media”. These include both metallic and non-metallic subtypes. The non-metallic abrasives include silicon carbide and aluminium oxide and glass beads.

In the metallic manufactured media steel shot and steel grit are the most commonly used. Manufactured abrasives come in chilled iron, cast steel, heat-treated aluminium, brass or copper. However, considerable skill is required to avoid over and under-blasting with these abrasives. Furthermore, the advantage of reusing them may be lost through contamination with rust and lubricants.

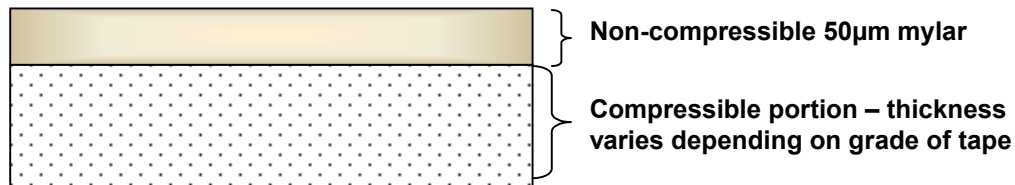
b. PROFILES, PREPARATION RATES AND PREFERENCES

Earlier mention was made of profile creation on the steel during blast cleaning. The size of the abrasive is the major factor in determining the depth of this profile. Too fine an abrasive can provide patterns which result in inferior bonding of the primer while extremely coarse materials may product peaks which will project through the coating. Staying reasonable close to the coatings manufacturer's recommendation for abrasive selection is a good policy.



There are three different means used to determine the surface profile or anchor pattern: (1) replica tape, (2) profilometers, or (3) comparators. Nowadays, the replica tape method (often referred to as “Textex Tape”) is the

Replica Tape



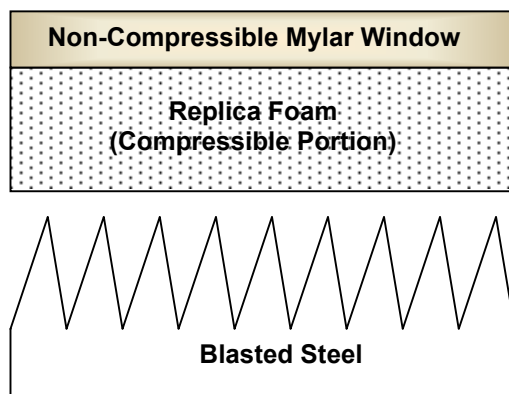
most commonly used method of determining anchor profile for several reasons. It is available in several different grades depending upon the profile and it provides a permanent record. The tape is composed of a non-compressible portion that is 50 microns in thickness and a compressible portion. The compressible portion is pressed into the anchor pattern or surface profile and it creates a reverse image replica of the blast profile.

The tape comes in several different grades depending upon the profile depth. It is very important to use the proper tape, so that enough of the compressible portion is present to measure the entire profile. The four grades of replica tape offered by Testex and their ranges are as follows:

Table 11: Testex Replica Tape Grades & Ranges

Tape Grade	Range
Coarse	20 - 50 microns
Paint Grade	33 - 84 microns
X-Coarse	38 - 114 microns
X-Coarse Plus	>140 microns (varies by batch)

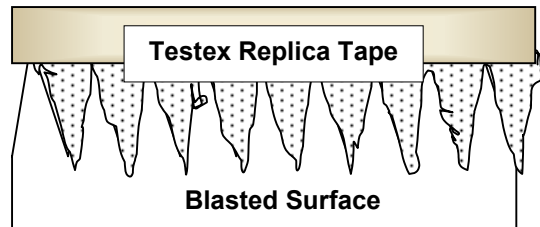
If a tape grade is used that does not contain enough compressible foam to measure the complete profile, it will provide inaccurate readings. For example, if Coarse tape is used to measure a 89µm blast profile, it will most likely only report 56 – 58µm. For a 89µm blast profile, the X-Coarse Tape is the proper tape to use.



To measure the surface profile using replica tape, the first step in the process is to select the proper tape for the anticipated profile. (See the chart above for the ranges.) The anticipated profile can be determined by looking at the specifications and by determining the type and size of abrasive that was used by the

contractor to blast the surface. Several tapes overlap other tapes. For example, Coarse, Paint Grade and X-Coarse overlap in the 38 μ m range. According to the literature from Testex, in this range the Coarse tape will produce the most accurate profile reading.

The tape is pressed into the surface profile and rubbed with a burnishing tool until the entire circular portion of the replica tape is uniformly darkened. The tape is then removed from the surface and placed into a special micrometer that is designed with the proper size anvil for the Testex tape. (Failure to use the proper anvil micrometer can result in substantially erroneous readings.)



When the tape is removed and put into the anvil micrometer, the clear window portion of the tape should be centred between the anvils. It is necessary to deduct 50 μ m from the reading on the gauge to account for the 50 μ m non-compressible portion of the tape.



An alternate method to deduct the 50 μ m is to back the micrometer off by 50 μ m (i.e. set it at the 200 μ m marker as shown in the picture at right) prior to taking any measurements.



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Some old specifications call for the use of a Profilometer to obtain a representative reading of the surface; however profilometers are laboratory instruments designed to measure surface roughness of machined metals and not as field-friendly. The sensing stylus is more likely to go around a peak than to go over it and is a laboratory test.

In the past surface profile comparators (Keane Tator or ISO) were used to determine the approximate anchor pattern; however the comparators rely upon visual assessments and therefore are somewhat subjective. With the Keane Tator comparators, each disc consists of only five legs each with a certain profile value shown in microns, therefore there are only five possible values. When a blast profile falls between two legs, one individual may grade it as the higher leg. Another individual may select the lower leg. A third individual may report it as

between two legs. This causes confusion and unnecessary disputes, so the replica tape is now the most commonly used method to determine surface profile since it minimises conflict and provides a permanent record.

Production rates for blasting to achieve an adequate profile, with a given abrasive, vary depending upon several factors. Brush-off Blast Cleaning (SSPC SP 7 / NACE No. 4 / ISO 8501-1 Sa 1) at a rate of about 37m² per hour can provide a satisfactory profile on most aged coatings when the recoat window has been exceeded, however Brush-off Blast Cleaning is rarely used anymore for new steel preparation since by definition it does not remove tightly adherent mill scale or tightly adherent rust. In the past most of the old oil-based red-lead primers adhered satisfactorily to such a surface, however nowadays many of the high performance coatings (when used in other than mild atmospheric conditions) require a minimum of a Commercial Blast (SSPC SP 6 / NACE No. 3 / ISO 8501-1 Sa 2) or a Near White Blast Cleaning (SSPC SP 10 / NACE No. 2 / ISO 8501-1 Sa 2½). The high preponderance of mill scale and rust remaining on the surface with a Brush-off Blast Cleaning makes it a dangerous choice for anything other than the mildest service conditions.

Reducing the blasting rate to about 18½m² per hour should produce a Commercial Blast (SSPC SP 6 / NACE No. 3 / ISO 8501-1 Sa 2). This surface is safe for many of the less severe exposures, such as non-immersion.

Often a Near White Blast Cleaning (SSPC SP 10 / NACE No. 2 / ISO 8501-1 Sa 2½) can be obtained at about 14m² per man-hour, however actual blasting rates can vary considerably depending upon the logistics of the project and the accessibility of the surface to be blasted. It is reliable for many services.

White Metal Blast Cleaning (SSPC SP 5 / NACE No. 1 / ISO 8501-1 Sa 3) is typically accomplished at a rate of 9½ to 11½m² per man-hour but with some steels, may be even more time consuming. (In addition, dehumidification may be required to maintain the SSPC SP 5 / NACE No. 1 / ISO 8501-1 Sa 3 after it is achieved.)

NOTE: The blasting production figures listed above are merely average production rates for a normal job. Readers are advised to calculate their own production rates based upon the specifics of the project, the region of the country, and many other variables that will effect the actual rates obtained.

C. BLASTING EQUIPMENT

Air and blast hoses are important so that a constant high volume of air is supplied to the blasting nozzle in order to maintain the proper blasting pressure. The selection of the correct size hose is essential if this is to be accomplished. For normal use, a 25.4mm I.D. hose is sufficient where a 9.5mm nozzle is used and

where hose length is 15m of blasting hose, a 32mm I.D. hose should be used. Smaller diameter blasting hoses will result in large pressure losses in the line unless respectively small nozzles are substituted. Since such large hoses are somewhat cumbersome, it is often advisable to attach a 3m "whip" of 19mm hose together with nozzle to the working end of the blasting hose. This gives the blaster greater manoeuvrability. With the proper hose, the cleaning rate can be increased approximately 100% which materially reduces the m² cost for blasting.

1. **NOZZLES**

The most common nozzle sizes used in maintenance operation are 6.3mm, 8mm and 9.5mm I.D. Naturally, the larger the nozzle the greater is the area which can be cleaned in a given length of time. In general, at 100 psi, a 9.5mm nozzle will result in a blasting rate approximately 2 1/4 times that of a 6.3mm nozzle, but it will require a greater volume of air.

Blasting nozzles are made of various materials of which the most common are ceramic, cast iron, and tungsten carbide. These first two types are cheapest in initial cost, but their useful life is limited to from 2 to 4 hours of continuous blasting. Various designs of the tungsten carbide nozzle will remain operational up through as many as 800 hours of actual blasting.



Photo Courtesy of Clemco Industries, Corp.

Nozzles wear out with use. As they wear out, they increase in size. This increase in orifice size requires more air to maintain blast pressure. If the compressor cannot handle this additional load, blast production (which among other things is a function of pressure) is significantly reduced. (See Table 12 for the Effects of Nozzle Wear on Air Consumption)

For one blaster using a 6.3mm nozzle to operate at 100 psi and to have sufficient air for the blast hood and the recommended 50% reserve, a minimum 151-cfm compressor is required. However, if the nozzle wears out to a 8mm size it requires a 236-cfm compressor.

Table 12: Effects of Nozzle Wear on Air Consumption

Orifice Size	Increase in Air Consumption
6.3mm	
8.0mm	60% more air needed than 6.5mm
9.5mm	38% more air needed than 8.0mm
11.0 mm	36% more air needed than 9.0mm
12.7mm	33% more air needed than 11.0mm

The most efficient nozzle is the long hard, high efficiency Venturi nozzle (tungsten carbide). This nozzle is designed to give abrasive particles maximum velocity. The design also concentrates sand particles in a compact pattern so maximum amount of cleaning can be done in a minimum of time.

The impact of abrasive particles against the surface is what does the cleaning. The magnitude of force of this impact is a function of the air pressure. The higher the pressure, the greater the force of the impact and therefore, the faster is the rust and scale removed from the steel. Usually 100 psi is considered the ideal working pressure.

Low nozzle pressure results in slow or incomplete removal of tight mill scale. The compressor should be capable of producing 300 cfm (cubic feet per minute).

2. BLAST POTS

All blasting pots function in essentially the same manner, that is, by furnishing a regulated amount of abrasive to a high-pressure air stream. The two differentiating factors for pots are the size and the number of chambers. A 5 or 6 bag pot, that is one which holds approximately 225 or 275 kg of abrasive, is commonly encountered in maintenance work. However, for touch-up work, spot blasting pots as small as 45 kg are used.



Photo Courtesy of Clemco Industries, Corp.

Pots are manufactured with either one or two chambers, the former capable of only intermittent blasting and the latter adapted to continuous work. In the operation of a one chamber pot, after all the abrasive has been emptied from the pot, blasting is discontinued until the chamber can be again refilled.



Photo Courtesy of Clemco Industries, Corp.

Double chamber pots enable the helper to fill one chamber at the same time that abrasive from the other chamber is being fed to the blasting hose. In this way, the pot is always at least half full and the blasting operations can continue uninterrupted. This naturally speeds up the blasting operation thereby increasing efficiency and decreasing cost.

Although most pots can be turned off and on by a helper, it is better that the blaster himself be able to perform this function. Therefore, manufacturers have made available a remote control air operated valve which is attached to the blasting nozzle and which enables the operator to turn the machine off even though he is working at some distance from the pot. In enclosed areas where signals from the blaster may not be easily seen or heard by the helpers, such an attachment is highly desirable, not only from an abrasive economy standpoint, but also from a safety point of view.

Proper equipment is essential to a good blasting job, but equipment alone is not enough; proper technique is essential too. The procedure indicated below should be followed:

1. Regulate the quantity of abrasive so there is enough to cut rapidly, but not so much that it smothers the air.
2. Hold the nozzle close enough to the surface to prevent loss of force. The average nozzle should be held within ten inches of the surface. (Some specially designed nozzles can be held farther away.)
3. Blast systematically. Move the nozzle back and forth across a small area until it is clean. Do not wave the nozzle haphazardly or reach out far to the side.
4. Move the nozzle slowly. A skilled blaster using a 9.5mm nozzle with proper auxiliary equipment and good abrasive can blast-clean to "white" metal not more than 14m² an hour on average steel, under the best conditions. The work cannot be hurried.
5. When blasting is completed, remove dust with brush or vacuum cleaner.

Some blasters believe that they must only remove loose scale and rust; they often say that tightly adherent scale is "in the steel" and cannot be removed. But it can be removed, and must be removed whenever a "White-Metal", "Near-White Metal", or "Commercial" blast cleaning is specified.

Removal of dust is extremely important. If dust remains, it prevents the coating from contacting the metal and results in lack of adhesion.

III ALTERNATE METHODS OF BLASTING

A September, 1974 study issued by the NIOSH called "Industrial Health and Safety Criteria for Abrasive Blast Cleaning Operations" says "Non-silica abrasives such as slag or steel shot are the safest materials for use as they are typically non-toxic and do not cause excessive dust exposure hazards."

A. WET BLASTING

Traditionally, dry abrasive and dry air are used when abrasive blasting to avoid rusting of the newly exposed steel surface. With the enforcement of more stringent environment laws, wet blasting may become the most reasonable approach to cleaning steel surfaces. Injection of water into the same flow at the nozzle or at the pot to reduce "dusting" is not a new procedure.

Inhibitors may be added to the blasting water or used in the rinsing water required to wash the surface free from residues prior to drying. Inhibitors prevent flash rusting on drying. (Note: The coatings manufacturer should be consulted whenever the use of his product over these inhibitors is contemplated.)



Photo Courtesy of Clemco Industries, Corp.

B. ULTRAHIGH PRESSURE WATER JETTING (UHP)

One of newer and more promising alternative methods to abrasive blasting is Ultrahigh-Pressure Water Jetting. This method uses ultra high-pressure jetting machines to propel water at pressures up to 40,000 pounds per square inch. UHP Water Jetting can remove existing coatings and linings, mill scale, rust, and other



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substances such as water-soluble surface contaminants, surface grease and oil. Since UHP WJ cannot produce surface profile, it is not a viable option prior to applying protective coatings unless a surface profile already exists or unless the coating that will be applied does not require a surface profile.

Large shipyards are successfully using UHP WJ to remove the coatings off previously blasted and painted ships. It is very cost effective (when total costs are considered) and in some situations the production rate is very close to that achieved by traditional abrasive blasting. In addition, UHP WJ is environmentally-friendly, especially compared to abrasive blasting.

In the picture above, depicting a UHP Water Jetting operation in progress it's easy to see why it is considered so environmentally superior to many other methods for removing previous coatings. The visibility during UHP WJ operations is excellent since it doesn't create the cloud of dust associated with open-air sandblasting.

One of the time-consuming and costly operations associated with traditional abrasive blasting is the collection and disposal of the used abrasives. With UHP Water Jetting there are no used abrasives to collect, recycle or dispose of – this saves considerable time and money.

Consider the following comparison between traditional abrasive blasting and UHP WJ:

Factors	Abrasive Blasting	UHP Water Jetting
Material Cost	Media cost	NONE (Use H ₂ O)
	Freight cost for abrasive	NONE
Labour Cost	Man-hours to blast	Man-hours to water jet
	Man-hours for pot tender to fill pot with abrasive	Man-hours for pump tender
	Man-hours for blowing down or vacuuming the surface to clean residual abrasives and dust	NONE
	Man-hours for recovering or cleaning up the abrasive	NONE
Equipment Costs	Replace nozzles	Replace nozzles
Other Costs	Disposal of removed coatings	Disposal of removed coatings
	Disposal of used abrasives	NONE

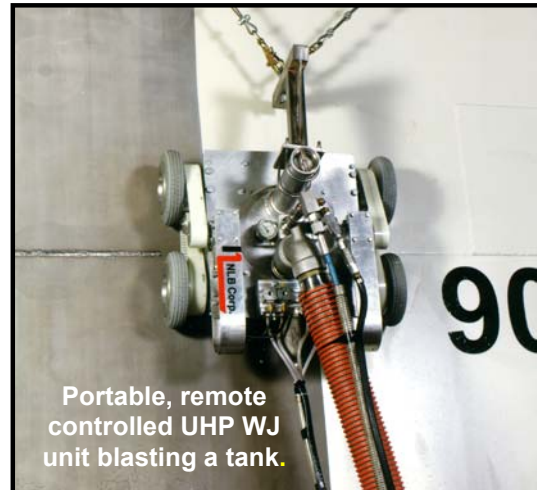
The UHP WJ method is especially effective in removing resilient materials that may not be removed efficiently by traditional abrasives or in cleaning surfaces of complex cross sections such as gratings or sieves. Standard abrasive blasting with abrasives may trap contaminants within the profile topography whereas the UHP WJ is effective in removing water-soluble surface contaminants from the pits and craters of badly corroded metal substrates.

UHP Water jetting will not produce a surface equivalent to that produced by abrasive blasting in appearance. It will NOT produce a surface profile if a profile is not already present so there are some applications, in particular new steel, where UHP WJ is not a suitable method of surface preparation.

The joint surface preparation standard SSPC SP 12 / NACE No. 5 provides the particular details related to UHP WJ including four visual and three non-visual surface preparation definitions for various conditions after UHP is performed. One of the primary advantages of UHP WJ is that it leaves no dust or other loose material on the cleaned surfaces that often act as contaminants interfering with adhesion or promoting corrosion.

This system may be regarded only as pre-cleaning if a surface profile is not already present on the surface because dry blasting will be required to finish the work of providing a profile. UHP WJ has no etching or profiling effect on steel.

Sometimes UHP WJ is used after abrasive blasting when the blasted surface shows evidence of spots that look like “black” rust. These black spots generally indicate the presence of chloride contamination that has been blasted into the steel through the abrasive blasting process or that was already present in the steel from previous blasting operations or through some other means. UHP WJ is used to remove these water-soluble chlorides. After removal of the chlorides by UHP, the surface is generally re-blasted using abrasives.



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UPH WJ equipment is available in many different forms including remote, portable units used on the side of tanks, ships and other large flat surfaces, (as shown above) and larger, more versatile, manual blasting units like the one shown below.



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The units are available for both purchase and rental and are manufactured in both skid mount and trailer mount types

There are four different types of cleaning using water that are referenced in SSPC SP 12 / NACE No. 5. An overview of the Joint Standard is shown in Table 7.

Table 13: Overview of SSPC SP 12 / NACE No. 5 Joint Standard

Description	Abbreviation	Pressure Range
Low-Pressure Water Cleaning	LP WC	< 5,000 psi
High-Pressure Water Cleaning	HP WC	5,000 - 10,000 psi
High-Pressure Water Jetting	HP WJ	10,000 – 25,000 psi
Ultrahigh-Pressure Water Jetting	UHP WJ	> 25,000 psi

Note: The SSPC SP 12 / NACE No. 5 standard addresses water jetting and not water cleaning.

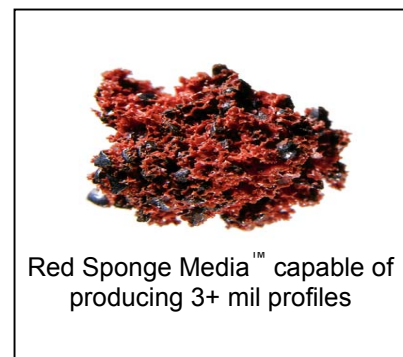
For further details regarding surface preparation and cleaning of steel and other hard materials by high and ultra high-pressure water jetting prior to recoating, you may purchase the complete surface preparation standard through either SSPC or NACE International.

C. SPONGE BLASTING OR SPONGE JETTING

Sponge Blasting™ offers another alternative to conventional abrasive blasting that is environmentally friendly. This method is often referred to informally as “Sponge Jetting” or more properly as Sponge-Jet’s Sponge Blasting™ System™, after the name of its manufacturer, Sponge-Jet, Inc. Sponge Blasting is a low dust process that requires reduced containment and the media is reusable.

The Sponge-Jet Sponge Media used for blasting (when a profile is required) is an open-celled, polyurethane particle, impregnated with various abrasives depending upon the depth of profile that is required. The Sponge Media is manufactured in several different colours since the colour is the primary means used to differentiate the various media.

The Sponge Media is also available in non-abrasive impregnated versions used to remove coatings from soft or easy-to-damage surfaces



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such as fibreglass, aluminium, sheetrock, plaster or soft woods.

The Sponge Media is pliable and it flattens on impact thereby exposing the abrasive. Unlike conventional abrasives that fracture upon impacting the surface and therefore produce large amounts of airborne dust, the Sponge Media possesses a unique ability to absorb upon impact. This results in two major advantages. First, the low media brake-up rate produces very little airborne dust or stray abrasive. Second, the abrasive impregnated into the sponge lasts considerably longer than conventional abrasives and is capable of 5 to 7 recycles. According to Sponge-Jet, Inc, approximately 60% - 90% of the sponge media are reusable after each blast cycle.

After the Sponge Media impacts the surface to remove the coating, it constricts and entraps much of abrasive dust. After it is used the Sponge Media is collected and run through a Sponge-Jet Media Classifier™ prior to being reused.

The chart below depicts the various types of Sponge Media that are available. All of these Sponge Media feature the MICROCONTAINMENT™ technology.

Table 14: Sponge-Jet® Sponge Media™ / Abrasive Choices

Profile	Abrasive Type	Sponge Colour	Cleaning Rate	Average Recycles
100+µm	Steel Grit	Red	5.6-16.8m ² /hour	8
75+µm	16 Grit Aluminium Oxide	Silver	5.6-16.8m ² /hour	8 - 10
75+µm	30 Grit Aluminium Oxide	Silver	5.6-16.8m ² /hour	8 - 10
50µm	Dupont Starblast®	Brown	5.6-11.2m ² / hour	8 - 10
> 25µm	220 Grit Aluminium Oxide	Silver	5.6-16.8m ² /hour	8 - 10
None	60-40 Mesh Plastic	White	5.6-11.2m ² / hour	8 - 10
None	Very Mild	Green	11.2-56m ² / hour	10*
None	None	Blue	16.8-84m ² / hour	15*
* Recycle rate varies based on containment characteristics.				

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Some of the primary features and benefits of the Sponge Blasting System are as follows:



Model 240 XL Feed Unit

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- Cost-effective – generating only 10% of the waste compared to blasting with the conventional abrasives saving both labour for pick-up and significantly reducing disposal costs.
- Very low media break up & minimal dust
- Portable, easy to use & quick to set up
- Reduced containment required
- Useable on a wide variety of substrates (i.e. fibreglass, sheetrock & composites)
- Abrasive impregnated sponges reusable from 8 – 10 times
- Low ricochet minimises damage to adjacent areas

The Sponge-Jet Feed Unit™ shown above is capable of delivering up to 120 PSI of clean, dry air with a blast time of approximately 45 minutes before refilling the abrasive. “Sponge Jetting” offers many advantages for facilities where the plants must remain operational while the blasting is performed. Conventional abrasives present a far greater hazard to workers and equipment and overall plant safety in comparison to the Sponge-Jet Sponge Media. For specifiers, facility owners and contractors Sponge Blasting can prove very cost effective and is certainly worth considering. On one 3250m² lead-removal project, a contractor averaged 44½m² / man day using the Sponge-Jet Blasting System.

Sponge-Jet, Inc. provides a world-wide technical assistance hotline and training and their staff are available to assist with estimating and bidding : www.spongejet.com

D. HIGH PRESSURE WATER BLAST CLEANING WITH ABRASIVE

For tight scale and for efficient removal of coating and rust, sand or other abrasives are injected into the high-pressure water stream. When used on metal surfaces, inhibitive chemicals are frequently incorporated in the water to prevent re-rusting of the steel during the time delay that occurs as the steel surface dries.

E. CATHODIC CLEANING

Surfaces which can be submerged in water, such as tanks, can be cleaned by making them the cathode in an electrical circuit. This method is used

successfully on tanks holding fuel oil and may be used on any metal surface that can be submerged in the proper electrolyte and submitted to an adequate potential. The electrical current reaching the surface of the cathode either produces hydrogen or reduces surface rust to a lower valence hydrated oxide which softens, partially dislodges and takes with it scale contamination from the surface.

IV. SURFACE PREPARATION FOR VARIOUS METALS

Although sandblasting is nearly always the best method for surface preparation, alternate or additional special treatments are recommended for certain metals. Regardless of the material used for blasting, all surfaces must first be degreased to remove any residual oil.

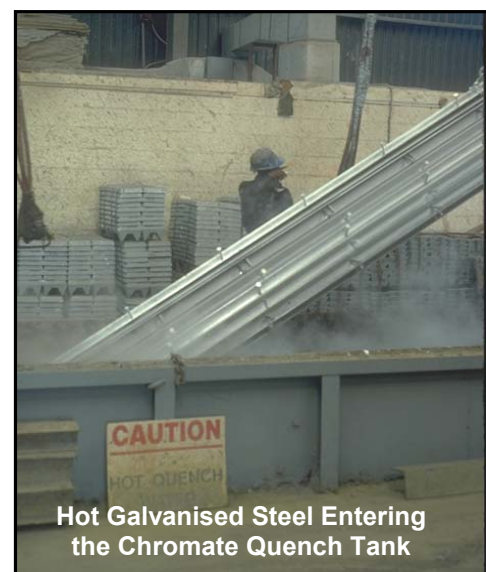
A. CAST IRON

Cast iron is a porous material, and is likely to absorb moisture or other liquids that it contacts. To drive out absorbed material from its pores, cast iron should be heated before blasting. This can be done by placing it in an oven for 8-12 hours at 150°C or by heating it with torches until this temperature is reached.

B. HOT-DIP GALVANISING

New galvanised zinc surfaces can be prepared for painting by the application of a specially formulated acid treatment such as phosphoric acid followed by a thorough cleaning to remove zinc salts. Such solutions, commonly referred to as T-Wash/Mordant solution, are especially formulated to etch zinc thereby providing sufficient roughness for the subsequent application of coatings. These solutions normally contained 85% - 90% solvent.

Alternative products include specially formulated water-based primers and low-film build 100% solids epoxy primers. However prior to the application of any coating system it is necessary to remove residues of oil from handling and to remove any water-soluble chromate's. These chromate's are often used to quench galvanised metal as a last step in the galvanising process to make the metal shinier. They must be removed by water and appropriate cleaners; solvents alone will not remove the water-soluble chromate's. In order to effectively remove



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the oils and the chromate's it often requires two distinct cleaning steps followed by a rinse with clean potable water.

Care should be exercised when preparing galvanised steel surfaces not to unduly remove excessive amounts of zinc.

Another alternative method sometimes used to prepare the galvanised surfaces for painting is to lightly blast the surface. However, if zinc coated surfaces are allowed to properly weather, sometimes sufficient roughness is obtained to permit direct coating without etching or blasting.

C. COPPER OR BRASS

These metals should be lightly abraded with abrasive paper or blasted to remove oxides and rinsed with fresh water or treated with a solution consisting of 5% ferric chloride and 5% muriatic acid. After allowing the solution to react for a few minutes, the surface should be washed with fresh water.

D. ALUMINIUM

For best results under corrosive environments, apply a chromate-type conversion treatment such as Alodine 1200, manufactured by the American Chemical Paint Company. An acceptable alternate treatment where corrosive conditions are less severe is a phosphate-type conversion treatment.

Where it is impractical to apply a conversion treatment, as described above, satisfactory results can be obtained under most conditions by lightly blasting the surface with fine abrasive.

As mentioned in the discussion above regarding galvanised metal, there are some specially formulated water-based primers and 100% solids, low-film build epoxy primers that are available to prepare difficult-to-bond-to surfaces like aluminium, copper and galvanised metal after proper cleaning.

E. NICKEL OR STAINLESS STEEL

Abrasive blast with aluminium oxide or glass beads. Do not use iron or steel abrasive since these types of abrasives can leave dust residues containing ferrous metal resulting in the possible formation of dissimilar metal corrosion.

V. STRUCTURAL DETAILS

Most coatings cannot be applied successfully over sharp corners or in narrow cracks. When applied over sharp corners or points, the coating draws back from the edge during drying. No matter how carefully it is applied, the coating will be thin on sharp edges and projections. There are some 100% solids specially formulated coatings used in US Navy tank lining applications that are classified as “edge retentive” but even these coatings are allowed to “shrink” back up to 30% on the edges. (In other words an “edge retentive” coating must retain at least 70% of its original applied film thickness on the edge after curing to meet the Navy’s edge retentive requirement.)

Cracks present another problem because of the difficulty of getting the coating down into a narrow opening.

For complete protection, as in lining a tank, sharp edges and cracks must be eliminated as follows:

- Round off all rough welds and sharp steel edges.
- Weld spatter must be knocked off with a scraper or a chisel.
- Seams joined with skip welds must re-welded with a continuous bead.
- Baffles must be welded on both sides.
- Rivets and bolts must be tight.

If additional welding or grinding is required, it should be done before abrasive blasting.

VI. SAFETY PRECAUTIONS

As in nearly all industrial operations, certain safety precautions must be observed in abrasive blasting surface preparation operations. Most commonly used is the safety suit which permits feeding a supply of clean air to the operator who might otherwise breathe in large volumes of particles of paint, abrasive and rust. These suits may be fed cooled air created by a Venturi-type device fitted to the suit. In tanks and confined areas, all blasting nozzles should be equipped with remote controls. These controls automatically shut off the blast if the blaster drops the nozzle for any reason.

VII. CONCLUSION

As previously indicated, blast cleaning is the best method for preparing steel surfaces. There are circumstances, however, where this procedure is not practical or economical, and a substitute method is desired. In these cases, the most practical method will depend upon the exposure, the type of finish coat to be used, and the present condition of the surface. Each case must be analysed individually.

VIII. SURFACE PREPARATION OF CONCRETE

A. Introduction

"Concrete is a combination of sand, gravel and crushed stone mixed with cement and water, which hardens into an artificial stone.

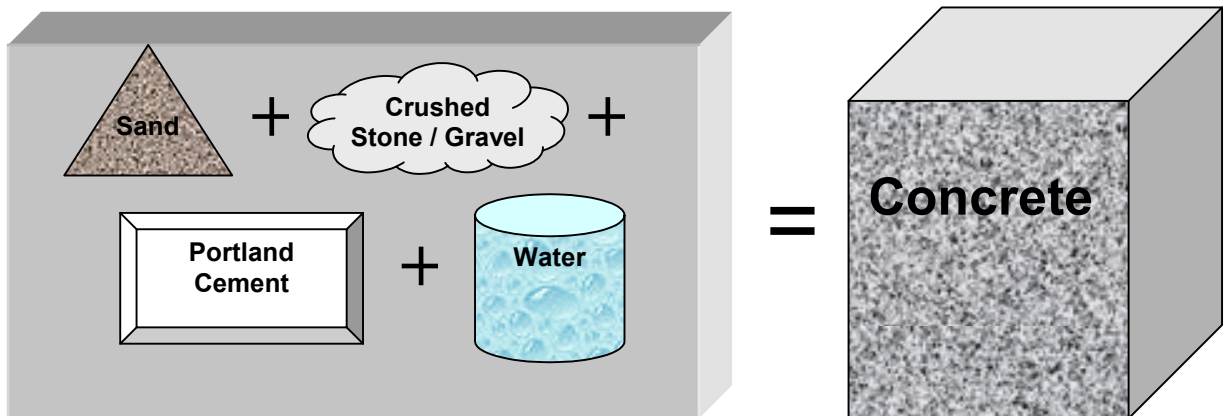


Figure: Ingredients Used to Make Concrete

Much of the concrete used is exposed to an environment where it is susceptible to attack by chemical agents. Therefore, to protect the concrete, a material (barrier) is applied that is resistant to the action of chemical agents.

The vulnerability of concrete to chemical attack results from its permeability, alkalinity and the capacity of hydrated cement compounds to undergo undesirable chemical reactions with its environment.

A coating can be applied to concrete to obtain a surface which is resistant to chemical fumes, splashes, and immersion or to provide a lining for tanks which protect the concrete from stored solutions and prevents product contamination.

Surface preparation of concrete depends on the end use of the area and the type of protective coating system specified for the service. Service will determine what type of pre-treatment is required. Regardless of the service, for best results, concrete surfaces should be clean, dry and normally well cured before coating.

Curing is the process of maintaining a satisfactory moisture content and a favourable temperature in concrete during hydration of the cementitious materials so that desired properties of the concrete are developed. Curing is essential in the production of quality concrete. In addition to proper formulation, the potential strength and durability of concrete will be fully developed only if it is cured for an adequate period prior to being placed in service. Moisture content is usually achieved from the continuous or frequent application of water through ponding, sprays, steam or saturated cover materials such as burlap or cotton wets, rugs, earth, sand, sawdust and straw or hay.

Recommended curing of concrete is typically 28 days after pouring. However, some coatings may be applied immediately after finishing or stripping forms.

Optimum concrete surfaces for adherence of any coating should be free of oils, waxes, or greases, laitence and should have the texture of medium grade sandpaper. The surface should be tightly adherent and not powdery.

B. Types of Concrete

Different types of concrete work possess inherently different surface characteristics. The most common surface types are formed concrete (walls), finished slabs (floors), gunite and concrete block.

Concrete block (CMU)

presents a relatively uniform surface with round holes. The surface is strong because of steam curing. Before coating, the block must be cleaned of loose dust, dirt and loose mortar. Sealing by brushing, rolling or spraying of thin-bodied sealers will provide a pore-free but not level surface. Level surfaces can be obtained on block by trowelling or squeegeeing heavy bodied thixotropic surfacing materials on the block. The surfacing or sealing material should be suitable to receive the intended topcoat.



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Formed concrete (walls) have air bubbles and holes of various sizes and shapes at or near the surface. The surface preparation depends on the desired chemical and physical characteristics of the finish.

Selected form facing material should be used to produce a smooth form finish. Immediately after the forms are stripped and while the concrete is green, repairs on voids should be made with cement-sand grout smoothed flush with the surface. Grouted areas should be kept wet and cured with the concrete to assure adhesion and strength. Laitence and dust should be removed by blasting or etching. Proper sacking can be used immediately after the forms are stripped. Before the application of any surfacing material, holes and voids should be opened by blasting or power sanding and filled.

Sacking is not recommended where tank linings are used. For tank linings or immersion service, the surface should be blasted and voids should be filled with a 100% solids epoxy or other suitable materials as recommended by the coating manufacturer.

Guniting or sprayed concrete results in surfaces that are hard, dense, and free from air bubbles and cement laitence. Usually the only treatment needed before coating is to remove foreign matter, dirt, or dust that could impair coating adhesion. If a guniting is trowel finished, acid etching or blasting can be used to obtain a surface texture similar to medium grade sandpaper.

Concrete floors do not contain major surface irregularities because of the use of hand or mechanical tool finishing. Concrete floors can be left floated finished or finished with steel, or given a broom finish depending on the smoothness desire. Regardless of the method used to finish floors, cement laitence will always be left on the surface. Blasting or etching should be employed whenever coatings or surfacing are specified and used on concrete floors.

C. Finishes

In order to know what must be done to prepare a concrete surface for a particular barrier, the type of finish for the concrete surface must be known.

1. For Formed Surfaces

- a. As-Cast Finish
 - 1) Rough Form Finish
 - 2) Smooth Form Finish
- b. Rubbed Finish
 - 1) Smooth Rubbed Finish
 - 2) Grout Cleaned Finish
 - 3) Cork Float Finish

2. For Slabs

- a. Floated Finish
- b. Trowelled Finish
- c. Broom Finish

3. As-Cast Finish

- a. Rough Form Finish -

No selected form facing materials shall be specified for rough form finish surfaces. Tie holes and defects shall be patched. Fins

exceeding 6.3mm in height shall be chipped off or rubbed off. Otherwise, surfaces shall be left with the texture imparted by the forms.

b. Smooth Form Finish

The form facing material shall produce a smooth, hard uniform texture on the concrete. It may be plywood, tempered concrete-form-grade hardboard, metal, plastic, paper, or other approved material capable of producing the desired finish. The arrangement of the facing material shall be orderly and symmetrical, with the number of seams kept to the practical minimum. It shall be supported by studs or other backing capable of preventing excessive deflection. Material with raised grain, torn surfaces, worn edges, patches, dents or other defects which will impair the texture of the concrete surface shall not be used. Tie holes and defects shall be patched. All fins shall be completely removed.

4. Rubbed Finish

a. Smooth Rubbed Finish

Smooth rubbed finish shall be produced on newly hardened concrete no later than the day following form removal. Surfaces shall be wetted and rubbed with carborundum brick or other abrasive until uniform colour and texture are produced. No cement grout shall be used other than the cement paste drawn from the concrete itself by the rubbing process.

b. Grout Cleaned Finish

No cleaning operations shall be undertaken until all contiguous surfaces to be cleaned are completed and accessible. Cleaning as the work progresses shall not be permitted. Mix 1 part Portland cement and 1-1/2 parts fine sand with sufficient water to produce a grout having the consistency of thick paint. White Portland cement shall be substituted for a part of the grey Portland cement in order to produce a colour matching the colour of the surrounding concrete, as determined by a trial patch. Wet the surface of the concrete sufficiently to prevent absorption of water from the grout and apply the grout uniformly with brushes or a spray gun. Immediately after applying the grout, scrub the surface vigorously with a cork float or stone to coat the surface and fill all air bubbles and holes. While the grout is still plastic, remove all excess grout by working the surface with a rubber float, sick, or other means. After surface whitens from drying (about 30 minutes at normal temperatures) rub vigorously with clean burlap. The finish shall be kept damp for at least 30 hours after final rubbing.

c. **Cork Float Finish**

Remove forms at an early stage, within 2 to 3 days of placement where possible. Remove ties. Remove all burrs and fins. Mix one part Portland cement and one part fine sand with sufficient water to produce a stiff mortar. Dampen wall surface. Apply mortar with firm rubber float or with trowel, filling all surface voids. Compress mortar into voids using a slow speed grinder or stone. If the mortar surface dries too rapidly to permit proper compaction and finishing, apply a small amount of water with a fog sprayer. Produce the final texture with a cork float using a swirling motion.

5. **Floated Finish**

After the concrete has been placed, consolidated, struck off, and levelled, the concrete shall not be worked further until ready for floating. Floating shall begin when the water sheen has disappeared and when the surface has stiffened sufficiently to permit the operation. During or after the first floating, planeness of surface shall be checked with a 3m straight-edge applied at not less than two different angles. All high spots shall be cut down and all low spots filled during this procedure to produce a surface within Class B tolerance throughout. The slab shall then be re-floated immediately to a uniform sandy texture.

6. **welled Finish**

The surface shall first be float-finished as specified above. It shall next be power trowelled, and finally hand trowelled. The first trowelling after power floating shall produce a smooth surface which is relatively free of defects but which may still show some trowel marks. Additional trowellings shall be done by hand after the surface has hardened sufficiently. The final trowelling shall be done when a ringing sound is produced as the trowel is moved over the surface. The surface shall be thoroughly consolidated by the hand trowelling operations. The finished surface shall be essentially free of trowel marks, uniform in texture and appearance, and shall be plane to a Class A tolerance, except tolerance for concrete on metal deck shall be Class B. On surfaces intended to support floor coverings, any defects of sufficient magnitude to show through the floor covering shall be removed by grinding.

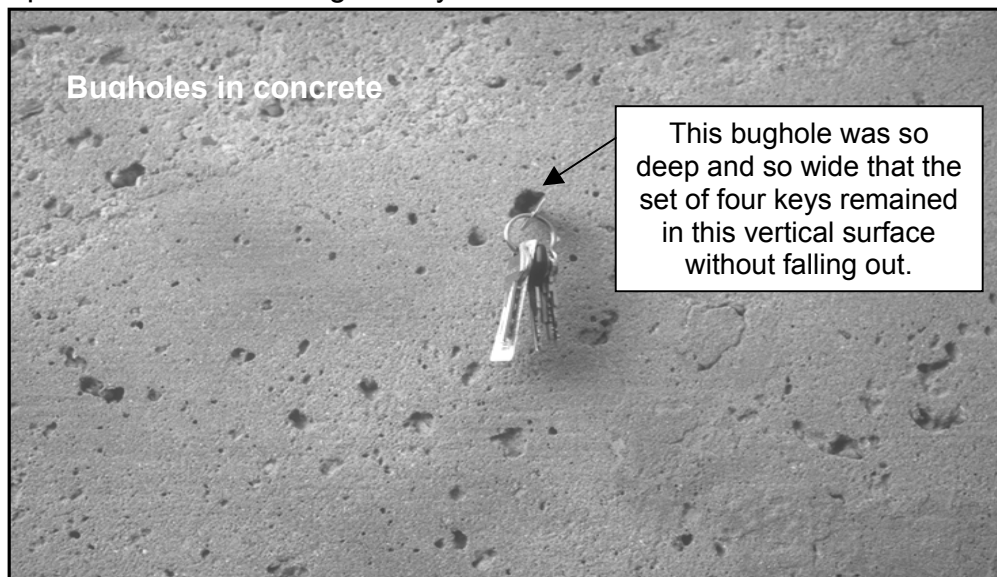
7. **Broom or Belt Finish**

Immediately after concrete has received a float finish it shall be given a coarse transverse scored texture by drawing a broom or burlap belt across the surface.

D. **PROBLEMS WITH CONCRETE**

There are numerous problems inherent in concrete which make the application of coatings more difficult than coating other surfaces such as steel. Some of these are as follows:

1. **Concrete is a non-homogeneous material** which actually can change with every pour on a large structure, with the weather at time of casting, with any of the additives which can be added to the mix, with the surface against which it is cast, and with the degree of vibration used during placement. Larger surface variations are evident when different casting and finishing methods are used such as pouring against forms, guniting and trowelling, and centrifugal casting. All these factors create different surface conditions each of which influences the surface preparation or treatment needed prior to applying a coating or surfacing.
2. **All concrete surfaces are alkaline** and, when wet, can develop conditions of high pH so that the coating must be alkali resistant. Certain types of coatings, such as all oil-based coatings and alkyds, should never be applied directly to concrete surfaces or saponification can result.
3. **Air and water pockets:** Well placed formed concrete is filled with surface imperfections even though many methods have been tried to eliminate them.



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For **non-immersion applications**, the bugholes on the surface are those which are critical. The smaller these imperfections, the more difficult it is to

achieve a continuous coating. If coatings are applied over such a surface some of the holes can be bridged or covered; however, because of the air in the concrete which expands as solvent evaporates into it, and as the air is heated, the coating blisters or bubbles form and break, leaving holidays. Special methods of surface preparation are necessary to overcome this problem such as the following: (a) trowelling cement mortar over the surface, (b) sacking the surface with cement grout, and (c) stoning the surface with carborundum bricks again working in cement grout. If cementitious fillers are used it is important to remember that they must be fully and properly cured prior to the application of coatings, generally 30 days with proper hydration throughout the period.

For immersion applications, the best practice is to blast the surface in order to open up all bugholes both on the surface and just below the surface. Failure to open up the sub-surface bugholes has resulting in premature lining failures due to blistering and offgassing especially if a thick topcoat is applied while the concrete temperature is rising. Depending upon the particular lining system and the roughness of the concrete after blasting, it may be necessary to apply some type of 100% solids mortar or other material to achieve a suitable lining system. There are some high-build 100% solids systems that can be applied at up to 3125+ microns dft with the addition of a geotextile fabric embedded into the lining after the first 625 microns are applied. Each concrete pour is unique and sometimes changes to the coating system are required after the surface is blasted and the condition of the concrete can be assessed.

4. **Concrete laitence** is a problem that many times is overlooked or not even considered when a coating is to be applied to concrete. Laitence is the fine mixture of sand rich in Portland cement that is floated to other surface during the placing and finishing. One of the places where it is most obvious is on the interior of centrifugally spun concrete pipe. Here, because of the centrifugal force, laitence is concentrated because most all of it is forced out of the mass of the concrete onto the inner surface. All finished concrete surfaces will have laitence to some degree. Because the laitence has low strength, coatings or surfacers applied over laitence may be doomed to early failure. The obvious remedy for this is to remove laitence from the surface. This can be done by lightly abrasive blasting the surface.
5. **Form oil and concrete curing agents:** Many times in the building of a structure, a contractor will overlook the fact that the structure must be protected after completion. Form oils containing large amounts of wax or soaps often are used because they strip easily. These compounds remain on the concrete surface and normally require removal by sandblasting. The effect of these waxes or soaps is the same for coatings as for the forms they strip easily from the surface. Waxes used as curing compounds have the same effect. Wherever concrete is to be coated for corrosion protection, forms

should be coated with film forming material which will remain on the form when it is stripped.

Also, curing compounds should be prohibited. An easy way to determine if form oils, curing compounds, clear stains, sealers, hardeners or laitence are present on the concrete is to pour a small amount of water on the floor. If the water ponds or puddles on the floor instead of spreading out and penetrating into the slab then something is present on or in the slab that will keep a coating from penetrating into the concrete. Muriatic acid, (used to remove laitence) will not remove curing compounds, stains, sealers, hardeners, coatings or form oils. Form oils can be removed by scrubbing with detergent or soap solutions followed by thorough rinsing. Paint strippers are required to remove certain types of sealers and often times the concrete slab is abrasive blasted to remove these undesirable products.

In the photograph on the right, several drops of water were applied to a concrete floor and they ponded up indicating that the floor was not ready to receive a coating. After using a chemical stripper to remove the curing compound, then rinsing and applying muriatic acid the floor was re-tested (see spots above and below) and the water penetrated into the concrete. (Note: Using chemical paint strippers on concrete floors is strongly discouraged since the concrete can become contaminated with these chemical strippers. For a small test patch however the chemical strippers are quick and easy to perform in the field.)



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If testing the floor indicates the presence of a hardener, sealer, or curing compound, many projects use portable centrifugal blast machines, (or "blastrac" machines) to remove both these compounds and the laitence.

Some concrete floor slabs are contaminated deep into the slab with oils, greases, animal fats and other similar contaminants. It is often necessary to use steam cleaning or flame cleaning to volatilise the residual oils or greases from these concrete surfaces.

6. **Efflorescence** is a white, loose, powdery material that sometimes forms on the surface of concrete. It is the result of deposition of alkaline salts from moisture. As moisture passes through the concrete it picks up alkaline salts from the concrete or in some cases from the soil in a below-grade structure. When the moisture evaporates it leaves salts on the surface. It can develop on

uncoated concrete block as seen in the picture on the picture on the previous page or it can occur underneath the coating on coated CMU and disrupt the paint film. Efflorescence can be removed by acid etching, wire brushing or by treating with special proprietary products.



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7. **Chemical contamination:** Chemically contaminated concrete must be neutralised before coating. If the surface is acidic, it must be neutralised with an alkaline cleaner and rinsed thoroughly with fresh water. If contaminated with alkali's, concrete must be cleaned with steam or with a detergent. Concrete contaminated with oils, greases or facts must be cleaned with an alkaline detergent or with steam, which also incorporated a detergent. Solvents can be used to remove oil and grease from the surface. Removal of chemical contaminants must be accomplished before any other surface preparation such as acid etching or blasting takes place.
8. **Concrete hardeners** are used to increase surface hardness, to decrease permeability to liquids, and to provide some added resistance to mild chemical attack. Hardeners should not be used when coatings are to be applied. They migrate to the surface and appear glossy and greyish-brown. Organic coatings may not adhere to the inorganic hardeners. The only way to properly prepare a hardened concrete surface to receive paint is to abrasive blast it using an expendable abrasive or with recyclable abrasives (i.e. steel shot or steel grit) by means of portable centrifugal blasting machines commonly referred to as "blastrac" machines.

E. SURFACE CLEANING

Surface cleaning is used to prepare concrete surfaces for coating in maintenance service and not intended as the sole method of preparation where protective systems will be used for continuous or intermittent immersion, mechanical loading or for protective systems needing optimum bond for satisfactory performance. Air, after cleaning, scrubbing, sweeping or vacuuming are acceptable methods. Cleaning agents may also be used to remove oil or grease spots. This should be followed by a fresh water rinse.

1. BROOMING OR VACUUMING

This procedure is intended to remove surface dust and other loosely adherent solid contaminants. It consists of sweeping the surface with a clean industrial stiff bristled broom and then vacuuming the surface with a heavy-duty industrial vacuum to provide an essentially dust-free surface.

2. AIR BLAST

This procedure is intended to remove debris, dust, dirt, loosely adherent laitence and concrete, break thin crusts over blow holes, and to provide a sound essentially dust-free surface. It consists of cleaning the surface with a compressed air stream. An often-suggested set-up involves subjecting the surface to 80-100 psi air passed through a 5.08cm nozzle held approximately 60-120cm from the surface. Suitable traps are used to ensure that the air-stream is free of oil and moisture.

3. WATER CLEANING

This procedure is intended to remove dust, dirt and water-soluble surface contaminants. It consists of hosing the surface with a low-pressure stream of clean fresh water and where necessary, hand scrubbing with a stiff bristled brush.

4. DETERGENT WATER WASH OR STEAM CLEANING

This procedure is intended to remove dust, dirt, water-soluble surface contaminants and oil, grease and other emulsifiable materials on the surface. It consists of hosing the surface with a low pressure stream of clean fresh water, or a jet of high pressure steam, followed by scrubbing with a stiff bristled brush using an aqueous solution of detergent or non-solvent emulsifier. Trisodium Phosphate or proprietary products may be used as required. Immediately after treatment, before the surface dries, the surface must be thoroughly flushed to remove residues of cleaning agent. For critical applications (immersion or severe mechanical washing) abrasive blasting is required.

F. ACID ETCHING

In the past, acid etching (with muriatic acid) was the most commonly used method to remove surface laitence and to provide a profile on concrete floors prior to the application of coatings. The primary reasons for its past popularity were due to its low cost for materials and application and its easy disposal "down the drain". Today, due to environmental regulations regarding the disposal of the used acid

and concern for worker health, acid etching of concrete floors has declined considerably.

Obviously acid etching has always proved impractical to use on vertical surfaces because of the difficulty in achieving the proper dwell time needed to etch the surface uniformly. In addition, acid etching on vertical surfaces (or on horizontal surfaces) does not open up subsurface voids and holes near the surface.

Prior to acid etching remove as much of the loose efflorescence or laitence as possible using a wire or fibre brush prior to applying the acid etch. Oil and grease also must be removed prior to acid cleaning, either by solvent wiping or by steam or alkali cleaning.

After removing grease, oil and other contaminants that cannot be removed by acid etching, the etching process typically consists of the following steps:

- (1) thoroughly wet the surface with clean water,
- (2) scrub with a 15% solution of muriatic acid, using a stiff fibre brush,
- (3) immediately after the surface is scrubbed and once the acid stops bubbling, wash the acid solution from the surface by rinsing with clean water,
- (4) neutralise any acid left on the surface using an appropriate solution,
- (5) test the surface using pH paper or pH meter,
- (6) test the floor using clean water to make sure it can penetrate down into the concrete without ponding,
- (7) reapply the acid if surface remains unsatisfactory for coating (i.e. laitence is still present or surface is still too smooth or possesses insufficient roughness)

In many cases more than one acid etching operation is required to obtain a satisfactory profile. Each acid etching procedure should be followed with thorough water rinsing. Normally, the desired profile is similar to that of fine sandpaper. This profile is satisfactory for many coatings. For the rinsing operation, a pavement broom with a water hose attached to it has been found useful.

Workmen handling the acid mixing, spreading and other operations must wear relevant safety goggles, protective clothing and rubber gloves and boots. Polyethylene or vinyl buckets should be used for mixing and spreading the acid. The acid should be added to the water rather than water to the acid.

Finally, the fumes from many acids used for etching can damage overhead uncoated galvanised ductwork, precision steel instruments etc. This damage is in the form of rust and it generally takes several months after the flooring job is completed before the rust spots are visible from the floor. If there is overhead galvanised ductwork present in a facility, it must be protected from the acid fumes. If this is not possible, it's best to select another method of surface preparation.

G. Abrasive Blasting

Blasting is used to prepare and clean poured concrete walls and floors in areas where this operation is permissible. Either wet or dry blasting is useful. Wet blasting is used to eliminate dusting.

Blasting of concrete removes loose and powdery concrete along with laitence. The resulting surface must be hard, with surface voids opened and with a profile that is satisfactory for coating adhesion. The blast nozzle must be kept at a distance that will provide satisfactory results without tearing the concrete. Dry, oil-free air must be used for the blasting operations. Normally, sand is used as the abrasive medium because it provides the desired results at a low cost.

Wire brushing is used to remove loose matter from surfaces and to a lesser extent open holes and voids on poured concrete before coating. Either power or hand wire brushing is suitable; however, the former normally is used for faster production.

Impact tools can be used for roughening poured concrete; however, this is slow and would normally be considered only for touch-up work.

Power grinding can be used to open holes and voids and to remove loose matter from the surface of poured concrete and pre-cast slabs. It can be used instead of blasting, but is slower.

The cleanest and most efficient method for preparing concrete floors, is centrifugal abrasive blasting, using a portable blasting machine that travels across the slab, leaving a blasted path several inches wide in its wake. Most abrasive and dust is recaptured in the machine. This procedure is often called "blast-tracking." The blasted surface is very uniform in profile and cleanliness. Dust clean-up prior to painting is minimal.

The major caution is that chemical and grease/oil contamination should be removed prior to blast-tracking to prevent contamination of the recycled abrasive.

H. Conclusion

One of the most overlooked duties of any construction job is inspection. The proper preparation of concrete surfaces and application of coatings is an extremely important part of the total coating job. It's important to remember that the specification is the governing document when it comes to inspection on the job site. It should tell the inspector the following: (1) what type of tests to perform, (2) when to perform them, (3) how often to perform them, (4) what results are acceptable, and (5) what to do when a non-conformance is found.

The first step to evaluate surface preparation requirements is to make a visual inspection of concrete surfaces to determine the reason for concrete condition, i.e., history of existing concrete.

The concrete should be inspected for porosity, exposed aggregate, form-tie holes, insets, joints fibres left in the surface from absorptive form liner, cracks. Latency or soft-weak surface cement, evidence of surface hardeners or use of additives such as silicones or various resinous materials that make coating of concrete difficult, evidence of penetration or saturation, and evidence of moisture damp or wet spots on floor and wall areas.

To assist the inspector in his work, forms should be provided which include a checklist for the various hold points during the concrete surface preparation.

- ◆ Identify the curing compound used
- ◆ Identify the hardeners, if any
- ◆ Identify the form oil used
- ◆ Record the use of spackling compounds
- ◆ Identify the grouts and caulking compounds used

The inspector should record the condition of the concrete.

- ◆ Honeycomb or porosity
- ◆ Roughness or smoothness
- ◆ Cracking Efflorescence
- ◆ Laitence
- ◆ Looseness
- ◆ Contaminants
- ◆ Temperature and humidity
- ◆ Excessive moisture
- ◆ Type of cleaning method used
- Sweep blast - abrasive used
 - Sandblast - abrasive used
 - Acid etch - strength and identify acid

The problems of coating concrete surfaces exposed to various operating service conditions will never be completely eliminated because of the many variables, which are inherent to the formation of concrete structures.

The degree of surface preparation required for contaminated concrete to achieve a sound substrate for application of corrosion-proof over laymen or coating system will vary widely depending on the following: (1) the type and quality of concrete (2) the type, nature and length of exposure conditions (3) the type of corrosion protection under consideration, and (4) economic and other considerations.

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SECTION 7

APPLICATION OF PROTECTIVE COATINGS

Revised: 02/2002

I. IMPORTANCE OF CORRECT APPLICATION

Every protective coating must be correctly applied in order to obtain the maximum performance. It is essential that the paint manufacturers' application instructions and the specifications are followed. The ambient conditions should be satisfactory during the application and the curing of the coating. The correct equipment (as stated on the manufacturers product data sheet) should be in good working order and used properly and good painting techniques should be practised.

The most important elements in producing good results and avoiding problems are described in the following section.

II. ENVIRONMENTAL CONDITIONS

Influence of Weather: The ideal time for painting is when the weather is warm and dry with little wind. Obviously, many coating projects cannot be delayed until these ideal conditions prevail. The following obstacles to good coating applications can be created by the weather.

Damp Weather: Under conditions of high humidity, condensation of moisture is likely to occur on surfaces. Condensation on the substrate interferes with bonding of the coating. Condensation on the surface of a freshly applied coating may alter its curing process. (See paragraph on condensation.)



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Dew Point: Dew point is the temperature at which water vapour will condense to form a liquid. Condensation can be in the process of forming before it is visible. The general rule of thumb for the application of most coatings is that the surface temperature must be 3°C above the dew point and not falling.

To determine the dew point and the relative humidity, the three most commonly used tools are the sling psychrometer, the surface thermometer and the psychrometric table. It is important to take reading throughout the day if coating operations are going on. In addition, the dew point readings should be determined in the area where the coatings are being applied, as close as possible to the surface. (Note: Take readings in the hottest and the coldest areas in the area that is being painted. On some vessels, exposed to sunlight the surface temperature on some portions of the tank can be considerably different than other areas.)

Extremely Dry Weather: Very low humidities can be a problem with water based products. "Shut off" of the water may result in film cracking. It can also cause poor curing rates with certain types of inorganic coatings and moisture cured coatings.

Low Temperatures: At low temperatures the film thickness of high build or "thixotropic" coatings becomes more difficult to achieve. Curing reactions slow down or stop for many materials. Water-based products may freeze. Solvents evaporate more slowly. Furthermore, at lower temperatures since the air holds less moisture, the relative humidity can increase causing condensation to develop.

High Temperatures: Although heat has many beneficial effects in the application of coatings, high temperatures can increase over-spray (dry fallout), trapped air or solvent bubbles, and, in the case of inorganic zinc's, the incidence of mudcracking. It also reduces the pot life of catalysed materials. High temperatures can also reduce the minimum and maximum recoat windows for a coating.

Strong Winds: Wind is a nuisance, particularly in spray painting. The material as it leaves the spray gun can be deflected from the target. Solvent tends to flash off, creating excessive dry spray at edges of the spray pattern. Lap marks become more evident. Dirt, abrasive and other debris may become embedded in the wet film.

Condensation: Condensation becomes a problem when humidities are high and surface temperatures are low. Unfortunately, on large-scale projects, primers are often applied late in the workday and sometimes at night. Abrasive blasting is a slow



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process, while applying a primer by spray goes very rapidly. Because of this wide difference in work rates, the contractor may take 6 hours of an 8 hour day to prepare steel for 1 to 1-1/2 hours of primer application. If he follows this practice, the contractor should establish that there is no likelihood of condensation during the night. Table 15, attached, illustrates the relationship of air temperature and percent relative humidity to dew point.

Condensation is particularly a problem during the early autumn and spring when wide variations in temperature occur within a few hours after the sun sets. If condensation forms on a freshly painted amine-containing epoxy surface an amine blush often forms (see picture at right) on the surface. The blush is often white and hazy. It must be removed prior to applying additional coats of paint or delamination can occur.



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Many amine blushes cannot be removed with solvents but will come off with water mixed with appropriate cleaners. To determine what is necessary to remove it from the surface contact the coating manufacturer. In the picture at right the amine blush is evident on the pipe. In a few spots (indicated by arrows) it was removed by using clean distilled water alone.

In tank lining work, condensation can be avoided by circulating warm, dry (de-humidified) air in the structure during the coating operation.

When weather is a problem, the following techniques may be of assistance.

Thinning: The thinner is simply a mixture of solvents compatible with the resins in the coating. Lowering the viscosity of the material can reduce many of the application and dry or curing problems created by weather conditions. This can be accomplished by adding the correct thinner in the proper amount. Most coating manufacturers produce solvents for “hot & windy” conditions and solvents for cool conditions.

For example, in “hot & windy” conditions the solvents used to spray inorganic zinc coatings often must be adjusted or replaced with another solvent to reduce dry spray. Regardless of the weather conditions, the maximum solvent limits shown in the product's application instructions should not be exceeded without written documentation from the coating manufacturer.

There may be local regulations regarding the amount of solvent that can be added to a coating. Specifiers and contractors are advised to comply with all local regulations when specifying and applying coatings.

Thinning can provide these benefits:

1. Improved flow and uniformity in application of the material.
2. Reduced over-spray, lap marks, bubble entrapment, and film "mud cracking" caused by rapid solvent flash off.

THE APPLICATOR MUST ONLY USE THE THINNER(S) RECOMMENDED OR ALLOWED BY THE COATING MANUFACTURER AS STATED ON THE PRODUCT DATA SHEET OR PROVIDED IN WRITING FROM THE TECHNICAL SERVICE DEPARTMENT OF THE COATING MANUFACTURER.

Heating Materials: With many materials, heating or warming has an effect similar to thinning. Several types of heating devices are available for use with spray equipment, including heat traced spray lines and drum heaters. It is important to make sure that the paint is stored at the proper temperatures as stated on the product data sheet. This is particularly important on construction sites subject to the cold winter months.

If the paint material is kept in an unheated trailer and becomes cold, it will increase in viscosity making application much more difficult. Often times, the contractor will simply add more solvent in order to spray the material; however adding solvent does not necessarily change the temperature of the material. Many coating materials require a temperature of at least 10⁰C to cure properly. Applying a coating that is -4⁰C to a surface that is barely 10⁰C is a formula for failure not success.

Unfortunately, on many job sites there is no heated storage area provided for the paint contractor and many contractors simply do not realise the important of storing materials at the proper temperatures to ensure proper curing and proper application properties.

Increasing Number of Coats: Since thinning reduces the volume solids of a coating, if an applicator thins a product, the film build may become difficult to obtain. In that situation, reducing the thickness per coat and increasing the number of coats will result in a better job. This is often true in both cold and extremely hot weather. Thinner films permit easier escape of solvent under both conditions. Bubbles and pinholes in hot weather and extremely slow hardening rates of thick film in cold weather are the result of the solvent's difficult in escaping at its ideal rate.

Other Environmental Problems:

When coating work is being done in an operating plant there is always the danger of "fall out" of dusts, chemicals or condensed fumes on the bare substrate or the surface between coats. Where the condition is excessive, major coating work may need to be delayed until there is a plant shutdown. In some instances "tenting" of the structure with thin polyethylene or polyvinyl chloride film is used to prevent this type of contamination.



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As much as possible, coating work should be planned and scheduled to prevent interference from other crafts. Some other construction trades such as welders, fitters, and electricians have little regard for "paint" operations. This apathy or indifference on the part of other tradesman can sometimes present bigger problems than the weather.

Table 15 : Dew point °C Determination Table

		Relative Humidity																			
		5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90	95	100
0	Air Temperature °C	-34.9	-27.8	-23.4	-20.2	-17.6	-15.4	-13.6	-11.9	-10.5	-9.1	-7.9	-6.8	-5.8	-4.8	-3.9	-3.0	-2.2	-1.4	-0.7	0.0
1		-34.2	-27.0	-22.6	-19.3	-16.7	-14.5	-12.7	-11.0	-9.5	-8.2	-7.0	-5.9	-4.8	-3.8	-2.9	-2.0	-1.2	-0.4	0.3	1.0
2		-33.5	-26.3	-21.8	-18.5	-15.9	-13.7	-11.8	-10.1	-8.6	-7.3	-6.1	-4.9	-3.9	-2.9	-1.9	-1.1	-0.2	0.5	1.3	2.0
3		-32.8	-25.5	-21.0	-17.7	-15.0	-12.8	-10.9	-9.2	-7.7	-6.4	-5.1	-4.0	-2.9	-1.9	-1.0	-0.1	0.7	1.5	2.3	3.0
4		-32.1	-24.7	-20.2	-16.8	-14.2	-11.9	-10.0	-8.3	-6.8	-5.4	-4.2	-3.0	-2.0	-1.0	0.0	0.9	1.7	2.5	3.3	4.0
5		-31.3	-23.9	-19.4	-16.0	-13.3	-11.1	-9.1	-7.4	-5.9	-4.5	-3.3	-2.1	-1.0	0.0	1.0	1.9	2.7	3.5	4.3	5.0
6		-30.6	-23.2	-18.6	-15.2	-12.5	-10.2	-8.2	-6.5	-5.0	-3.6	-2.3	-1.1	-0.1	1.0	1.9	2.8	3.7	4.5	5.3	6.0
7		-29.9	-22.4	-17.8	-14.3	-11.6	-9.3	-7.4	-5.6	-4.1	-2.7	-1.4	-0.2	0.9	1.9	2.9	3.8	4.7	5.5	6.3	7.0
8		-29.2	-21.6	-17.0	-13.5	-10.8	-8.5	-6.5	-4.7	-3.2	-1.8	-0.5	0.7	1.8	2.9	3.9	4.8	5.6	6.5	7.3	8.0
9		-28.5	-20.9	-16.1	-12.7	-9.9	-7.6	-5.6	-3.8	-2.3	-0.8	0.5	1.7	2.8	3.8	4.8	5.7	6.6	7.5	8.2	9.0
10		-27.7	-20.1	-15.3	-11.8	-9.1	-6.7	-4.7	-2.9	-1.3	0.1	1.4	2.6	3.7	4.8	5.8	6.7	7.6	8.4	9.2	10.0
11		-27.0	-19.3	-14.5	-11.0	-8.2	-5.8	-3.8	-2.0	-0.4	1.0	2.3	3.6	4.7	5.8	6.8	7.7	8.6	9.4	10.2	11.0
12		-26.3	-18.6	-13.7	-10.2	-7.4	-5.0	-2.9	-1.1	0.5	1.9	3.3	4.5	5.6	6.7	7.7	8.7	9.6	10.4	11.2	12.0
13		-25.6	-17.8	-12.9	-9.4	-6.5	-4.1	-2.1	-0.2	1.4	2.8	4.2	5.4	6.6	7.7	8.7	9.6	10.5	11.4	12.2	13.0
14		-24.9	-17.0	-12.1	-8.5	-5.7	-3.3	-1.2	0.6	2.3	3.8	5.1	6.4	7.5	8.6	9.6	10.6	11.5	12.4	13.2	14.0
15		-24.2	-16.3	-11.3	-7.7	-4.8	-2.4	-0.3	1.5	3.2	4.7	6.1	7.3	8.5	9.6	10.6	11.6	12.5	13.4	14.2	15.0
16		-23.5	-15.5	-10.5	-6.9	-4.0	-1.5	0.6	2.4	4.1	5.6	7.0	8.3	9.4	10.5	11.6	12.6	13.5	14.4	15.2	16.0
17		-22.8	-14.7	-9.7	-6.1	-3.1	-0.7	1.5	3.3	5.0	6.5	7.9	9.2	10.4	11.5	12.5	13.5	14.5	15.3	16.2	17.0
18		-22.1	-14.0	-8.9	-5.2	-2.3	0.2	2.3	4.2	5.9	7.4	8.8	10.1	11.3	12.5	13.5	14.5	15.4	16.3	17.2	18.0
19		-21.4	-13.2	-8.1	-4.4	-1.4	1.1	3.2	5.1	6.8	8.4	9.8	11.1	12.3	13.4	14.5	15.5	16.4	17.3	18.2	19.0
20		-20.6	-12.4	-7.3	-3.6	-0.6	1.9	4.1	6.0	7.7	9.3	10.7	12.0	13.2	14.4	15.4	16.4	17.4	18.3	19.2	20.0
21		-19.9	-11.7	-6.5	-2.8	0.3	2.8	5.0	6.9	8.6	10.2	11.6	12.9	14.2	15.3	16.4	17.4	18.4	19.3	20.2	21.0
22		-19.2	-10.9	-5.8	-1.9	1.1	3.7	5.9	7.8	9.5	11.1	12.6	13.9	15.1	16.3	17.4	18.4	19.4	20.3	21.2	22.0
23		-18.5	-10.2	-5.0	-1.1	2.0	4.5	6.7	8.7	10.4	12.0	13.5	14.8	16.1	17.2	18.3	19.4	20.3	21.3	22.2	23.0
24		-17.8	-9.4	-4.2	-0.3	2.8	5.4	7.6	9.6	11.3	12.9	14.4	15.8	17.0	18.2	19.3	20.3	21.3	22.3	23.1	24.0
25		-17.1	-8.6	-3.4	0.5	3.6	6.2	8.5	10.5	12.3	13.9	15.3	16.7	18.0	19.1	20.3	21.3	22.3	23.2	24.1	25.0
26		-16.4	-7.9	-2.6	1.3	4.5	7.1	9.4	11.4	13.2	14.8	16.3	17.6	18.9	20.1	21.2	22.3	23.3	24.2	25.1	26.0
27		-15.7	-7.1	-1.8	2.2	5.3	8.0	10.2	12.3	14.1	15.7	17.2	18.6	19.9	21.1	22.2	23.2	24.3	25.2	26.1	27.0
28		-15.0	-6.4	-1.0	3.0	6.2	8.8	11.1	13.1	15.0	16.6	18.1	19.5	20.8	22.0	23.1	24.2	25.2	26.2	27.1	28.0
29		-14.3	-5.6	-0.2	3.8	7.0	9.7	12.0	14.0	15.9	17.5	19.0	20.4	21.7	23.0	24.1	25.2	26.2	27.2	28.1	29.0
30		-13.6	-4.9	0.6	4.6	7.8	10.5	12.9	14.9	16.8	18.4	20.0	21.4	22.7	23.9	25.1	26.2	27.2	28.2	29.1	30.0
31		-12.9	-4.1	1.4	5.4	8.7	11.4	13.7	15.8	17.7	19.3	20.9	22.3	23.6	24.9	26.0	27.1	28.2	29.2	30.1	31.0
32		-12.2	-3.4	2.2	6.3	9.5	12.3	14.6	16.7	18.6	20.3	21.8	23.2	24.6	25.8	27.0	28.1	29.2	30.1	31.1	32.0
33		-11.5	-2.6	3.0	7.1	10.4	13.1	15.5	17.6	19.5	21.2	22.7	24.2	25.5	26.8	28.0	29.1	30.1	31.1	32.1	33.0
34		-10.9	-1.9	3.7	7.9	11.2	14.0	16.4	18.5	20.4	22.1	23.7	25.1	26.5	27.7	28.9	30.0	31.1	32.1	33.1	34.0
35		-10.2	-1.1	4.5	8.7	12.0	14.8	17.2	19.4	21.3	23.0	24.6	26.1	27.4	28.7	29.9	31.0	32.1	33.1	34.1	35.0
36		-9.5	-0.4	5.3	9.5	12.9	15.7	18.1	20.3	22.2	23.9	25.5	27.0	28.4	29.6	30.9	32.0	33.1	34.1	35.1	36.0
37		-8.8	0.4	6.1	10.3	13.7	16.5	19.0	21.1	23.1	24.8	26.4	27.9	29.3	30.6	31.8	33.0	34.0	35.1	36.1	37.0
38		-8.1	1.1	6.9	11.1	14.5	17.4	19.9	22.0	24.0	25.7	27.4	28.9	30.2	31.6	32.8	33.9	35.0	36.1	37.1	38.0
39		-7.4	1.9	7.7	11.9	15.4	18.2	20.7	22.9	24.9	26.7	28.3	29.8	31.2	32.5	33.7	34.9	36.0	37.0	38.0	39.0
40		-6.7	2.6	8.4	12.8	16.2	19.1	21.6	23.8	25.8	27.6	29.2	30.7	32.1	33.5	34.7	35.9	37.0	38.0	39.0	40.0
41		-6.0	3.4	9.2	13.6	17.0	20.0	22.5	24.7	26.7	28.5	30.1	31.7	33.1	34.4	35.7	36.8	38.0	39.0	40.0	41.0
42		-5.3	4.1	10.0	14.4	17.9	20.8	23.3	25.6	27.6	29.4	31.1	32.6	34.0	35.4	36.6	37.8	38.9	40.0	41.0	42.0
43		-4.6	4.9	10.8	15.2	18.7	21.7	24.2	26.5	28.5	30.3	32.0	33.5	35.0	36.3	37.6	38.8	39.9	41.0	42.0	43.0
44		-4.0	5.6	11.6	16.0	19.5	22.5	25.1	27.3	29.4	31.2	32.9	34.5	35.9	37.3	38.5	39.7	40.9	42.0	43.0	44.0
45		-3.3	6.3	12.4	16.8	20.4	23.4	25.9	28.2	30.3	32.1	33.8	35.4	36.9	38.2	39.5	40.7	41.9	43.0	44.0	45.0
46		-2.6	7.1	13.1	17.6	21.2	24.2	26.8	29.1	31.2	33.0	34.7	36.3	37.8	39.2	40.5	41.7	42.8	43.9	45.0	46.0
47		-1.9	7.8	13.9	18.4	22.0	25.1	27.7	30.0	32.1	33.9	35.7	37.3	38.7	40.1	41.4	42.7	43.8	44.9	46.0	47.0
48		-1.2	8.6	14.7	19.2	22.9	25.9	28.5	30.9	33.0	34.8	36.6	38.2	39.7	41.1	42.4	43.6	44.8	45.9	47.0	48.0
49		-0.5	9.3	15.5	20.0	23.7	26.8	29.4	31.7	33.8	35.8	37.5	39.1	40.6	42.0	43.3	44.6	45.8	46.9	48.0	49.0
50	0.1	10.0	16.2	20.8	24.5	27.6	30.3	32.6	34.7	36.7	38.4	40.0	41.6	43.0	44.3	45.6	46.8	47.9	49.0	50.0	

III. METHODS OF APPLICATION

Although there are many ways to apply coatings, the three most commonly employed methods are by brush, roller, or spray. Spray application method, by conventional or airless spray, is the most popular means of applying protective coatings. Brushes and rollers are often used when spray application is either impractical due to overspray or undesirable as in the case of stripe coating nuts, bolts, rivets, sharp edges and difficult to reach areas.

Brush: Various materials are used to manufacture brushes including synthetic materials such as nylon and polyester, and natural hair bristle brushes made from hogs, oxen and other animals. The proper type of brush is selected based upon the coating material that will be used.

1. Generally for water-based coatings synthetic brushes (nylon, polyester, or a blend of nylon and polyester) are used.
2. For strong-solvent containing paints, most contractors use the natural bristle brushes. Certain solvents attack synthetic fibres so they are not generally used with most high performance paints containing strong solvents.

Although many epoxy mastics, water-based acrylics, oils and most alkyds apply readily by brush, some coatings such as vinyl's, chlorinated rubbers, inorganic zinc's, certain epoxies, urethanes and do not usually lend themselves to this type of application except for touch-up.

Materials with fast-evaporating solvents become tacky very rapidly and resist the flow-out that is necessary to use a brush effectively. However, for some applications, brushing out the primer coat is recommended to ensure that it has been worked into the substrate surface. When this is necessary, some manufacturers recommend that the primer be liberally thinned to allow material flow. Check with the coating manufacturer before thinning material beyond the limits stated on the product data sheet. (Note: It is not a good practice to thin 100% solids tank lining materials unless specifically directed to do so by the coating manufacturer.)

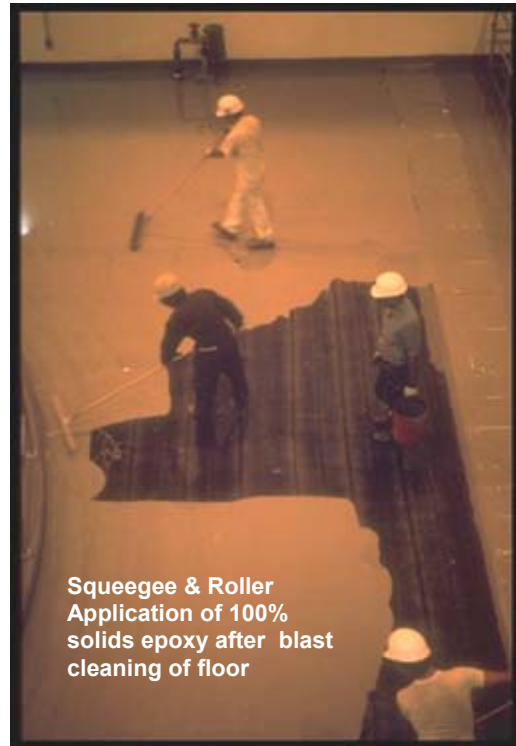
When brushes are used it is important to ensure that no brush hairs are left in the film since this can serve as a wick to the substrate and cause premature corrosion.

It is a common practice to use brushes to apply a stripe coat to the weld seams in tank lining applications immediately prior to the application of the full prime coat. Another typical application for a brush is in applying aluminium epoxy mastics to rusty, pitted steel in areas where blasting and spray application are not allowed.

Roller: Like brushes, rollers are made out of either synthetic or man-made fabrics. In addition, rollers are available in different thicknesses, (referred to as nap or pile). Rolling works well with some coatings but is impossible with others. A few materials dry on the roller and do not dissolve on dipping. In a short time the roller becomes too heavy to hold. Some coatings possess very poor flow properties. Products containing fast-evaporating solvents generally do not roll well.

Some 100% solids flooring products are formulated for roller application. These products flow out to produce a mirror like finish. Often special types of rollers are used in these applications.

When rollers are used to apply high-performance, strong-solvent containing coatings, the roller fabric should be shed-resistant and solvent-resistant. In addition, the roller should contain a "phenolic" core so that the solvents will not attack and disintegrate the core and embed portions of it in the finished coating film.



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From a corrosion standpoint, one of the primary concerns when rollers and brushes are used to apply high-performance coatings is to make sure that no brush bristles or roller nap are left in the coating. Any bristles or nap left in the coating, especially the primer, can serve as a type of wick for electrolytes providing them with direct access to the surface.

IV. SPRAY PAINTING

Certainly the largest volume of high-performance maintenance coatings are applied by spray equipment. This method of application is not only faster than alternate methods, but the resulting films are more uniform in thickness. The object in spray painting is to create a mist of atomised (finely dispersed) coating particles that will cling to the target in a uniform pattern and then flow into a continuous, even film.

In industrial and marine painting two types of equipment are used:

- ◆ Conventional (spray) and,
- ◆ Airless (hydraulic) pressure.

CONVENTIONAL (AIR ATOMISATION) SPRAY: When conventional or air spray equipment is used, the coating is atomised by the use of compressed air. The conventional spray system consists of the following primary components:

1. A pressurised pot
2. A compressor
3. A spray gun
4. An air hose
5. A fluid hose
6. An air cap
7. A fluid needle
8. One or two regulators
9. Moisture separator for compressor air (optional – but highly recommended)
10. Agitator in pot (optional for inorganic zinc's)

The spray gun (See Figure 1), which is the primary component in a spray system, brings the air and paint together. This is accomplished in such a way that the fluid is broken up into a spray that is then directed at the surface to be coated. There are two adjustments in most conventional spray guns, one which regulates the amount of fluid which passes through the gun when the trigger is pulled back, and a second which controls the amount of air passing through the gun, thus determining the width of the fan.



Figure 1:
Conventional Spray Gun

Photo courtesy of ITW Industrial
Finishing Binks / DeVilbiss

There are two types of conventional guns, external mix and internal mix. In the external mix spray gun, (which is the most widely used type), the air breaks up the fluid stream outside the gun after being directed through a specially designed air cap. The number, position, and size of the holes in the air cap determine the manner in which the air stream is broken up. This in turn governs the break-up or atomisation of the fluid stream.

The fluid leaves the gun through a small hole in the fluid tip. A needle that is operated by the gun's trigger controls the flow of material through this tip. As with air caps, fluid tips are manufactured in different sizes to accommodate various materials, the diameter of the orifice in the tip being the differentiating factor. Various coatings require different types of air caps and fluid tips in order to properly atomise the material. It is wise to follow the coating manufacturer's recommendation as to the proper spray gun, air cap, and fluid tip for the application of a specific material.

In general, vinyl, epoxy, and chlorinated rubber based coatings can be successfully sprayed with a DeVilbiss MBC or JGA type spray gun equipped with a 78 or a 765 air

cap and an "E" fluid tip and needle or equivalent epoxy equipment made by Binks and others.

There are two methods for bringing the fluid to the gun -- suction-feed or pressure-feed.

For **suction-feed**, the gun is usually fitted with a one-quart cup holding the fluid to be sprayed. When the trigger is pulled, suction is developed at the tip of the gun, drawing fluid out of the cup and up to the nozzle where it is sprayed. This type of set up has the following severe limitations: (1) the gun must be operated only pointing horizontally, (2) it will not spray viscous material, (3) spraying is slow, and (4) the cup must be refilled frequently.

With the **pressure-feed**, the fluid to be sprayed is forced to the gun under pressure. The pressure-feed type has the following advantages: (1) material of high viscosity can be sprayed, (2) a heavier coat can be applied, and (3) spraying is much faster. Although a one-quart pressure cup is sometimes attached to the gun for small applications, the majority of pressures fed spray operations are conducted with a separate pressure pot. This system ensures better pressure control and permits faster spraying.

The pressure pot as seen in the picture at the right (See Figure 2) is a closed chamber of usually two to ten gallons capacity that contains the fluid to be sprayed. A large air hose, preferably 2.5cm ID connects the pressure pot to the air source. A fluid hose and an air hose connect the pot to the spray gun. Air is directed into the pot through a regulator that maintains the proper pressure upon the fluid. The fluid is forced under pressure out through the fluid hose to the gun. The adjustment of the pressure regulator on the pot determines the amount of fluid available to the spray gun. Air is also bypassed from the main source in to the air hose leading to the gun.

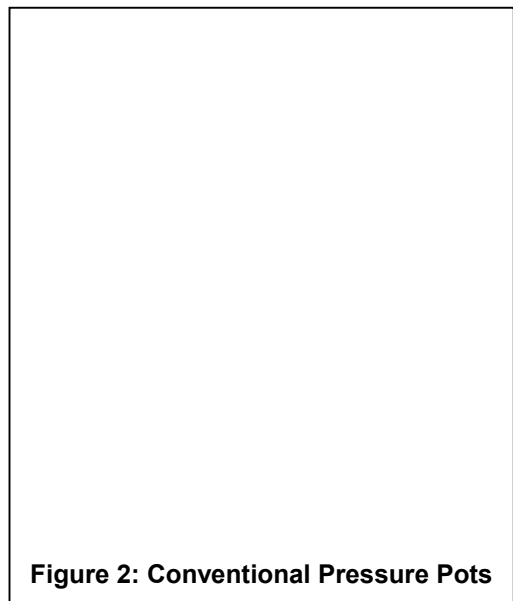


Figure 2: Conventional Pressure Pots

Photo courtesy of ITW Industrial Finishing
Binks / DeVilbiss

It is extremely important that the correct size fluid and air hoses be used. For best results, the gun should be equipped with a 12.7mm ID. Fluid hose and a 8mm air hose. Smaller air hoses should be avoided since they cause excessive pressure losses. For example, if an MBC gun with 765 air cap is connected by 15m of 6.3mm ID air hose to an air supply at 90 pounds pressure, when the trigger is opened, the actual pressure at the gun will drop to 50 pounds. This is not enough pressure to atomise and spray most coatings. However when 15m feet of the recommended 8mm air

hose is used, under the same conditions, the pressure will only drop to 75 pounds, which in most cases, is satisfactory.

Other equipment: Spray applications which take place in enclosed spaces or which involve tank linings may require additional equipment. In confined spaces, the workers should wear suitable fresh-air supplied respirators – expert advice should be sought.

It is also essential in confined areas that the proper air stream is set up using fans or blowers to remove solvent fumes. Many solvent fumes are heavier than air so they tend to collect at the bottom of the tank. If fumes are allowed to accumulate, they can cause acute health hazards to the workmen and create a serious fire hazard. Explosion proof lighting and tools should be used inside of tanks that are being coated with solvent-containing coatings.

The best means to accomplish this is to set up the blower to suck air from inside and exhaust it outside. Blowing air into the tank normally results in stirring up rather than removing the vapours. Since the solvents used in most maintenance coatings are heavier than air, it is necessary to attach a conduit or tube to the blower in order to draw up the vapours from the bottom of the tank.

When used for continuous immersion, many tank-lining materials should be force-dried. Small-coated units should be dried in an oven circulating air at 60⁰ – 95⁰C.

For large tanks a heater and a dehumidification unit may be required. Explosion-proof and spray-proof equipment should always be provided for coating operations in enclosed areas. This includes motors, junction boxes, lights, and any other equipment which could generate a spark or flame.

A. TECHNIQUES

1. MIXING MATERIAL

It is essential that coatings are stirred thoroughly before use. This is to ensure that all the solids are in the solution and are uniformly dispersed. Always follow the paint manufacturers' directions as printed on the product data sheet. Here's an example of a common mixing procedure:

- a. Remove the lid from the container.
- b. Pour off most of the liquid, without stirring, into a clean, empty container.
- c. Stir the mixture in the original container until all pigment is loosened from the sides and bottom and is mixed into the liquid.

- d. Pour the liquid taken off the top back into the bottom portion. Add a little at a time and stir thoroughly.
- e. Box (pour) the coating from one container to another until completely mixed.

2. SETTING UP SPRAY EQUIPMENT

- a. Cleaning - Spray equipment must first be cleaned with a suitable solvent. If equipment is not thoroughly clean, old dried paint from the interior of equipment and hoses may be removed by the new solution, causing gun stoppage and unsatisfactory results.
- b. Adjusting fluid pressure - Most manufacturers' application instructions give approximate pressures for spraying a particular coating. However, the exact pressure depends on temperature size of hose, length of hose, viscosity of the material, etc. The equipment should be adjusted as follows:
 - 1. Pour the stirred coating into the pressure pot and clamp on the lid.
 - 2. Turn on the air supply to the pot.
 - 3. Turn on the fluid hose to the gun.
 - 4. Turn off the air hose to the gun.
 - 5. Remove the air cap from the spray gun.
 - 6. Open the fluid adjusting screw on the spray gun as far as it will go and pull the trigger all the way back.
 - 7. Holding the gun waist high, pointing out in a horizontal position, screw the pressure regulator on the pot until the fluid is forced in a stream that travels 1.8 to 2.4m before hitting the ground. This is the proper fluid pressure.
 - 8. Replace air cap.
- c. Adjusting air pressure - The air pressure at the gun is the pressure of the air source. The fluid pressure regulator on the pot does not control it. The pressure at the source (line pressure) should usually be 90 to 100 pounds. (Using 15m of 8mm air hose to the gun, this will result in about 75 to 80 pounds at the gun.) After fluid pressure is adjusted, as described above, test for proper air pressure as follows:
 - 1. Turn on air to the gun (fluid also turned on).
 - 2. Pull trigger back.

3. Adjust fan about 20cm to 25cm wide by turning fan adjustment screw on gun.
 4. Spray a test pattern, holding gun about 25cm from surface and swinging rapidly to produce a thin coat. If droplets of liquid hitting surface appear to be less than 4mm across, air pressure is adequate. If coating is spattered with drops appearing 3mm or larger, coating is not being atomised and air pressure must be increased.
- d. Adjustment at gun - Adjust the fan to produce a spray pattern 20cm to 25cm wide. Adjust fluid control at the gun so that a smooth, wet film is produced on the surface when the gun is moved at the desired speed.

3. SPRAYING PROCEDURE

The most important point to remember in spraying fast-drying, synthetic resin based materials, is that they must be applied in a heavy, wet film. If the coating is allowed to dry before it hits the surface or thin spots occur in the film, the protective value of the coating is greatly reduced.

Proper straying technique is important to the success of the job, and the following points must be observed:

- a. Hold the gun not more than 25cm from the surface
- b. Make even parallel passes with the spray gun, overlapping each pass to ensure thorough coverage.
- c. Move the gun parallel to the surface at all time. Do not swing it in an arc or shoot at an angle.
- d. Do not tip the gun up or down. Point it perpendicularly toward the surface.
- e. Apply an extra coat to all corners, welds, rivets, bolts, or other sharp edges.
- f. "Trigger" the gun at the end of each pass. (Shut off the fluid at the end of each stroke to prevent blowing across adjacent surfaced.)

AIRLESS (HYDRAULIC) SPRAY: With this equipment, the coating is atomised by forcing the material under high pressure through a very small orifice in the tip of the spray gun. As the material leaves the orifice, it expands and is broken up into fine droplets. Unlike, conventional air spray, air is not used to atomise the coating.



Figure 3: Airless Spray Pump
Photo courtesy of Graco, Inc.

The two outstanding advantages of airless spray equipment is the reduction of over-spray and increased production. Smoother applications can be made especially to corners and crevices, and material loss to the wind is considerably less than with conventional air spray. Total job savings with airless spray due to (1) higher speed, (2) more coverage per litre, and (3) reducing air consumption are said to range from 30% to 70%, depending upon type of material sprayed and other factors.

Adaptability to various types of material is obtained by providing a series of interchangeable fluid tips for the gun, each of which has a fixed orifice and fan. Since the size and shape of the orifice determine the break-up of the material, the width of the fan and delivery rate, it is important to select the proper tip for spraying a particular coating. The pigment size is the primary factor affecting the required tip size. The coating manufacturer knows the maximum pigment size in a particular product, therefore they typically state the recommended tip size on the product data sheet.

An airless tip wears out with usage. As it wears out the fan width of the spray pattern is decreased. This reduction in the fan width can cause a number of undesirable effects including the following:

1. Applying more paint within a given area increasing the likelihood of runs, sags or excess dry film thickness.
2. Reduction in the production rate since less area is covered by each pass.

The only other adjustment is the pressure that is applied on the fluid. An air-driven pump with a ratio of approximately 30:1 or higher is commonly used to supply this pressure. Thus, if 100-psi air pressure is supplied to the pump, the resulting pressure on the material at the gun will be 3000 psi. As with the fluid tip, the pump pressure must be regulated to meet the application characteristics of various



Figure 4: Airless Spray Gun

Photo courtesy of Graco, Inc.

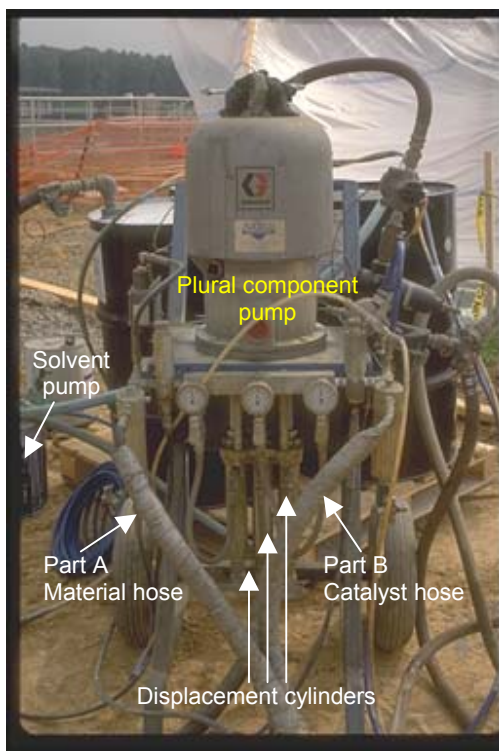
materials.

High solids materials such as Amercoat 385 and Amerlock 400 are particularly suitable for application with this equipment. Pinholing is practically eliminated and the heavier dried films present a smooth surface. Amerlock, for example, can be applied with airless spray in a smooth, uniform film, free from streaking, running or sagging to a dry film thickness up to 200 microns in only one cross-spray coat.

Other types of coatings can be applied satisfactorily with the airless system but certain disadvantages can occur, such as accidental application of excessive wet film thicknesses, leading to pinholing and solvent bubble entrapment.

PLURAL COMPONENT AIRLESS SPRAY EQUIPMENT

A special type of airless spray equipment gaining in popularity today with the advent of 100% solids coatings is “plural component equipment”. For years this type of equipment was used to spray adhesives, sealants, foams, elastomeric polyurethane's and other speciality products but industrial painters rarely used it.



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After the enactment of VOC regulations, coating manufacturers began developing and marketing solventless, 100% solids epoxies, novolacs and polyureas. Without solvents, many of these materials possess a very short “pot life” after the two-components are mixed. In some cases, the set-up time after mixing both components together is only 10 seconds. The short pot life rendered traditional airless equipment impractical since the material would set up in the pump, gun and hoses. The solution to this dilemma – use plural component airless spray equipment.

The picture on the left shows a Graco plural component pump in use. This pump is a fixed ratio unit, set up to spray a 2:1 ratio, two-component elastomeric polyurethane. The three gauges in the front of the unit indicate the pressure on each of the 3 displacement cylinders. The coating material is being pumped from the two 205-litre drums behind the unit. Notice all the hoses on this unit. This pump is one of the less expensive plural component units.

There are many variations of plural component airless equipment but the basic principle is to pump the Part A and the Part B separately from different supply pumps through a proportioning pump (with different displacement cylinders) and through different hoses. The two-components generally meet and are combined together in a

manifold-mixer located before the spray gun. (For “instant set” materials the material is mixed together at the spray gun.)

Plural component equipment is expensive even though the initial investment is high, the payback period is generally very short (i.e. 6 – 9 months) for large volume paint users.

Significant savings to offset the initial cost are often seen in the following areas:

(1) reduction in solvent usage, (2) reduction in material (paint) usage due to less waste, (3) reduction in solvent & waste material disposal costs, (4) labour savings by reduction in clean-up time, and (5) labour savings in elimination of mixing time.

Most plural component pumps consists of the following minimum components:

- (1) Base Supply Pump (for Part A)
- (2) Catalyst Supply Pump (for Part B)
- (3) Proportioning Pump – (either fixed ratio or variable ratio)
- (4) Solvent Supply Pump – (to flush the lines from the manifold mixer to the spray tip)
- (5) Mixer manifold
- (6) Spray gun & tip
- (7) Several hoses
- (8) Heat traced lines (optional to reduce the material viscosity)
- (9) Drum heaters or heated hoppers (optional to reduce material viscosity for easier sprayability)

To learn how to operate and properly maintain plural component special training is required. Most pump manufacturers provide this training for a fee when the pump is purchased. It is essential to keep thoroughly clean the pump in order to keep it in good working order.

One of the essential safeguards for this type of equipment is maintaining the proper ratio between the Part A and the Part B. Pump manufacturers use a variety of mechanisms to monitor the ratio and to shut the pump down the material becomes “off ratio”.

Recently, a major US shipbuilder conducted a study on several different plural component pumps. As a part of the evaluation, they intentionally disconnected the Part B (catalyst) to determine how long the pump would continue pumping before shutting down. One pump shut off immediately upon finishing the stroke it was in the process of completing. Most of the pumps eventually shut off but one pump never shut down. Unfortunately, as their study discovered, some plural component equipment takes longer than others to respond to this condition meaning that improperly mixed material may end up on the surface and will need to be removed.

Regardless of the difficulties associated with plural component equipment, there are several reputable pump manufacturers in the United States and Europe that manufacture well-engineered pumps.

Units are available in a wide array of configurations including portable, trailer mounted units.

V. INSPECTION

To obtain a proper finished coating job, it is essential that periodic inspections be made before, during, and following the application. Proper inspection procedure begins with an inspection of the prepared surface. The specification for the job and or the product data sheet (if there is no specification) spell out the required surface preparation, but making sure this is accomplished is often the job of the inspector. Therefore, it is important that the inspector be familiar with the specifications, the product data sheets and the inspection tools necessary to perform the necessary checks. However just because there is a third-party inspector on a project, this does not relieve the contractor of their responsibility to perform in accordance with the specifications. The contractor is responsible for their own quality control.

After the surface has been satisfactorily prepared in one of the manners described in the previous chapter, it should be thoroughly dusted or vacuumed if abrasives or other dust generating materials were used to perform the surface preparation. Surfaces that do not meet the specification standards must be redone before any further steps are taken.

Each coat should be carefully inspected before the subsequent coat is applied. Over-spray or dust should be removed by light sanding or dusting. All loose brush hairs or roller nap in the prime coat should be removed, and along with any holidays be re-primed. Runs and sags are to be avoided. The inspector must insure that sufficient drying time (i.e. minimum recoat window), as stated in the manufacturer's product data sheet / application instructions, be allowed between successive coats.

To ensure proper coverage it is recommended that succeeding coats be of alternating colours.

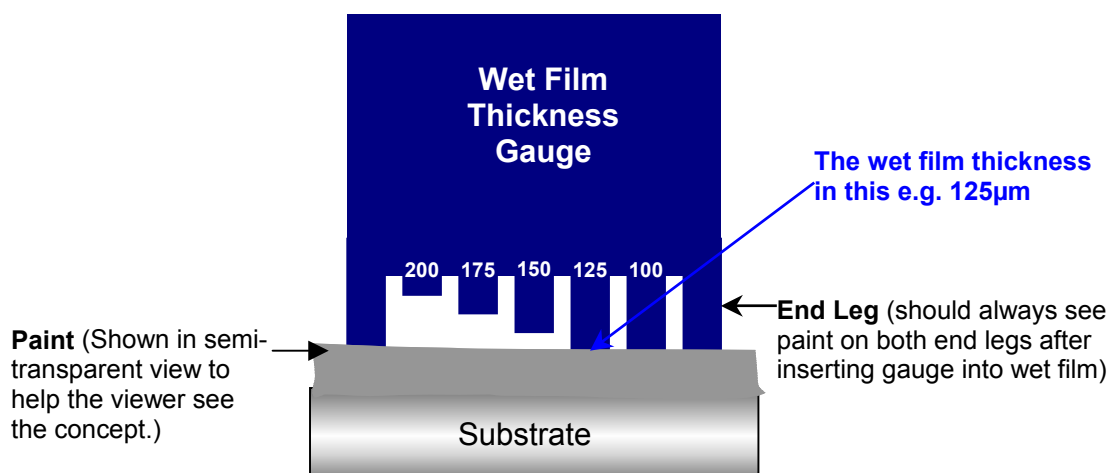
COMMON WFT & DFT INSPECTION TOOLS

A brief overview of the inspection tools commonly used to check the coating in both the wet and the dry states is provided below. For complete instructions on the use of these tools consult the manufacturers.

USING A WET FILM THICKNESS GAUGE

Specifications for the finished coating system usually call for a minimum dry film thickness. For such measurements a variety of instruments are available. The simplest and least accurate of these is the **wet film gauge**. To determine the wet film thickness (wft) of a coating, follow these steps:

1. Select the portion of the wft gauge that represents the range of wft that is specified.
2. Immediately after the coating is applied, insert the wft gauge into the wet film perpendicularly to the surface.
3. Remove the gauge from the surface and turn it over to reveal the portion of the gauge that was just in the paint. Look at the gauge. At a minimum, the end legs of the gauge should contain some of the wet paint from the surface.
4. If NONE OF THE OTHER LEGS ARE WET, reinsert the gauge into the wet paint, using the portion of the wft gauge with lower wft values.
5. If SEVERAL BUT NOT ALL OF THE LEGS ARE WET, (as in the example below) find the last leg or foot that is wet and then look at the side of the gauge to determine its value. Record the value of the last leg that is wet. For instance in the example below the proper wft is 125 microns.



6. If ALL OF THE LEGS ARE WET, turn the gauge to the next higher set of numbers and reinsert it into the wet paint. If only the end legs are wet (that have no values associated with them), then record the highest value leg from the previous insertion when all the legs were wet. If one or several legs are wet on the new side, then record the value of the last leg that is wet.
7. ALL WFT READINGS ARE STEPPED (i.e. 25, 50, 75 μm steps) even if the paint is $\frac{1}{4}$ of the way up the side of the 25 μm leg and the next leg is 50 μm .

Naturally, coating thickness will diminish as the solvent in the paint evaporates. Therefore, the wet film gauge should always indicate a greater film thickness than actually exists, except in the case of 100% solids paints.

One of the drawbacks of a wft gauge is that it cannot be used accurately in measuring coatings that dry within seconds, such as some of the 100% solids instant setting polyureas. In addition, it does not provide accurate measurements on coatings that are filled with hard pigments like flake glass, glass beads or metals (i.e. inorganic zinc's). With these types of products the wft gauge may come in contact with the pigment that rests on the substrate instead of the substrate. In this case, the wft indicated by the gauge is less than the actual wet film thickness.

A second big drawback with this instrument is the inability to measure total film thickness in a multi-coat application since only wet coat readings are obtainable. Therefore, at best, the wet film gauge can only give the inspector a rough idea of the thickness of each coat as it is being applied. Its area of greatest use is in spot checking the paint film as it is being sprayed; and in so doing, enabling the painter to immediately correct low film thicknesses. It is also possible with this instrument to measure coating films that are being applied over concrete surfaces.

USING DRY FILM THICKNESS GAUGES

Dry film thickness measurements over steel are usually taken with non-destructive gauges. There are two different classifications of non-destructive dft gauges used on steel "Type 1" Pull-Off Gauges and the "Type 2" Constant Pressure Probe Gauges. These gauges are designed to measure non-magnetic coatings over ferrous (magnetic) substrates.

The Type 1 gauge functions by the principle of magnetism. It contains a permanent magnet-calibrated spring mechanism to give reading on a graduated scale. It measures the force necessary to pull the magnet off the surface. The thicker the paint, the weaker is the magnetic attraction to the magnetic surface and therefore the sooner the magnet will pull-off the surface resulting in a higher dft than if there was less paint on the surface.

The most popular of these Type 1 gauges are the Mikrotest, the Positest and the Elcometer. There are both manual and automatic version of these instruments. More operator care is required for the manual



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inspector does not continue to operate the gauge after the magnet releases, thereby reporting a lower reading than the actual reading. Some inspectors prefer the Type 1 gauges because they are more durable and less expensive to replace (if they are accidentally dropped from a structure) than the Type 2 gages.



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When using a Type 1 gauge, first check the calibration of the gauge by the use of calibration blocks, and then determine the base metal reading (BMR) by placing the gauge on the blasted, uncoated steel. Finally proceed to take the dft readings and subtract the BMR from each individual gauge reading.

The reported accuracy (by the manufacturers) on most of the Type 1 gauges is $\pm 5\%$ of the reading. These gauges typically do not report the readings in decimal form so the

inspector or contractor must “guestimate” the approximate number when it falls between the values displayed on the dial.

Type 2 gauges : these gauges use a probe that exerts a constant pressure on the coated surface throughout the entire measuring process. The work on the principle of electromagnetism and are used to measure non-magnetic coatings over a ferrous (magnetic) substrate.

Most, if not all of the Type 2 gauges, report the dft measurements to 1 or 2 decimal places (i.e. 4.6 OR 4.63) with a direct reading so there is no need for the inspector to “guestimate” with the Type 2 gauges. According to the manufacturers the gauges are accurate to within $\pm 2\%$ or $\pm 3\%$ of the reading.

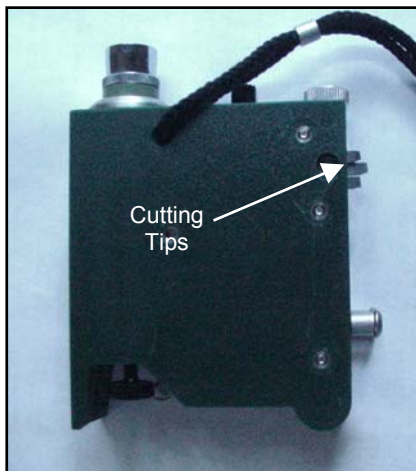


Photo courtesy of DeFelsko Corp.

The calibration of Type 2 gauges is verified by the use of traceable calibration blocks or shims in accordance with the manufacturers instructions and are adjusted for use over blasted ferrous surfaces (to compensate for the BMR) by placing a shim of a known thickness (verified by a micrometer) on the blasted surface and adjusting the gauge so that it reads only the thickness of the shim. This adjustment is made with the gauge lifted off the surface. The gauge is then placed on the shim, re-measured and readjusted if necessary by following the procedure described earlier. (Note: Do not adjust the gauge while it is on the surface; lift it off the surface before adjusting it.)

Both the Type 1 and the Type 2 gauges are subject to problems associated with vibration, proximity to edges, proximity to other mass of steel, magnetic fields, tilt of the probe, roughness of the substrate, and dirty, tacky or soft films.

TOOKE GAUGE (PIG) OR PAINT INSPECTION GAUGE



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Sometimes disputes develop regarding how many coats were applied by the contractor or how many microns were applied in each coat. To determine answers to these questions the inspector can use a destructive dft gauge, called the Tooke gauge.

The Tooke gauge works on the principle of geometry and utilises an illuminated 50-power microscope with a measuring reticule and 3 separate tungsten carbide cutting tips (1x, 2x and 10x). The cutting tip used is selected after determining the dry film thickness of the coating. Each tip produces a cut of a different angle. The inspector must select and use the proper gauge based upon the dry film thickness.

The chart below shows the angle and dft range for each tip when using the Tooke gauge.

Cutting Tip	Angle	Each Line Represents
1X	45 ⁰	500 – 1250 µm
2X	26.6 ⁰	50 – 500 µm
10X	5.6 ⁰	0 – 75 µm

The Tooke gauge is a destructive instrument since it requires cutting through the film to the bare substrate (in one cut). It is always advisable to obtain the owners

permission before performing this test or any other destructive test. In order to measure each coat in a multi-coat system with a Tooke gauge, it is necessary for each coat to contrast in colour with the previous coat to a sufficient degree so that there is a clear distinction between each layer.

One of the additional advantages of the Tooke Gauge is its versatility. It can be used for dry film thickness measurements over many different types of substrates including the following: ferrous metal, non-ferrous metal, ceramic, wood, concrete, plastic and glass. In addition, the gauge also contains a 50-power microscope that is useful for examining defects, cracks in the film, blisters and a wide variety of visible surface contaminants.

HOLIDAY DETECTORS

For some applications, such as tank linings, it is extremely important that the dried coating film contain no bare spots or "holidays". Often such areas are too small to notice with the naked eye. Therefore, to ensure 100% coverage in critical applications, holiday detectors are used prior to placing the coating into service. These electrically operated instruments are capable of detecting non-visible pinholes or bare areas in the coating and may be used to inspect any non-conductive coating which are applied over a conductive surface.

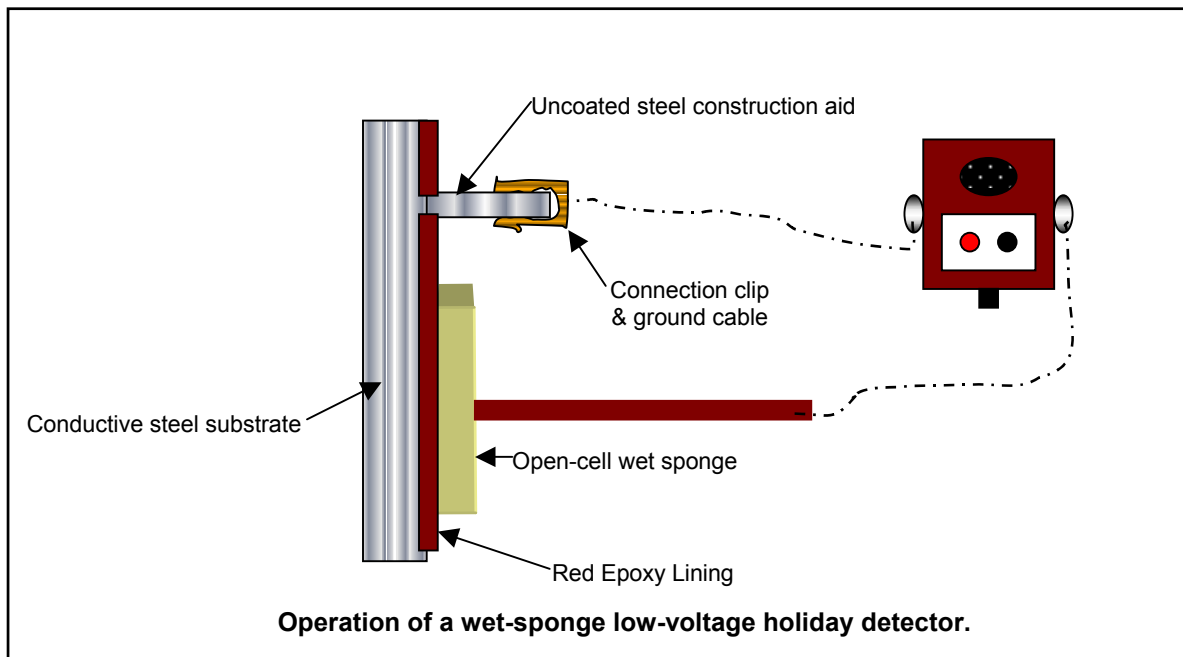
There are three types of holiday detectors:

- (1) Low-voltage wet sponge holiday detectors
- (2) High-voltage DC Holiday Detectors
- (3) High-voltage AC Holiday Detectors

Type	Minimum / Maximum microns (μm)	Indicator	Rate of Speed
Low-voltage wet sponge holiday detector	0 – 500 μm (must add 1 ounce of surfactant to water if the dft is over 250 μm)	Beeping sound - audible	0.3m / second double pass
High-voltage DC holiday detector	Varies by manufacturer from 97.5 μm up to 3125+ μm	Spark arcing- visible	0.3m / second double pass

A typical example of a low-voltage holiday detector would consist of a rod holding a open-cell (cellulose) wet sponge that is electrically connected to a power supply. This source in turn must be connected directly (grounded) to a bare spot on the metallic

surface over which the coating is applied. (Note: the bare spot can be on the outside of the vessel or tank as long as it is electrically connected to create a potential circuit.) If there are no holidays, the coating film acts as an insulating barrier, thereby preventing completion of the electrical circuit. If however, there is a holiday in the coating, the circuit is completed, current flows and some type of signalling device such as a bell or buzzer alerts the inspector.



This method of inspection is extremely important where the coating is to be continuously immersed in a highly corrosive solution. Holidays, if not corrected, become focal points for corrosion, often resulting in deep pitting of the underlying surfaces.

VISUAL DEFECTS

After the coating is cured it should also be inspected for runs, sags, overspray, blisters, roughness and any other “defects” as defined by the specification. Any areas found that do not comply with the specifications in regards to surface defects should be repaired and / or re-coated.

RECOAT TIMES

Finally, the inspector should ensure that adequate force or air-drying time (as stated in the specifications and / or the product data sheet) is allowed before the coated piece is placed in service. This is especially important if the coating is to be immersed or subjected to splash and spillage. If the coating is not allowed to cure for a sufficient period of time there is a substantial danger of trapping solvents in

the film. This may result in blistering, improper adhesion of the coating and reduced chemical resistance.

The **minimum recoat time** is the minimum time that the previous coat must be allowed to dry after it is fully applied before the next coat can be applied. The recoat time is a function of several factors including the following: (1) the dry film thickness applied, (2) the surface temperature, (3) the air temperature, and (4) the relative humidity. The product data sheet normally lists the recoat time when a coating is applied at a certain dft with 50% relative humidity and 20°C. If any of the actual application conditions are different than those stated on the product data sheet, check with the coating manufacturer to determine the minimum recoat window.

Generally, if the coating is applied at higher dft than that stated on the product data sheet, or if the temperature is lower or the relative humidity is higher, the coating will require a longer period of time to elapse before recoating it.

In addition to the minimum recoat time, most high-performance, multi-component and some single component coatings possess a maximum recoat window. The maximum recoat window is the maximum safe time after the previous coating is applied that a subsequent coat can be applied without the need for additional surface preparation.

If the maximum recoat window is exceeded, consult the coating manufacturer to determine what is required to apply an additional coat. Many manufacturers recommend roughening up the coating.

NO Recoat Zone				SAFE Painting Zone				NO Recoat Zone without Special Preparation			
DANGER Solvents still coming out of coating. Do NOT recoat yet.				Minimum Recoat Time (24 hours) Maximum Recoat Time (48 hours)				CAUTION Coating is cured too much to allow proper adhesion of next coating. Consult coating manufacturer.			
6	12	18	23	24	36	42	48	49	60	66	72
Hours elapsed after the application of the previous coating											

Table 4: Example of coating with a minimum recoat of 24 hours and a maximum recoat of 48 hours

VI. PRODUCT DATA SHEETS (PDS)

Product data sheets are critical to virtually all aspects and all people involved with the specification, application and inspection of protective coatings. The information provided on the following pages is an excerpt from a copyrighted article written by Mike O'Brien, President of MARK 10 Resource Group, Inc. and used with permission.

VII. SIMPLE INSPECTION EQUIPMENT

- Sling Psychromatic
- Surface Temperature Gauge
- Knife/Tape, X cuts – ASTM D3359
- Magnifying Glass

MANUFACTURERS PRODUCT DATA SHEETS

THE AUDIENCE

Well-written product data sheets (PDS) provide helpful, practical information for all individuals involved in the coating project from the design stage to the finished project. Obviously, the type of information an individual needs or wants from a PDS varies depending upon their function on the project. The PDS target audience consists of three distinct groups of people listed below.

- Specifiers (Architects & Engineers) & Owners
- Applicators / Contractors (Fabricators & Field Painters)
- Inspectors

Each of these groups is interested in obtaining different information from the product data sheet. For example, a field painting contractor doesn't care about the flowery words used by the marketing departments of coating manufacturers to entice the specifier into putting their products into the specification. The paint contractor wants answers to practical issues that affect his production rates and profitability. His concerns revolve around topics like "pot life after mixing", "minimum application temperatures" and "recommended dft per coat".

The paint contractor wants answers to practical issues that affect his production rates and profitability.

Therefore the information presented on a product data sheet must focus on the needs of at least three distinct audiences: (1) those writing specifications, (2) those applying the material in the field or shop, and (3) those inspecting the application during the project

GENERAL FORMAT OF A PRODUCT DATA SHEET

The format of a well-designed product data sheet, usually consists of the following two general sections:

- *Product Information*
- *Application Information*

(Note: Some manufacturers prepare a separate Application Instruction Data Sheet, listing in great details the application information.)

The *Product Information Section* focuses primarily on the interests and concerns of the specifier. It often contains several sub-sections. The titles vary by manufacturer but generally include the following categories:

- Product Description & Generic Type
- Recommended or Typical Uses

- Product Characteristics
- Recommended Dry Film Thickness (dft)
- Solids By Volume
- Performance Characteristics (Testing)
- Volatile Organic Content (VOC's)
- Colour Availability
- Ordering Information (Sizes)

The other major section found on most PDS's is the *Application Information Section*. It provides helpful information to the specifier but it's directed principally toward another target audience, namely the applicator and the inspector. This section normally includes the following sub-sections:

- Surface Preparation
- Application Conditions
- Application Equipment
- Thinning & Clean-Up
- Dry Times & Recoat Times

CONFLICTS BETWEEN SPECIFICATIONS & PRODUCT DATA SHEETS

..... in the case of a conflict between the specification and the manufacturers product data sheet, the more restrictive document will govern

When manufacturers compose "good" product data sheets and specifiers use this information to write the specs, it significantly reduces problems, conflicts and even premature failures. However, sometimes specifiers inadvertently incorporate statements into their specification documents that create a direct conflict between the specifications and the manufacturers product data sheets. For example, consider the commonly used sentence, "*prepare the surface and apply the coatings in accordance with the manufacturers recommendations*". The specification may require a Near-White Blast Cleaning (Sa 2½ ISO 8501-1), whereas the product data sheet may require only a Commercial Blast Cleaning (Sa 2 ISO 8501-1).

A good specification provides clear direction regarding what to do in this type of situation, by including a statement such as "*in the case of a conflict between the specification and the manufacturers product data sheet, the more restrictive document will govern as determined by the engineer*".

FINDING THE CRITICAL INFORMATION ON A PDS

On a product data sheet all information is not of equal importance. Each of the three parties mentioned previously who are involved with PDS typically focus on those issues that are critical to them.

The specifiers primary task (related to the product data sheet) involves determining the suitability of a particular product for application to the proposed substrate, given both the operating conditions and the in-service conditions. His objective is to select

the most cost-effective product that can be practically applied within the application and in-service parameters to achieve the desired life expectancy. His time reference focuses on both the present and the future. Prior to selecting products to include in the material (paint) section of the specification, *the specifier* should obtain the following critical information about each product under consideration:

- Minimum application temperature? (surface & air)
- Maximum recoat window?
- Maximum dry temperature resistance?
- Maximum wet temperature resistance? (if immersion)
- Chemical resistance?
- Physical resistance?
- UV Resistance? (if outside)
- Minimum surface preparation required?
- Acceptable dry - film thickness (DFT) range
- Compatibility
- VOC's
- Time & temperature for full cure?
- Application methods?
- Minimum & maximum relative humidity?
- Dew point requirements?
- Minimum anchor profile?
- Force curing requirements?
- Safety?

If the specifier determines after examining these issues that the product under consideration cannot be applied successfully within the anticipated application conditions, he or she should exclude it from the specifications.

The specifiers principal interest lies in recommending to the owner (his customer), products and systems that furnish a cost-effective solution over their useful life. Properly written PDS's should provide the specifiers with all the pertinent and specific coating-related information required to apply that particular product so that it performs successfully over its anticipated life. Inadequate or missing information on the PDS can result in serious problems.

Paint problems on large projects often end up dragging in the engineering or architectural firm that wrote the specification. This can become very distracting and expensive for the A/E firms, especially if the problem turns into a lawsuit. The hours spent preparing and giving depositions are non-billable. Poorly written PDS's do affect specifying engineers especially when the engineering firms include in their specification statements like, *"apply the product in accordance with the manufacturers instructions"*.

Engineering firms are regularly involved with selecting products to include on their specifications, evaluating product submittals, and approving product submittals.

Specifiers are well advised to carefully select the paint manufacturers to include on their specifications. Requiring properly-written, comprehensive product data sheets is one valid criterion for A/E firms to use in determining which coating manufacturers to list by name in the specification as an “acceptable manufacturers”.

Applicators comprise a second group of individuals that regularly rely upon information contained in product data sheets. The *applicators (either field-painting contractors, in-plant paint crews or shop fabricators)* concerns are present-time oriented as opposed to the long term. Their concerns are practical and production-oriented. The primary areas of interest to the *applicator* are as follows:

- Pot life? (after mixing)
- Minimum application temperature?
- Minimum & maximum relative humidity?
- Dew point requirements?
- Minimum surface preparation?
- Storage conditions?
- Solids by Volume?
- Application Methods?
- Application Equipment?
 - Tip sizes
 - Hose lengths
 - Hose diameter
 - Pressure requirements
- Maximum recoat window
- DFT range?
- Wet film thickness (WFT) range?
- Dry to handle
- Maximum thinning allowed?
- Dry to recoat?
- Final cure?
- Mixing requirements?
- Force curing requirements?
- VOC's?
- Safety?

Applicators review product data sheets to determine their material consumption and their labour hours based upon applying the material in accordance with the manufacturers product data sheet and the specifications. Dry times, recoat times, solids by volume, wet film thickness limitations, and temperature parameters for application vary considerably from product to product. The wise contractor carefully reads and makes sure he understands the product data sheet to avoid potential problems and to protect his reputation and his profits.

KEEPING PRODUCT DATA SHEETS UP-TO-DATE

Product data sheets are dynamic documents. They change more often than most people who rely upon them realise.

Relying on “old” information is a dangerous and at times a very expensive practice for specifiers, applicators and inspectors. Product data sheets are dynamic documents. They change more often than most people who rely upon them realise. Sometimes, manufacturers suddenly learn that their PDS contains misleading or incorrect information. This new “knowledge” sometimes manifests itself shortly after a contractor successfully sues a paint manufacturer or settles for a lucrative out-of-court settlement. This “new” information may include putting in statements about what the contractor must do if the “maximum recoat windows is exceeded for epoxies”, or it might involve a change in the amount or type of thinner or in the maximum dry film thickness per coat.

It is very important to make sure that the specifier, applicator and the inspector are all relying upon the current printed product data sheet. Most manufacturers list the revision date of the product data sheet on the front page in either the upper or lower corner of the PDS. A contractor should locate the revision date of the PDS and include it in his written records for the project. In addition, it’s a recommended practice to keep one copy of the PDS’s for all the products used on the project in a file at the office in case of a problem in the future. It’s amazing how a printed product data sheet can cure amnesia two or three years down the road.

MODIFYING PRODUCT DATA SHEETS

Before leaving the topic of “product data sheets”, there is one more critical issue to discuss. When a specifier selects a coating system, this selection should include comparing the anticipated application conditions (i.e. air temperature and relative humidity) with the application parameters for the product under consideration. Assuming that no conflict exists, the specifier writes the product into the specification.

However, at times, job site conditions differ substantially from the conditions anticipated by the specifier when selecting the coating. Generally unforeseen or unplanned delays cause this situation to arise. The first question out of the mouth of the contractor to his local paint salesperson usually sounds something like this, *“Just how low can I put this product on at? I know that the data sheet has a margin of error built in. I have to finish this job before winter. I didn’t bid this job to provide heaters or dehumidifiers.”*

Only the specifying engineer can change the specification parameters.

When this situation presents itself, the contractor essentially wants his paint salesperson to write a convincing letter modifying the application parameters of the product data sheet so that he can continue on the project. Some contractors even “volunteer” to help the salesman compose the most “advantageous” wording to

satisfy the inspector. However, the local sales person may not possess the technical capability or the corporate authority to modify the product data sheet. In any case, neither the sales person nor his company possesses the legal authority to alter the specifications. Only the specifying engineer can change the specification parameters.

This situation regarding modifying product data sheets involves three separate questions:

1. Is it ever appropriate to alter the product data sheet?
2. Who has the authority to change it?
3. What is the proper process for requesting a change to specification parameters via altering the product data sheet?

To properly answer these questions one needs to gather far more information; however, listed below are some general considerations and thoughts regarding this matter. This is not intended as legal advice but merely to stimulate thinking.

In regards to whether it is ever appropriate to modify the product data sheet, two issues are paramount. Is the modification within the parameters of the original specification or does it require loosening the specification parameters? What data from the coating manufacturer is available to technically support such a modification?

Keep in mind that one of the primary reasons for writing product data sheets involves positioning the product to “compete” favourably against competitive products. The Sales & Marketing Department often provides considerable input on how to “best” describe the product in the Product Information Section (discussed earlier). However, another major objective of product data sheets is to protect the company from losing customers due to premature coating failures and to avoid lawsuits. In some companies, the Technical Service Department oversees the function of reviewing product data sheets before they are issued. This provides a check and balance to the Sales & Marketing Departments “enthusiasm” in the use of words.

Some coating manufacturers end up leaning too heavily on the Sales & Marketing Department in the production and wording of product data sheets. At times this results in PDS that contain extravagant claims and minimal technical information. Others coating manufacturers rely almost entirely on their Technical Department to compose the product data sheets. This approach sometimes results in an overly conservative and “laboratory” set of application instructions that proves impractical in the real world. The best balance lies somewhere in the middle ground. Regardless of which end of the spectrum a company leans toward, their PDS reflects their comfort zone.

Conservative companies tend toward a technical-orientated product data sheet with some margin of error built in. They pursue a more technically confining stance regarding application conditions and parameters. (This position is often based upon their presumption that the contractor will at times push the envelope without asking

permission. Some contractors follow the old adage that *"it's easier to ask forgiveness than to ask permission"*.) However, often these more conservative companies are willing to write a letter allowing a loosening of the product data sheet limitations based upon a careful consideration of the facts regarding a particular situation and bases upon their confidence level in and experience with the contractor performing the work.

In short, there are times when it is technically sound for a company to loosen the restrictions imposed on the product by their overly conservative PDS. Such modifications should be written, preferable by the Technical Service department, on

The best time to read and make sure you understand the product data sheet is before the project begins not after the failure occurs.

the corporate letterhead with specific reference to the project by name. This modification letter should be sent to the specifier through whatever proper channels exist for the project.

Product data sheets, when written properly by coating manufacturers and used properly by applicators and inspectors serve a critical function in the successful completion of a coating project. The best time to read and make sure you understand the product data sheet is before the project begins not after the failure occurs.

COMMON OMISSION & COMMISSION ERRORS ON PDS

Sometimes product data sheets omit information that is important to the specifier, applicator or inspector. Several of the more common omissions are listed below. These areas often seem unimportant until a problem, failure or claim occurs on a project, then they quickly become major issues.

1. Giving an exact number for the recommended dft instead of a range
2. No minimum material temperature provided
3. Giving an exact number for the recommended anchor profile of a blasted surface instead of listing an suitable range
4. Cure and recoat times are listed at a single temperature. No information is provided for higher or lower temperatures
5. No mention of maximum recoat windows for epoxies, polyurethanes, moisture-cured urethanes and other types of coatings with recoat parameters.

The minimum recoat time reported on most PDS is based upon a specific surface temperature, a specific dft, and a specific relative humidity. If the application conditions differ from those stated on the PDS, it may lengthen or shorten the minimum recoat window. Some manufacturers use a general rule of thumb that for every 10⁰ C that the surface temperature is higher than the temperature given on the PDS, the recoat time is reduced by 25% - 50% and for every 10⁰ C that the surface

temperature is lower than the listed surface temperature, the recoat time is lengthened. (Note: It is best to check with each manufacturer regarding their particular products.)

Common Errors & Omissions on Product Data Sheets

Area	Problem	Solution
Recommended Dry Film Thickness	Exact number listed for the recommended dft (i.e. 50 µm dft)	List an acceptable range (i.e. 50 – 75 µm dft)
Material (Paint) Temperature	No minimum or maximum temperature given	Provide minimum and maximum temperature
Recommended Anchor (Blast) Profile	Exact number listed for the recommended dft (i.e. 25 µm dft)	List an acceptable range (i.e. 25 – 75 µm dft)
Surface Temperature	No maximum surface temperature given	Provide minimum and maximum surface temperature
Minimum recoat time before applying the next coat	Single temperature listed (i.e. 12 hours @ 20°C)	List various temperatures (higher and lower) (i.e. 8 hours @30°C) 16 hours @10°C
Maximum recoat times for epoxies, polyurethanes, MCU's and other types of catalysed coatings	Manufacturers fail to put notifications or warnings about the dangers of exceeding recoat window	Add a statement regarding the maximum recoat window (at several different surface temperatures) and provide instructions on what to do if this is exceeded

SPECIFIERS & ENGINEERS CHECKLIST FOR PRODUCT DATA SHEETS

Engineering firms, consulting engineers, and others who are involved in writing specifications receive little formal training in reading product data sheets from paint manufacturers. Listed below are some helpful suggestions for the specifying engineer regarding obtaining information from PDS's.

1. Focus on the technical and practical issues listed on the product data sheet not on the marketing hype.

2. Check for consistency between the specifications and the manufacturers product data sheets in the following areas:
 - Recommended dft
 - Recommended surface preparation
 - Recommended anchor profile (if applicable)
 - Compatibility with substrate type
 - Compatibility with other coatings
 - Compatibility with VOC regulations (where the work will be performed)
 - Colour requirements
3. Use caution when looking at PDS's containing an excessive amount of ASTM test results. Determine what tests are relevant to your application. Ask questions. For example, Can the manufacturer provide independent, certified test reports? If not, the test most likely were performed in-house by the manufacturer themselves. This does not necessarily mean the results are inaccurate, but it could create a double standard if the engineering firm requires "certified, independent test reports" from other paint manufacturers submitted as "or equals" by the contractor.

Sometimes excessive "in-house" lab results and irrelevant tests provided in an "approved product listing" are used to exclude suitable alternative products from gaining approval by the engineering firm during both the specification and the submittal processes. Most engineers are not familiar enough with the ASTM tests or the test procedures and therefore they cannot properly interpret the results or adequate compare results that differ from each other.

One must exercise extreme caution when looking at test results. In a college statistics class one professor often opened up his first class by reminding the students that *"figures don't lie, but liars figure"*. When presenting test results, it's possible to interpret or show the data in a manner that is legally accurate, but misleads the reader. Sometimes differing test results do not necessarily mean any significant reduction in performance or life expectancy of the coating system.

SUMMARY

Contracts, often consisting of legal documents, are often defined as "an exchange of promises". Similarly, product data sheets are "legal" documents designed to express to specifiers, contractors and inspectors the conditions under which that particular product can be successfully applied. In this sense, they represent a type of "implied contractual" document, in setting forth conditions under which the product can be applied successfully and environments in which it is suitable for use. When the product is applied in accordance with these conditions in a suitable environment, the manufacturer is "promising" (in a sense) that it will provide satisfactory performance.

Product data sheets are useful and indispensable tools when they are well-written and used at the appropriate time by all the parties to whom they are directed. It is

imperative that the specifier read the most current version of the PDS prior to writing the material section and before issuing the final specifications. It is equally important that contractors and inspectors carefully read the product data sheets, especially the application parameters, to make sure that the specified product is useable under the existing application conditions and to report any discrepancies that are discovered.

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SECTION 8

SAFETY

Revised: 02/2002

I. HAZARDOUS SUBSTANCES

Most coatings contain materials that are flammable and/or are to some degree hazardous to health. It is necessary to develop and initiate occupational safety and health standards through labels, material safety data sheets and other appropriate forms of warning to ensure that workers are fully aware of all hazards to which they are exposed, as well as meeting the requirements of all appropriate local legislation.

A coating may be considered a health hazard when its properties are such that it can either directly or indirectly cause injury from exposure by contact, inhalation or ingestion.

Hazardous substances in the workplace in some forms and concentrations pose potential acute and chronic health hazards to employees who are exposed to these substances. Employers and workers have a right and need to know the properties and potential hazards of substances to which they may be exposed, and such knowledge is essential to reducing the incidence and cost of occupational accidents.

Threshold limit value (TLV) refers to airborne concentrations of substances and represents conditions under which it is believed that nearly all workers may be repeatedly exposed day after day without adverse effect. Because of wide variation in individual susceptibility, however, a small percentage of workers may experience discomfort from some substances at concentrations at or below the threshold limit, a small percentage may be affected more seriously by aggravation of a pre-existing condition or by development of an occupational illness. Smoking may act to enhance biological effects of chemicals encountered in the workplace and may reduce the body's defence mechanisms against toxic substances.

Threshold limits are based on the best available information from industrial experience, from experimental human and animal studies and when possible, from a combination of the three. The basis on which the values are established may differ from substance to substance; protection against impairment of health may be a guiding factor for some, whereas, reasonable freedom from irritation, narcosis, nuisance or other forms of stress may form the basis for others. Threshold limit values for hazardous substances are published.

Some of the pigments used in organic coating materials are toxic. Lead compounds and chromate's are considered particularly dangerous when ingested or inhaled. These minute particles of lead may cause lead poisoning if exposure is not avoided.

The epoxides and isocyanates used in epoxy and polyurethane coatings and compounds are particularly irritating to the skin. Common reactions of people sensitised include swelling around the eyes or lips, rashes of the skin, etc. Most all epoxy coatings have polyamines as curing agents that range from mild to strongly alkaline and react much like a mild acid on tender mucous membranes.

Virtually all solvent solution coatings are highly flammable in liquid form and vapours released in the process of application are explosive in nature if concentrated in sufficient volume in closed areas. Reports also associate repeated and prolonged occupational over-exposure to solvents with permanent brain and nervous system damage.

There are two principles that govern the combustion of solvent vapours in air: 1) The vapours will not support combustion until a critical temperature (flash point) is reached. 2) There is a definite range of vapour-air ratios that permit combustion. If the vapour concentration either fails to reach the lower limit or exceeds the upper limit, ignition will not occur.

Flash point of a liquid is the temperature at which it gives off vapour sufficient to form an ignitable mixture with air near the surface of the liquid or within the vessel used. Ignitable mixture is a mixture within the explosive range (within the upper and lower limits) that is capable of the spread of flame from layer to layer away from the source of ignition. The term applies mostly to flammable liquids although there are certain solids, such as camphor and naphthalene, which slowly evaporate or volatilise at ordinary room temperature and therefore have flash points while still in solid state.

Explosive limits are the range of gas or vapour concentrations (percent by volume in air) which will burn or explode if an ignition source is present. LEL is the lower explosive limit and UEL is the upper explosive limit. Knowledge of the LEL will aid in determining the volume of ventilation needed for an enclosed space to prevent fires and explosions. It is based upon normal atmospheric temperatures and pressures. See Table 15 for summary of threshold limit values, flash points and explosive limits of commonly used solvents.

TABLE 15: SOLVENT PROPERTIES

Threshold limit values in parts per million, flash points and upper and lower explosion limits for some common solvents. The lower allowable concentration, the greater the toxicity.

SOLVENT	TLV (ppm)	Flash Point (°C – TCC)	LEL%	UEL%
Acetone	75	-18	2.6	12.8
Normal Butyl Alcohol	50 (c,s)	29	1.4	11.2
Normal Butyl Acetate	150	27	1.3	7.6
Cyclohexanone	25 (s)	54	1.1	8.6
Diacetone Alcohol	50	52	1.8	6.9
Ethyl Amyl Ketone	25	43	Unknown	Unknown
Ethylene Glycol Ethyl Ether Acetate	5 (s)	47	1.7	6.7
Ethyl Alcohol	1,000	13	3.2	19.0
Ethylene Glycol Mono Ethyl Ether	5 (s)	43	2.6	15.7
Ethylene Glycol Mono Butyl Ether	25 (s)	66	1.1	10.6
Furfuryl Alcohol	10 (s)	65	1.8	16.3
Isopropyl Alcohol	400	12	2.5	12.0
Methyl Ethyl Ketone	200	-5	1.8	10.0
Methyl Isobutyl Ketone	50	16	1.4	7.5
Methyl n-Amyl Ketone	50	39	1.1	7.9
Mineral Spirits	225	41	1.1	6.4
VM&P Naphtha	300	13	1.0	6.0
N-Propanol	200 (s)	23	2.1	13.5
Toluene	100	5	1.4	6.7
Xylene	100	21	1.1	7.0

(c) = ceiling

(s) = skin

II. VENTILATION

From either a fire, explosion or health hazard standpoint, adequate ventilation is the key to safe coating practice. Recommended ventilation procedures draw clean air into an enclosed space from an opening at the top by exhausting air from the lowest portion of the enclosed area. Since solvent vapours are heavier than air, the air coming in at the top tends to wash down through the space, carrying the solvents with it, and the maximum concentration of solvents is removed rapidly from the lowest point.

Virtually all of the common solvents used in coatings have a lower explosive limit (LEL) greater than one percent by volume of vapour in air. Recommended ventilation systems should be sized to keep vapour concentrations well below the one percent level to avoid explosive vapour mixtures. Maintain ventilation in the coated area until the coating is sufficiently dry so that any remaining solvents cannot build up to the explosive mixture concentrations.

A clean air supply is required for all operations involved during the preparation of substrates prior to coating application, during the application of the coating materials, and during the curing and drying of the coating after application.

Air used to fulfil the requirements of surface preparation and coating will require monitoring both prior to, during and following use to assure proper quality. Effluent treatment may be required for the removal of fumes, vapours, and particulates where monitoring analyses indicate that levels exceed the acceptable discharge limits.

The preparation of ambient atmospheric air for the general area ventilation during surface preparation, coating application, and curing and drying may involve controlling the temperature, relative humidity, air volume and velocity, gases, fumes, dusts and mists.

Refer to local regulations concerning occupational safety, health standards, ventilation requirements and safe practices in coating operations.

Ameron products carry warnings on their application instructions and labels as well as having detailed material safety data sheets that identify hazardous materials and describe precautions that must be followed.

III. VOLATILE ORGANIC COMPOUNDS (VOC's)

Earlier in this manual, we mentioned that most coatings are comprised of three ingredients: resins, pigments and solvents. Many of the solvents used in the manufacturing of paints contain volatile organic compounds or VOC's. At temperatures of approximately 30°C and above, the VOC's in VOC-containing coatings react to form ground level or tropospheric ozone. This ozone is a photo-chemical oxidant that greatly contributes to smog. The smog impacts the health of some people and is widely believed to produce long-term damaging effects upon the environment

Many coating manufacturers have reformulated a large portion of their product line to comply with the anticipated changes. Some manufacturers, unwilling or unable to spend the significant sums of Research & Development money needed to reformulate, simply sold out to larger manufacturers or went out of business.

METHODS TO DETERMINE VOC CONTENT

VOC's are reported in grams per litre. Two common formulae are used to calculate the VOC content of a coating :

A. Coatings containing water

$$\text{VOC} = \frac{(100 - W_s - W_w)}{(100/\text{SGc}) - (W_w / 0.998)} \times 1000\text{g/litre less water}$$

B. Coatings containing no water

$$\text{VOC} = 10 \times (100 - W_s) \times \text{SGc g/litre less water}$$

Where:

Ws = % solids content of the coating

Ww = % water content of the coating

SGc = Specific gravity of the coating

SG = of water taken as 0.998 at 25°C

IMPACT OF VOC REGULATIONS

The impact of the air quality regulations on the coatings industry is significant. Specifiers and applicators are both effected. Listed below is a brief summary of the impact on each of these groups.

Specifiers:

No longer can specifiers simply select products without regard for their effect upon the environment. A product with a long-track record of proven success in a given application may not meet the current or proposed future regulations and therefore may have to be eliminated from consideration.

1. Specifiers must consider WHERE the coating application will occur. (For example shop or site application)
2. Specifiers must consider WHEN the coating will be applied as new regulations may be in force at the time of coating application
3. Specifiers must re-evaluate WHAT TYPES of products they are specifying. (There is a movement towards compliant coatings)
4. Specifiers may want consider some of coatings that offer high durability which offer superior endurance and performance in comparison to traditional coatings. In some cases, these coatings are expected to provide a coating life that is 3 or 4 times longer than normal coatings, resulting into a 25 – 30+ year life expectancy before repainting thus reducing the long term VOC emissions through less maintenance.

Applicators:

The impact on applicators of protective coatings in some cases is substantial, although the specific effects vary depending upon whether the applicator is a “stationary source” or a “field-painter” applying paint to stationary objects.

Major “stationary source” users of protective coatings, such as large fabricators and large original equipment manufacturers (OEM's) fall under local regulations. Many of the larger fabricators are investing or have invested large sums of money to upgrade their facilities and their equipment in order to comply with the present and future regulations.

Some large volume paint users are switching to 100% solids coatings and water-based coatings whenever possible. In the case of 100% solids coatings this often means an investment expensive in plural component spray equipment.

Other large volume “stationary sources” choose the water-based route. This decision often necessitates installing expensive environmental systems for heating and dehumidification in order to control the air temperature and relative humidity.

There are still many small stationary source applicators using traditional solvent-based coatings. Some of them are moving to higher solids coatings and upgrading their equipment accordingly.

For “field painters”, the impact of the regulations, varies depending upon the type of industries they are involved with, the type of structures they coat and the types of paints they use. Traditionally field painters applied single-component alkyds and low-solids epoxies. Many of these products were very user-friendly to apply. The switch to high-solids, 100% solids and water-based coatings requires better equipment, different size hoses, different type of spray guns, and in some cases more stringent environmental parameters.

Some field contractors have experienced major coating failures as a result of changing to more complicated, environmentally-friendly and VOC compliant coating systems. In most cases, these failures were preventable if the contractor simply read the product data sheet PRIOR to starting.

One of the habits hardest to break for some field contractors is the amount of “field adjusting” or thinning that is performed. Contractors tend to thin the material until it sprays properly, generally with little regard for the maximum thinning limits stated on the product data sheets. With the increasing focus on VOC emissions, contractors should be weary of the implications of thinning. With the increasing use of high solids materials contractors may require a change in their equipment (i.e. bigger pumps, larger diameter hoses, bigger size tips, etc..). Many of the high solids coatings available today are formulated for application with minimal need for additional thinner IF the application instructions and equipment requirements are followed.

Storing the material in warm surroundings (within the range stated on the product data sheet) facilitates sprayability. Viscosity (or “thickness”) increases as a material gets colder, so storing material at warmer temperatures makes it easier to spray without adding thinners.

Remember the figures stated on the paint manufacturers product data sheets is “as supplied” from the manufacturer. Any thinner added in the field increases the VOC’s for the paint.

IV. LABELLING

Labelling is the principle means of communication regarding the safe use of products.

All product labels provide for identification of the product and the warning statements necessary to meet the user's needs, and to conform with local regulations.

While most commercial products are named for convenience, much more important in labelling is identification of the hazards associated with the handling, storage and use of the product.

V. MATERIAL SAFETY DATA SHEETS

Material Safety Data Sheets document the real and/or potential hazards of a product, the precautions to be observed, and the emergency actions and treatment to be given in case of an accident.

The employer shall furnish employees who may be exposed to a hazardous substance with information on the contents of the MSDS for the hazardous substance or equivalent information, either in written form or through training programs, that may relate to the entire class of hazardous substances to the extent appropriate and related to the job.

The information contained in the sheets can be used as a reference source for emergency situations, as training materials for employees, and to determine what control measures are appropriate for each given workplace. Material Safety Data Sheets are available to employees from manufacturers, suppliers, industrial trade associations or other commercial information sources. Employees and authorised representatives are to have access to all Material Safety Data Sheets maintained by an employer.

Material Safety Data Sheets must be kept up-to-date and evaluated continually as to the hazards of the material.

SECTION 9

GLOSSARY OF TERMS USED IN DESCRIBING CORROSION & COATINGS

ABRASION	Wearing away of material as a result of friction.
ABRASION RESISTANCE	The property of a surface by which it resists being worn away as a result of friction. This property is not necessarily related to hardness of the surface, but is more often correlated with its toughness.
ABRASIVE	A substance such as sand, steel grit, steel shot, metallic oxide particles, coal slag, or agricultural products etc., used in blast cleaning.
ACCELERATOR	Catalyst; a material which accelerates the hardening of certain coatings.
ACID	Compound producing hydrogen ions in water, See "pH."
ACID ETCH	A cleaning method that roughens a surface by using an acid.
ACRYLIC RESIN	Synthetic resin that has excellent water- resistance and hardness.
ACTIVE	A state in which a metal tends to corrode.
ADDITIVE	A substance added in a small amount, usually to a fluid for a special purpose such as to reduce friction, corrosion, etc.
ADHESION	The bond or attraction of a material to the underlying surface such as a substrate or another coat.
AEROBIC	Micro-organism (bacteria) contributing to corrosion. Needs oxygen for growth.
AIR DRIED	Coatings that normally reach a desired hardness without external heat.
AIRLESS SPRAY	Method of applying coatings using high fluid pressure - no air for atomisation.
ALKALI	Term applied to caustic and strong bases. See "pH."
ALKYD	Resin used in many types of industrial enamels. The reaction products of polyhydric alcohol's and polybasic acids. Properties vary widely.

ALLIGATORING



Pronounced wide cracking over the entire surface of a coating that does not extend to the surface. Resembles alligator skin.

ALLOY

Mixtures of metals that are blended to provide various physical characteristics; i.e., brass, stainless steel, bronze.

ANAEROBIC

Micro-organism growth contributing to corrosion where no oxygen is present.

ANCHOR PATTERN PROFILE

Roughness of a blast cleaned surface usually measured in microns from the bottom of the valley to the top of the highest adjacent peak. It depends upon the original condition of the surface and the degree of surface preparation. The type and velocity of the abrasive are the major factors affecting the profile.

ANODE

Positive terminal of an electrolytic cell; that portion of the metal that corrodes.

ANODIZING

Generally pertains to an oxide deposited on aluminium electrolytically.

ANTIFOULING

Coating applied to ship bottoms to prevent marine growth. Generally contains toxic ingredients.

ANTI-SLIP

Coating containing textured surface (via pigments) to provide traction and prevent slip and fall accidents on walkways, decks and garages

AROMATIC HYDROCARBON

Volatile solvent such as benzene, toluene, xylene. Usually extracted from coal tar, but can be made from petroleum. See "Solvent." Term refers to chemical structure - not smell.

ASPHALT

Black resinous material of petroleum origin.

BINDER

The resin portion of coatings whose function is to hold pigments together, and to provide a cohesive film.

BLAST CLEANING	A method of surface preparation using abrasives, propelled through nozzles or by centrifugal wheels, to remove mill scale, rust, rust scale, old paint, laitence and other foreign contaminants that would interfere with the adhesion of the subsequent coating.
BLEEDING	The diffusion of coloured matter through a coating from the substrate; also the discoloration arising from such diffusion.
BODY	Viscosity; middle or under(coat) in a multi-coat system.
CATALYST (in coatings)	Accelerator; curing agent; a component of a multi-component coating that causes cross-linking and film formation
CATHODE	Negative terminal of an electrolytic cell; hydroxyl ions usually produced here.
CAVITATION	Force exerted by a high-velocity liquid forming a gas-filled space. Usually a combination of corrosion and erosion.
CHALKING	Form of paint degradation in weather resulting in loose pigment on surface.
CHECKING	Breaks or cracks in the film that do not penetrate to the underlying surface.
CHLORINATED RUBBER	A particular film former used as a binder, made by chlorination of rubber. A very hard, brittle material which is normally modified with other resins or plasticizers to achieve suitable properties.
COAL TAR	Black resinous material derived from coal. A resin used in coatings.
COAT (of paint)	One application. Can include several passes, if no drying time is allowed between.



COATING SYSTEM	A multi-component polymeric protective film usually consisting of prime, intermediate or finish coats or both.
COATINGS (Liquid Applied)	Polymeric materials that, applied in a fluid phase, cure to a continuous film.
COLD FLOW	Characteristic of many plastics to take a permanent set after pressure is applied.
COLD ROLLED STEEL	Produced from hot rolled; has little if any mill scale. Typical use - auto industry.
COMMERCIAL BLAST CLEANING	SSPC-SP6 / NACE No. 3, or ISO 8501-1 Sa2 abrasive cleaning.
CONCRETE	Material made from Portland cement and aggregates such as sand and gravel, which are mixed with water to a plastic consistency and placed in forms or slabs to harden and gain strength.
CONCRETE HARDENER	An aqueous solution of a chemical such as magnesium fluosilicate, sodium silicate, etc. which is applied to concrete surfaces to harden the surface and reduce dusting due to traffic.
CONDUCTIVE COATING	Accomplished by the addition of pigment which will conduct (static) electricity.
CONTAMINANT	A foreign substance inadvertently added to a coating or found on a substrate that adversely affects the application, adhesion, curing and/or subsequent performance of the applied coating. Atmospheric moisture and condensation can be considered as substrate contaminants, as is a solution of mixed fission products or radioactive nuclides.
CONVENTIONAL SPRAY	Uses compressed air to "atomise" or break the paint into small droplets.
CORROSION	Adverse reaction of any material with its immediate environment.
CORROSION FATIGUE	Effect of the application of repeated or fluctuating stresses in a corrosive environment, characterised by shorter life than would be encountered as a result of either the repeated or fluctuating stresses alone or the corrosive environment alone.
CRATERS	Circular domes in dried film with a thin spot in centre. Can be minute up to 3mm in diameter.

CRAZING	A network of checks or cracks appearing on the surface.
CROSS-SPRAYING or CROSS-HATCH	Pertains to making two passes with a spray gun over the same surface at right angles to each other.
CURING	The changing of the physical and chemical properties of a coating into a final more stable, usable condition by the some mechanism such as the action of heat, oxygen, moisture, radiation or the reaction between chemical components.
CURING AGENT	Activator or hardener added to a synthetic resin to increase chemical resistance and hardness.
CURING COMPOUND (concrete)	A temporary or permanent coating applied to new concrete to retard the loss of water from the mass in order to facilitate its curing.
CURTAINS	Long horizontal runs in film; occurs on vertical surfaces.
DEGREASE	Removal of grease, petroleum products, fish oil, etc. Generally by the use of solvents; i.e., trichloroethylene, methylethylketone.
DEIONIZED WATER	See "Demineralized."
DELAMINATION	Separation between coats and very poor adhesion.
DEMINERALIZED WATER	Purified water from which metallic cations are removed by a hydrogen cation exchanger. Anion exchanger removes anions.
DEW POINT	Temperature at which moisture condenses under given conditions of humidity and barometric pressure.
DILUENT	Product introduced as a portion of the solvent to reduce cost.
DISPERSION	Suspension of minute particles in a suitable medium.



DISTILLED WATER	Water that has been vaporised and then condensed to remove impurities.
DRY FILM THICKNESS (DFT)	Thickness of applied coating when dry usually expressed in microns (1×10^{-6})m. To determine the dry film thickness, a gage is used, such as a Mikrotest Pull-off Gauge or an Elcometer Fixed Probe Gauge.
DRYING OIL	A fatty oil capable of conversion from a liquid to solid by slow reaction with oxygen in the air. The "drying," thus refers to a change of physical state, and not an evaporation of solvent. Paints can be made from drying oils due to this hardening ability.
DRY SPRAY	Result of over-atomisation. Produces dull powdery or pebbly finish. Some of the surface dust can be wiped off with the palm of hand. Also called over-spray or spray dust. A common problem with inorganic zinc's when the applicator holds the spray gun too far away from the surface or in hot and windy conditions. To eliminate the problem due to hot and windy conditions, contact the manufacturer to see if a substitute thinner is available to minimise dry spray.
DRY-THROUGH	See Dry-to-Handle
DRY-TO-HANDLE TIME	Generally the film shall be considered dry-through or dry-to-handle when there is no loosening, detachment, wrinkling or other evidence of distortion of the film when pressed with thumb; exerting maximum pressure of the arm, at the same time turning the thumb through an angle of 90 degrees in the plane of the film.
DRY-TO-RECOAT TIME	Generally a film shall be considered dry for re-coating when a second coat or specified topcoat can be applied without the development of any film irregularities, such as lifting or loss of adhesion of the first coat, and the dry time of the second coat does not exceed the maximum specified for the first coat.
DRY-TO-TOUCH	Generally the film is considered dry-to-touch when it still shows a tacky condition but none of it adheres to the finger.
ELASTIC	Springiness, rubbery quality -- can be stretched.

ELECTROCHEMICAL	Chemical changes produced by an electrical current or the production of electricity from a chemical reaction.
ELECTROLYTE	A solution of ions in water capable of conducting current.
ENAMEL	Type of oil-base paint with high gloss.
ENCAPSULATION	Covering over, masking and shielding existing coatings containing toxic ingredients such as lead or asbestos, to prevent environmental exposure.
ENVIRONMENT	The surroundings or conditions (physical, chemical, mechanical) in which a material exists.
EPOXY	Synthetic resin derived from petroleum products that can be cured by a catalyst or formulated to upgrade other synthetic resins to form protective coatings.
EPOXY-BAKED	Epoxy formulation that requires higher than normal temperatures to cure or react. Requires another resin or catalyst.
EPOXY-CATALYZED	Epoxy formulation that cures, generally at room temperature by the addition of a curing agent or catalyst.
EPOXY-MODIFIED	Predominantly epoxy but mixed with other resin or resins; i.e. epoxy-phenolic.
EROSION	Destruction of materials by the abrasive action of moving fluids, usually accelerated by the presence of solid particles.
ESTER	Compounds formed by the reaction of alcohol's with organic acids; i.e., butyl acetate.
ETCHING	Generally pertains to the result of the treatment of a surface with acid.
EXTERNAL ATOMIZATION	When air is used to break up the coating material after it has left the spray gun nozzle.
FILLER	An extender or inert pigment.

FILM	Coating or paint thickness. A wet film is one that has just been applied.
FINAL CURE	Interval of time necessary for a coating to achieve a degree of cure to normally permit placing in expected service.
FINGERS (airless)	Broken spray pattern; finger-like
FLASH POINT	Lowest temperature at which a given flammable material will flash if a flame or spark is present.
FLEXIBILITY	Ability of a film to bend without breaking.
FLOODING	Pigment that floats to the surface of a film, usually in streaks.
	
FORCE DRIED	Application of heat above room temperatures to hasten drying. Maybe up to 80°C, but below that of baking temperatures.
FOREIGN THINNER	A thinner that is not specifically recommended by the coating manufacturer.
FOULING	Marine growth, weeds, barnacles; growth of attachments to hulls of ships, or marine structures.
FUMES	Types of contaminants or particles generated by condensation from a gaseous state.
FURAN	Resin formed from reactions involving furfuryl alcohol itself or in combination with other constituents.
GALVANIC CORROSION	Corrosion associated with the current, resulting from the electrical coupling of dissimilar electrodes in an electrolyte (frequently called electrolysis).
GALVANIC SERIES	A list of metals and alloys arranged according to their relative corrosion potentials in a given environment.

GALVANIZED	Coated with molten metallic zinc by dipping.
GELLED	Coating which has coagulated and formed a jelly-like body.
GLOSSY	Mirror-like finish.
GRIT	Angular abrasive particles made from by-product steel or iron slag. Frequently used instead of silica sand for blast cleaning.
GROUT	A mixture of resins and fillers or cementitious materials and water used as a filler for cracks, or other void spaces, in concrete surfaces to be coated.
HEAVY SCALE	Iron oxide rust formed in layers from 3mm to 13mm thick.
HIGH BUILD	Coatings normally applied at a dry film thickness of at least 125 microns in one coat.
HIGH-PRESSURE WATER CLEANING (HP WC)	Cleaning with water performed at pressures from 5,000 to 10,000 psi or 34 to 70 MPa
HIGH-PRESSURE WATER JETTING (HP WJ)	Cleaning with water performed at pressures from 10,000 to 25,000 psi or 70 to 170 MPa
HIGH SOLIDS	Coatings characterised by having total volume solids of 60-100% as packaged.
HOLIDAY	Any discontinuity or bare spot in a painted surface.
HOT ROLLED STEEL	Normally used in structure and tankage; has mill scale on surface. See "Cold Rolled."
HYDRAULIC SPRAY	See Airless Spray.
HYDROCARBON	Extracts from petroleum; i.e., gasoline, lube oil.
IMMERSION	Refers to an environment that is submerged continuously.

INHIBITIVE PIGMENT	A pigment added to coatings capable of passivating or retarding the corrosion of the metal over which the coating is applied. Examples: red lead, chromate salts.
INHIBITORS	Compounds added in small concentration to form protective films or, which combined with corrosion products, form less active compounds.
INORGANIC	Chemicals such as salts, acids, alkali's, etc. Based on all chemical elements except carbon.
INORGANIC ZINC	Coating containing a zinc powder pigment in an inorganic vehicle; i.e., zinc silicate.
INTERNAL MIX	Refers to a conventional air spray gun in which the material is mixed with air before being discharged through the tip.
ION	An electrically charged particle derived from soluble mineral chemicals on dissolving in water. Ions are both positively and negatively charged, and equal amounts of each are formed by splitting of the original chemical when it dissolves.
IRON OXIDE	Ferric oxide rust. Reddish in colour. Also used as paint pigment.
ISOCYANATE	Type of chemical compound that can react with several types of polymers to form coatings or elastomers with varying properties.
KETONES	Very powerful synthetic solvents used in connection with many plastic resins, especially vinyl copolymers.
LACQUER	Type of coating that dries solely from evaporation of solvent.
LACQUER THINNER	Used to describe such solvents as ethyl alcohol, ethyl acetate, and toluene.

LAITENCE	A fine whitish powder on concrete surfaces. Consists of cement particles that are carried by water rising to the surface of freshly placed concrete. The resulting concrete surface is dusty and unsuitable for proper adhesion or bond of subsequent fillers or protective coatings.
LATEX	Milk-like fluid made up of particles of rubber or synthetic resin suspended in water.
LEL	Lower Explosive Limit aids in determining the volume of ventilation needed for an enclosed space to prevent fires and explosions.
LOW-PRESSURE WATER CLEANING (LP WC)	Cleaning with water performed at pressures less than 5,000 psi or 34 Mpa.
MASTIC	Term used to describe a heavy bodied paste-like coating.
MEK	Ketone solvent – methyl ethyl ketone
METALLIZING OR METAL SPRAY	Method of applying atomised molten metal to a surface; i.e., zinc aluminium.
MIBK	Ketone solvent – methyl iso butyl ketone.
MICRONS	One millionth of a meter (1 micrometer).
MILD SOLVENT	Solvent that has a limited range of dissolving ability.
MILL SCALE	Layer of iron oxide formed on the surface of steel plates and sheet during manufacture. May be 50 to 125 microns thickness.
MILS	Units used to designate film thickness. 1 Mil = 25.4 microns
MIXING RATIO	Ratio, expressed by weight or volume, of separately packaged components of a multiple component coating by which the components are to be combined and mixed to uniform condition before application.

MODIFIED	Pertaining to a mixture of resins - one of which is predominant.
MONOMER	Molecule of low molecular weight capable of conversion into polymers, plastics and synthetic resins.
MOTTLED	Description of coatings of spotted appearance, blotches of a different colour, shades of a colour.
MOULD RELEASE AGENT	An oil or plastic coating used on concrete moulds to reduce damage to the concrete and to the moulds when they are stripped from the hardened concrete.
MUD CRACKING	Phenomenon that occurs to films as they dry, appearing like mud drying in hot weather. When inorganic zinc's are applied too thickly, they often mudcrack, especially in the fillet areas of steel girders or beams.
NATURAL RUBBER	Sap or gum taken from the rubber tree.
NEAR WHITE BLAST CLEANING	SSPC10 / NACE No. 2 or ISO 8501-1 Sa2 ½ abrasive cleaning standard.
NEUTRAL	Term used to describe an environment that is neither acid nor alkaline. (pH = 7)
NON-FERROUS	Term used to designate metals and alloys that do not contain iron or steel; i.e., brass aluminium, magnesium.
NON-IMMERSION	Refers to an environment that is not continuously submerged.
OIL AND MOISTURE TRAP	Device on air compressors to eliminate moist oil and moisture from the incoming air supply.
OIL CLEANER	Solvent and detergent often used to remove heavy deposits of asphalt and oils from ship hulls.
ORANGE PEEL	Appearance of a coated surface resembling the skin of the orange.



ORGANIC	Chemicals based on carbon, as contrasted to mineral chemical compounds. Carbohydrates, synthetic resins, solvents and an enormous variety of chemicals are organic.
ORGANIC ZINC	Coating containing zinc powder pigment and an organic resin; i.e., zinc and epoxy.
ORGANOSOL	Colloidal dispersion of an insoluble material (synthetic resin) in a plasticizer with a solvent added. See "Plastisol."
OSMOSIS	Diffusion of molecules through a paint film or other semi-permeable membrane caused by a difference in concentration.
OSMOTIC BLISTERING	If water that penetrates the film encounters soluble matter such as salt deposits, it will set up an osmotic cell drawing more water into the coating thus forming a blister. See "Osmosis."
OVERSPRAY	Sprayed coating that is dry when it hits the surface, resulting in dusty, granular adhering particles.
OXIDATION	Loss of electrons by a constituent of a chemical reaction or reaction with oxygen.
OXIDIZED FILM	Coating that has lost its gloss and/or its surface has become powdery.
pH	Value indicating the acidity or alkalinity of a solution. Pure water is neutral and has a pH value of 7. Acidity ranges down to pH 1 and alkalinity up to pH 14.
PASSIVE	Surface that has shown no active corrosion or an atmosphere that is not corrosive.
PATTERN (Spray)	Shape of stream of material coming from the spray gun.
PEBBLY	Rough, irregular surface having a coarse grainy texture.
PEELING	Poor adhesion but implies cohesion of film.

PHENOLIC	Synthetic thermosetting resin. The most important type historically is phenol-formaldehyde (Bakelite). These resins can be formulated to produce coatings, varnishes, moulding materials and adhesives.
PHOSPHATISING	Use of phosphoric compounds as a surface treatment to combat corrosion, i.e., parkerizing, bonderizing.
PICKLING	Chemical treatment of iron or steel, usually with hydrochloric or sulphuric acid to remove mill scale and/or rust.
PIGMENT	Insoluble finely divided material whose function is to provide obscuring value, colour and protection.
PINHOLES	Formation of tiny circular holes in the film up to a few millimetres in diameter, usually having a residual solid in their centre.
PITTED	Result of local corrosive attack forming holes in a metal surface. May be described as shallow or deep, small or large in diameter, and quantity or number per unit area.
PLASTIC	Resinous material that may be moulded into desired shapes or dissolved to form a coating.
PLASTICIZER	Materials added to improve flexibility and assist in compounding a coating.
PLASTISOL	Similar to an organosol, but is packaged at 100% solids content.
PLURAL COMPONENT SPRAY	Spray equipment designed for applying extremely fast reacting 2-component products. Each fluid component is separately pumped to a mixing unit just before the spray gun. Mixing time is measured in seconds or fractions of a second.
POLYMER	Substance composed of giant molecules formed by, the union of a group of simple molecules (monomers).
POLYMERIZATION	Uniting of monomers to form polymers.



POLYSILOXANE	A class of coating based on the element Silicon, designed to provide exceptional heat, chemical and weathering resistance
POLYURETHANE RESINS	Class of resins obtained by the reaction of diisocyanate with organic compounds, i.e., phenols, amines, to form polymers.
POST-CURED	Term referring to inorganic zinc coatings that require separate curing solution.
POT LIFE	Interval after mixing of two component coatings during which the liquid material is usable before gelling or losing its properties.
POTABLE WATER	Water fit for human consumption -drinking water.
PRIMER	First coat applied to a surface. See "Coating System." Formulated to have good bonding and wetting characteristics, and may or may not contain inhibitive pigments.
PROFILE	Term used to describe anchor pattern on a surface, produced by sandblasting or acid treatment.
RAW MATERIAL	Basic ingredients used in manufacturing coatings.
REDUCER	See "Thinner."
REDUCTION	Gain of electrons by a constituent of a chemical reaction.
RELATIVE HUMIDITY	Ratio of the quantity of vapour actually present in air to the greatest amount possible at the given temperature.
RESIN	Any of a group of amorphous organic materials; usually can be moulded or dissolved. Can be natural or synthetic.
RETARDER	Thinner added to a coating usually used to slow down the drying rate in hot weather.
RUN	Synonymous with sagging and curtaining caused by improper thinning or poor application.

RUST	Formation of visible iron oxide, a result of corrosion of iron or steel. May be described in order of severity; scattered pinpoints, blush or powdery, freckled or streaked, light scale, paper thin, flaked, medium scale (layers up to 3mm), heavy scale (over 3mm thick).
SACKING	Treatment of concrete with a grout to fill voids. A burlap sack may be used.
SALT SOLUTION	Commonly known as any combination of cation and acid radical as distinguished from acids and alkali's.
SANDBLAST	Blast cleaning using sand as an abrasive.
SATIN FINISH	Descriptive term generally with reference to decorative paints.
SCALING	The formation of corrosion product layers on a metal surface. The deposition of water insoluble constituents on a metal surface.
SCRUBBERS	Devices to remove contaminants from air by washing air with liquid
SEALER	A low viscosity (thin) liquid applied before priming wood, masonry and sometimes metals.
SELF-CURING	Property of single component and 2-component inorganic zinc coatings that cure after application by a reaction with atmospheric moisture and humidity. Differentiated from earlier products requiring separate use of curing compound.
SHELF LIFE	Time period in which a material may normally be stored in usable condition.
SILICA SAND	Clean sand made up of sharp silica particles. Does not contain dirt or clays. Usually recommended for blast cleaning.
SILICONE RESIN	Resin formulated into coatings to withstand high temperature.
SLUSH COAT	Coating that is applied to the interior of a container by revolving the container and then draining out the excess coating.

SOLVENT	Liquid whose function is to put the non-volatile film composition in a liquid state so that it may be applied conveniently.
SOLVENTLESS	Liquid coatings containing no volatile solvents, also defined as 100% volume solids coatings. All ingredients of the coatings as packaged remain on the substrate and form the final cured in-place coating.
SUBSTRATE	The uncoated base surface to which the coating is applied.
SURFACE-TOLERANT COATING	A coating, normally epoxy-based, that does not require complete removal of existing coating and rust prior to application. Will be compatible with residues of tightly adherent paint and rust without compromise of performance.
SURFACER	Pigmented composition for coating concrete to protect the surface or to fill holes and depressions in preparation for topcoats.
SWEEP BLAST	Term often used to refer to SSPC-SP7 or NACE No. 4 or ISO 8501-1 Sa1 – “Brush off Blast Cleaned Surface Finish”.
SYNTHETIC	Manufactured, as opposed to, made by nature.
SYSTEM COATING	See "Coating System."
TENSILE STRENGTH	Longitudinal resistance of a material to resist elongation. Expressed in pounds per square inch at the failure point.
THERMOPLASTIC RESIN	Resin having the property of becoming soft upon the application of heat. Regains hardness on cooling.
THERMOSETTING RESIN	Resin having the property of becoming insoluble upon the application of heat.
THINNER	A liquid (solvent) added to a coating to adjust viscosity.

THIXOTROPY	A specific type of variable consistency behaviour. A thixotropic coating formulation shows a "false body" or apparent high viscosity, but on stirring or other agitation, readily flows and shows low viscosity. Thixotropic paints are easily brushed or sprayed in thick films; but after application, quickly "set" and do not run or wrinkle. Examples: catsup, mayonnaise, whipped cream, Amerlock 400.
TOXICITY	The potential of a substance to cause injury by direct chemical action with the body tissues. A measure of the adverse effect exerted on the human body by a poisonous material. A relative property of a chemical agent with reference to a harmful effect on some biological mechanism and the condition under which this effect occurs.
TUBERCLES	Round protuberances having the appearance of a plant-root segment, usually rust growth.
ULTRAHIGH-PRESSURE WATER JETTING (UHP WJ)	A surface preparation method using water performed at pressures above 25,000 psi or 170 Mpa to achieve various degrees of surface preparation as listed in SSPC SP 12 / NACE No. 5.
URETHANE	Product resulting from reaction of an isocyanate with one of several types of polymers (typically polyols) to produce a tough, chemical resistant material. Final properties can vary depending on types of reactants used.
VARNISH	Usually a clear coating-based on natural resins and oils. The resins are chemically combined with the oil at high temperature to give a product increased hardness and much faster drying time. Chemical resistance is also improved.
VEHICLE	Liquid portion of a coating; a fluid or mixed solution made up of the binder and solvent.
VINYL RESIN	Series of resins usually based on polyvinyl chloride, acetate, alcohol's, etc., and copolymers. Polyvinyl chloride resins are tasteless, odourless and chemically resistant. Can be formulated to produce adhesives, sheets, textile coatings, etc.

VOC	Volatile Organic Compound - the volatile portion, normally solvent, of the coating as packaged expressed in grams per litre. Local air quality regulations stipulate maximum allowable levels of V.O.C., so this property is critically important in determining compliance with these.
VOIDS	A term generally applied to paints to describe holidays, holes, and skips in the film. Also used to describe shrinkage in castings or welds. Also used in reference to porosity in inorganic zinc coatings.
VOLATILE	Thinner component of the vehicle. The non-volatile components are known as the film formers.
WATERJETTING	A technique of surface preparation using water at pressures above 10,000 psi to remove substances such as loose paint, rust, grease or other contaminants as listed in SSPC SP 12 / NACE No. 5.
WELD SPATTER	Round particles of extraneous metal that adjoin a welded joint.
WET FILM	Designates the coating after application, but before the thinner volatilises.
WET SANDBLASTING	Use of wet sand in blast cleaning; has the effect of reducing dust particles in surrounding areas.
WHITE METAL BLAST CLEANING	SSPC-SP5 / NACE No. 1 or ISO 8501-1 Sa3 abrasive blast cleaning standard.