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Body Corrosion - A Comprehensive Introduction

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Documents

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1. Scope—The mechanism of automotive body corrosion is scientific, based on established laws of chemistry and physics. Yet there are many opinions related to the cause of body corrosion, not always based on scientific axioms. The purpose of this SAE Information Report is to present a basic understanding of the types of body corrosion, the factors that contribute to body corrosion, the testing procedures, evaluation of corrosion performance, and glossary of related terms.

1.1 Purpose—The purpose of this document is to provide a basic understanding of body corrosion as influenced by materials, environment, design, pretreatment and paint systems, and evaluation thereof. If the reader requires in-depth information on these subjects, additional reading material and personal contacts should be pursued with raw material, paint, chemical, and equipment suppliers.

2. References

2.1 Applicable Publications—The following publications form a part of the specification to the extent specified herein. Unless otherwise indicated the latest revision of SAE publications shall apply.

2.1.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE 892578—U.S. Automotive Corrosion Trends at 5 and 6 Years

2.1.2 OTHER PUBLICATIONS

1. Annual statistical report 1990, American Iron and Steel Institute, Washington, DC (1991), p. 25–27.
2. H. E. Townsend, "Coated Steel Sheets for Corrosion-Resistant Automobiles," Materials Performance, October 1991, p 60.; National Association of Corrosion Engineers, Corrosion '91, Paper # 91416, NACE, Houston, TX.
3. Y. Miyoshi, "State of the Art in Precoated Steel Sheet for Automotive Body Materials in Japan," ISIJ International, 31,1,1991, p1.
4. D. Quantin, D. Deparis, and J. C. Charbonnier, "Coated Steel Sheets for the Automotive Industry," Steel Technology International, 1990/1991, p245.
5. K. Yamoto, T. Ichida, and T. Irie, "Progress in Precoated Steel Sheets for Automotive Use," Kawasaki Steel Technical Report, #22, May 1990, p57.

6. "Cracking Down on Corrosion," American Iron and Steel Institute, Washington, 1991.
7. "Data on Aluminum Alloy Properties and Characteristics for Automotive Applications," The Aluminum Association, Washington, D.C., 4th Edition, February 1982.
8. "Registration Record of International Alloy Designations and Chemical Composition Limits for Wrought Aluminum and Wrought Aluminum Alloys," The Aluminum Association, Washington, D.C., April 1991.
9. "Aluminum Standards and Data, 1990," The Aluminum Association, Washington, D.C.
10. "Formability of ABS," Alcoa paper for SAE '93.
11. Aluminum: Properties and Physical Metallurgy, John E. Hatch ed., American Society for Metals, Metals Park, OH, 1984.
12. T. Komatsubara, T. Muramatsu, M. Matsuo; "Aluminum Alloy Rolled Sheet and Production Therefore," U.S. Patent No 4,838,958, June 13, 1989.
13. Metals Handbook Volume 13, Corrosion, American Society for Metals, Metals Park, OH, 1987.

3. Definitions

- 3.1 Acid**—Acids can be defined in several ways. For many purposes it is sufficient to say that an acid is a hydrogen containing substance which dissociates on solution in water to produce one or more hydrogen ions. The Bronsted concept states that an acid is any compound that can furnish a proton. The more general Lewis definition of an acid is anything that can attach itself to something with an unshared pair of electrons.
- 3.2 Acidic**—Anything having a pH that is less than 7 is considered acidic.
- 3.3 Acrylic**—Resin polymerized from acrylic acid, methacrylic acid, esters of these acids, or acrylonitrile.
- 3.4 Active**—A state in which a metal tends to corrode (opposite of passive).
- 3.5 Active Potential**—The potential of a corroding metal.
- 3.6 Alkaline**—For aqueous solutions, anything having a pH that is greater than 7 is considered alkaline.
- 3.7 Alkyd**—Resin used in coatings. Reaction products of polyhydric alcohols and polybasic acids.
- 3.8 Alligatoring**—Pronounced wide cracking over the entire surface of a coating having the appearance of alligator hide.
- 3.9 Aluminum Coated**—Aluminum coated steel is produced by hot-dip coating cold-rolled sheet steel on continuous lines. It provides a material with the superior strength of steel and the surface properties of aluminum.
- 3.10 Aluminum-Zinc Coated**—Aluminum-zinc alloy coated steel is produced by hot-dip coating cold-rolled sheet steel on continuous lines. It has the superior strength of steel and excellent corrosion resistance.
- 3.11 Anion**—A negatively charged ion or radical (for example Cl^- or SO_4^{2-}) which migrates toward the anode under the influence of a potential gradient.
- 3.12 Anode/Anodic**—An electrode or portion of an electrode at which a net oxidation reaction occurs. This is the electrode, or area, that has the greater tendency to dissolve or corrode.
- 3.13 Anodic Coating**—A coating that is anodic to the underlying substrate. Anodic coatings offer sacrificial protection to the substrate.
- 3.14 Anodic Inhibitor**—A chemical substance or combination of substances that prevent or reduce the rate of the anodic or oxidation reaction by a physical, physico-chemical, or chemical action.

- 3.15 Anodic Potential**—Electronegative potential.
- 3.16 Anodic Protection**—A technique to reduce corrosion of a metal surface under some conditions by applying sufficient anodic current to it to cause its electrode potential to enter and remain in the passive region.
- 3.17 Anodizing**—Oxide coating formed on a metal surface (generally, aluminum) by an electrolytic process.
- 3.18 Barrier Protection**—A type of protection that relies on the coating preventing access of moisture or oxygen to the material being protected. Organic coatings often offer barrier protection to underlying substrates.
- 3.19 Base**—Bases can be defined in several ways. For many purposes it is sufficient to say that a base is a substance which dissociates on solution in water to produce one or more hydroxyl ions. The Bronsted concept states that a base is any compound that can accept a proton. The more general Lewis definition of a base is anything that has an unshared pair of electrons.
- 3.20 Base Metal**—A metal that is usually high in the Electromotive Force Series. Base metals have relatively poor corrosion resistance.
- 3.21 Basic**—For aqueous solutions, anything having a pH that is greater than 7 is considered basic.
- 3.22 Bimetallic Corrosion**—Corrosion resulting from dissimilar metal contact; galvanic corrosion.
- 3.23 Bituminous Coating**—Coal tar or asphalt based coating.
- 3.24 Blister**—A region of lifted paint typically caused by loss of adhesion within the paint system or between the paint and metal surface.
- 3.25 Block Coat/Blocking**—Tie coat (adhesive) between noncompatible paints.
- 3.26 Blushing**—Whitening and loss of gloss of a coating due to moisture; blooming.
- 3.27 Catalyst**—A substance which alters the rate of a reaction by its presence and may be recovered unaltered in nature or amount at the end of the reaction.
- 3.28 Cathode**—The electrode of an electrolytic cell at which reduction occurs. In corrosion processes, usually the area at which metal ions do not enter the solution. Typical cathodic processes are cations taking up electrons and being discharged, oxygen being reduced, and the reduction from a higher to a lower valence state.
- 3.29 Cathodic Coating**—A coating that is cathodic to the underlying substrate.
- 3.30 Cathodic Corrosion**—An unusual condition in which corrosion is accelerated at the cathode because the cathodic reaction creates an alkaline condition which is corrosive to certain metals (esp. with Al, Zn, Pb).
- 3.31 Cathodic Delamination**—Type of corrosion damage caused by loss of adhesion between the paint finish and the metal.
- 3.32 Cathodic Inhibitor**—A chemical substance or combination of substances that prevent or reduce the rate of cathodic or reduction reaction by a physical, physico-chemical, or chemical action.
- 3.33 Cathodic Potential**—Electropositive potential.
- 3.34 Cathodic Protection**—Reduction or elimination of corrosion by making the metal a cathode by means of impressed direct current or attachment to a sacrificial anode (usually Mg, Al, or Zn).

- 3.35 Cation**—A positively charged ion or radical (for example Fe^{++} or NH_4^+) which migrates toward the cathode under the influence of a potential gradient.
- 3.36 Cavitation Corrosion**—Cavitation Corrosion occurs on the low pressure side of propellers and pump impellers where interruption in smooth flow causes vapor bubbles to form. When these bubbles collapse, they can destroy any protective coating and remove minute particles of metal.
- 3.37 Cell**—Electrochemical system consisting of an anode and a cathode immersed in an electrolyte. The anode and cathode may be separate metals or dissimilar areas on the same metal. When the electrodes are in electrical contact with each other, they develop a difference in potential which causes current to flow and produces corrosion at the anode. A cell involving an electrolyte in the corrosion process is referred to as an electrolytic cell.
- 3.38 Chalking**—The development of loose removable powder at or just beneath a coating surface.
- 3.39 Checking**—Surface cracking in a checkerboard-like pattern; this may be in a surface layer (coating) or on the metal surface itself.
- 3.40 Chemical Conversion Coating**—A protective or decorative coating produced in situ by chemical reaction of a metal with a chosen environment.
- 3.41 Chromated**—Parts treated with chromic acid to improve their corrosion resistance.
- 3.42 Clear Coat**—A paint without pigment applied over a color basecoat to enhance the appearance and durability of the total paint system.
- 3.43 Concentration Cell**—A cell involving an electrolyte and two identical electrodes, with the potential resulting from differences in the chemistry of the environments adjacent to the two electrodes.
- 3.44 Conductivity**—The ability of a material to transfer heat or electricity. Copper is a good conductor of electricity.
- 3.45 Contact Corrosion**—A term mostly used in Europe to describe galvanic corrosion between dissimilar metals.
- 3.46 Conversion Coating**—An adherent reaction product layer on a metal surface formed by reaction with a suitable chemical; such as an iron phosphate film on iron developed by H_3PO_4 .
- 3.47 Corrosion**—The deterioration of a material, usually a metal, because of a reaction with its environment.
- 3.48 Corrosion Fatigue**—Effect of the application of repeated or fluctuating stresses in a corrosive environment characterized by shorter life than would be encountered as a result of either the repeated or fluctuating stresses alone or the corrosive environment alone.
- 3.49 Corrosion Potential**—The potential that a corroding metal exhibits under specific conditions of concentration, time, temperature, aeration, velocity, etc. Also called: rest potential, open circuit potential, freely corroding potential.
- 3.50 Corrosion Rate**—The speed (usually an average) with which corrosion progresses (it may be linear for awhile); often expressed as though it was linear, in units of mdd (milligrams per square decimeter per day) for weight change, or mpy (mils per year) for thickness changes. Corrosion rates may be reported as: (a) A weight loss per area divided by the time (a milligram is 1/1000th of a gram) (there are 453.6 g/lb); and a decimeter is 3.937 in, or (b) The depth of metal corroded, divided by the time (a "mil" is 1/1000th of an inch).
- 3.51 Cosmetic Corrosion**—Corrosion typically characterized by blistering and/or rusting that is aesthetically displeasing, but may not result in catastrophic failure of the item.

- 3.52 Couple**—A cell developed in an electrolyte resulting from electrical contact between two dissimilar metals.
- 3.53 Cracking**—Fracture of a metal in a brittle manner along a single or branched path.
- 3.54 Craze**—A network of checks or cracks appearing on a surface.
- 3.55 Creepback**—The undercutting or the separation of paint from the substrate from an edge, damage site, or a scribe line.
- 3.56 Creep/Creepback**—Time-dependent strain occurring under stress.
- 3.57 Crevice Corrosion**—Localized corrosion resulting from the formation of a concentration cell in a crevice formed between a metal and a nonmetal, or between two metal surfaces.
- 3.58 Critical Humidity**—The relative humidity above which the atmospheric corrosion rate of a given metal increases sharply.
- 3.59 Current**—The "flow" of electricity expressed in amperes, milliamperes, and microamperes.
- 3.60 Current Density**—The current per unit area; generally expressed as amps per sq cm.
- 3.61 Cyclic Testing**—Accelerated testing and simulation of service conditions by the use of controlled alternating exposures to at least two corrosive environments, such as, salt or other chemical exposure, water immersion, temperature variations, humidity variations, ultraviolet (UV) light exposure, mud or clay contamination, gravel or shot blasting, and driving.
- 3.62 Deicing Salt**—Salts, typically NaCl and/or CaCl₂, applied to highways to aid in seasonal deicing.
- 3.63 Deionized Water**—Water that has had the charged species (Cl⁻, Ca²⁺, etc.) removed from it.
- 3.64 Deposit**—A foreign substance, which comes from the environment, adhering to a surface of a material.
- 3.65 Deposit Attack**—Corrosion occurring under or around a discontinuous deposit on a metallic surface.
- 3.66 Dew Point**—Temperature at which condensation of water vapor from air occurs.
- 3.67 Differentially Zinc Coated**—A sheet (usually steel) with a zinc coating of a different thickness on one side than on the other side.
- 3.68 Diffusion**—The movement of one substance through another. Diffusion of contaminants into a paint system is often the cause of corrosion attack.
- 3.69 Direct Current**—Electricity which flows in one direction at all times.
- 3.70 E Coat/ELPO**—Common names for the electrocoating process.
- 3.71 Electrochemical**—A chemical reaction which is driven by a difference in electrode potential from one site to another on the same or different parts.
- 3.72 Electrochemical Corrosion**—Corrosion of metal caused by current flowing between anode and cathode areas in an electrolyte.
- 3.73 Electrochemical Potential**—The partial derivative of the total electrochemical free energy of a constituent with respect to the number of moles of this constituent where all factors are kept constant.

- 3.74 Electrocoating**—A method of coating a metal requiring the application of high voltages between an anode and a cathode in an electrolyte. Based upon the method of deposition, two types of electropaint have been developed: anodic and cathodic. Cathodic electrocoating is commonly used in the automotive industry.
- 3.75 Electrode**—A conductor (usually a metal) through which current enters or leaves an electrolyte.
- 3.76 Electrode Potential**—Voltage or potential of an electrode with respect to a reference half cell.
- 3.77 Electrodeposition**—The deposition of a coating on an electrode by means of electrolysis.
- 3.78 Electrogalvanized**—Steel containing a zinc coating produced by continuously electroplating zinc onto the steel surface.
- 3.79 Electrolysis**—The chemical change in an electrolyte resulting from the passage of electricity.
- 3.80 Electrolyte**—A chemical substance or mixture, usually liquid, containing ions which migrate in an electric field.
- 3.81 Electrolytic Cleaning**—The process of degreasing or descaling a metal by making it an electrode in a suitable bath.
- 3.82 Electromotive Force**—Force which causes a flow of current. Electromotive force is usually expressed in volts.
- 3.83 Electromotive Force Series/EMF Series**—An orderly listing of elements according to their standard electrode potentials. (Hydrogen electrode is a reference point and is given the value of zero.)
- 3.84 Electroplated Coatings**—Coatings applied in a low temperature continuous process where negatively charged steel sheet is passed between positively charged anodes. Metallic ions in an electrolyte bath are reduced and plated on the surface of the steel sheet forming the coating.
- 3.85 Embrittlement**—Severe loss of ductility of a material due to a chemical or physical change.
- 3.86 Epoxy**—Resin formed by the reaction of bisphenol and epichlorohydrin.
- 3.87 Erosion Corrosion**—A corrosion reaction accelerated by the relative movement of a corrosive fluid and a metal surface.
- 3.88 Exfoliation Corrosion**—Localized subsurface corrosion in zones parallel to the surface which result in thin layers of uncorroded metal resembling the pages of a book.
- 3.89 Filiform Corrosion**—Corrosion which occurs under films in the form of randomly distributed hairlines.
- 3.90 Film**—A thin surface layer that may or may not be visible.
- 3.91 Flash Coating**—A very thin coating of paint or plating applied to provide limited corrosion protection or to improve the adhesion of subsequent coatings.
- 3.92 Fretting Corrosion**—Deterioration at the interface between two contacting surfaces accelerated by relative motion between them of sufficient amplitude to produce slip.
- 3.93 Galvanic Cell**—A cell consisting of two dissimilar metals in contact with each other and with a common electrolyte (sometimes refers to two similar metals in contact with each other but with dissimilar electrolytes; differences can be small and more specifically defined as a concentration cell).

- 3.94 Galvanic Corrosion**—Corrosion associated with the current resulting from the electrical coupling of dissimilar electrodes in an electrolyte.
- 3.95 Galvanic Series**—A list of metals arranged according to their relative corrosion potentials in some specific environment; sea water is often used.
- 3.96 Galvanized**—Zinc coated sheet steel.
- 3.97 Galvanneal**—Steel containing a zinc/iron alloy coating produced by either the hot-dip or electroplating process.
- 3.98 General Corrosion (see Uniform Corrosion)**—Corrosion in a uniform manner.
- 3.99 Gravelometer**—Machine used to cause consistent intentional paint damage to samples prior to or during laboratory corrosion testing. A gravelometer propels gravel or metal shot of a particular size and shape at the surface of a painted test specimen. The gravelometer is used to simulate the type of field paint damage caused by gravel or other road debris.
- 3.100 Heat Affected Zone (HAZ)**—That portion of the base metal that was not melted during brazing, cutting, or welding, but whose microstructure and properties were altered by the heat of these processes.
- 3.101 Hem Flange**—A method of joining two pieces of metal together in which the edge of one piece is folded tightly over the edge of the other.
- 3.102 Hot-Dip Coating**—A continuous process of applying coatings to steel in which the steel is immersed in a molten bath of the coating material.
- 3.103 Holiday**—Any discontinuity or bare spot in a coated surface.
- 3.104 Hot-Dip Galvanized**—Steel containing a zinc coating produced by immersion of the steel in a molten zinc bath.
- 3.105 Impingement**—Localized erosion-corrosion caused by turbulence or impinging flow at certain points. Also impact or road debris on surfaces.
- 3.106 Inhibitor**—A chemical substance or combination of substances, which when present in the proper concentration and forms in the environment, prevents or reduces corrosion.
- 3.107 Inside-Out Corrosion**—Corrosion that starts from the inside surface of a body panel and works outward.
- 3.108 Ion**—An electrically charged atom or group of atoms.
- 3.109 Lamellar Corrosion (see Exfoliation)**—Localized subsurface corrosion in zones parallel to the surface which results in thin layers of uncorroded metal resembling the pages of a book.
- 3.110 Local Cell**—A galvanic cell resulting from inhomogeneities between areas on a metal surface in an electrolyte. The inhomogeneities may be of physical or chemical nature in either the metal or its environment.
- 3.111 Localized Corrosion**—Corrosion resulting in differential attack across a metallic surface. Localized corrosion is typically of a cosmetic nature, but can lead to catastrophic failure if a primary structural component is the site of severe attack.

- 3.112 Long Terne**—Cold-rolled sheet steel coated on both sides with a lead-tin alloy by a continuous hot-dip process.
- 3.113 Metal Ion Concentration Cell**—A galvanic cell caused by a difference in metal ion concentration at two locations on the same metal surface.
- 3.114 Metallizing**—A process of coating a surface with a layer of metal; spraying, vacuum deposition, dipping, plasma jet, cementation, etc., are used.
- 3.115 Neutral**—In aqueous solutions, a substance having a pH of 7 is considered neutral.
- 3.116 Neutralization**—Hydrogen ions of an acid combined with hydroxyl ions of a base to form water ($H^+ + OH^- = HOH$).
- 3.117 Nickel Terne**—Cold-rolled sheet steel electrolytically nickel flash plated and then coated on both sides with a lead-tin alloy by a continuous hot-dip process. Corrosion resistance is superior to standard long terne.
- 3.118 Noble/Noble Metal**—A metal which is not very reactive, as silver, gold, and copper and may be found naturally in metallic form on earth.
- 3.119 Organic Coatings**—Coatings, primarily paints, applied to metallic or other substrates typically to provide corrosion protection and to improve aesthetic characteristics of the material.
- 3.120 Outside-In Corrosion**—Corrosion that starts from the outside surface of a body panel and works inward.
- 3.121 Oxidation**—Loss of electrons by a constituent of a chemical reaction. The combination of oxygen with metal ions to form an oxide. Rust is iron oxide.
- 3.122 Passivation/Passive**—A reduction of the anodic reaction rate of an electrode involved in electrochemical action such as corrosion.
- 3.123 Perforation Corrosion**—Penetration of a panel due to corrosion. Perforation corrosion is usually associated with inside-out corrosion.
- 3.124 pH**—A measure of the acidity or alkalinity of a solution. A value of seven is neutral; low numbers are acid, large numbers are alkaline. Strictly speaking, pH is the negative logarithm of the hydrogen ion concentration.
- 3.125 Phosphate Coatings**—Protective coatings formed by reaction of a metallic substrate with an acidic phosphate containing solution. The primary role of the phosphate coating is to enhance adhesion of the primer (electrocoat or other) to the metal. Phosphate coatings are typically Zn, Fe, Zn-Ni, or Zn-Ni-Mn phosphates.
- 3.126 Pits**—Localized corrosion of a metal surface, confined to a small area which takes the form of cavities.
- 3.127 Pitting**—Highly localized corrosion resulting in deep penetration at only a few spots.
- 3.128 Pitting Corrosion**—A type of perforation corrosion. Pitting corrosion is highly localized corrosion resulting in deep penetration at only a few spots.
- 3.129 Polarization**—The deviation from the open circuit potential of an electrode resulting from the passage of current.

- 3.130 Polarization Curve**—A plot of current density versus electrode potential for a specific electrode-electrolyte combination.
- 3.131 Polyester**—Resin formed by condensation of polybasic and monobasic acids with polyhydric alcohols.
- 3.132 Potential**—See electrochemical potential.
- 3.133 Poultice**—An accumulation of mud, sand, salt, and other road debris on the interior surface joints of body panels and structural components.
- 3.134 Precoated**—A material that has been coated prior to the manufacture of the ware or part.
- 3.135 Pretreatment**—The treatment of a surface prior to the process of interest, for example: a phosphate coating is a pretreatment for electrocoat or painting.
- 3.136 Prime Coat**—A first coat of paint applied to inhibit corrosion and/or improve adherence of the next coat.
- 3.137 Primer—Primer**—First coat of paint applied to a surface. Formulated to have good bonding and wetting characteristics; may or may not contain inhibitive pigments.
- 3.138 Proving Ground Tests**—Cyclical programs primarily conducted by the automotive companies to realistically evaluate the effects of corrosive elements on the performance of fully assembled vehicles. Proving Ground Tests often combine on-road and laboratory exposures.
- 3.139 Reaction Cell**—A cell at which a chemical reaction is occurring. See "Cell."
- 3.140 Reduction**—Gain of electrons by a constituent of a chemical reaction.
- 3.141 Relative Humidity**—The ratio, expressed as a percentage, of the amount of water present in a given volume of air at a given temperature to the amount required to saturate the air at that temperature.
- 3.142 Rust**—Corrosion product consisting primarily of hydrated iron oxide—a term properly applied only to iron and ferrous alloys.
- 3.143 Rust Proofing**—The application of coatings intended to prevent or greatly reduce the formation of rust on steel parts.
- 3.144 Sacrificial Protection**—Reduction of corrosion of a metal in an electrolyte by galvanically coupling it to a more anodic metal. A form of cathodic protection.
- 3.145 Saponification Corrosion**—Formation of a soap by the reaction of corrosion products with some organic coatings.
- 3.146 Scab Corrosion**—Cosmetic corrosion caused by break down of the surface protection system often preceded by blisters.
- 3.147 Scribe**—Intentional paint damage typically used for material evaluation during corrosion testing.
- 3.148 Sealers**—Products applied to joints or seams to prevent the entry of moisture or contaminants. Paint coatings applied to prevent the undesirable interaction of a subsequent coating with a previous coating or to enhance adhesion or corrosion protection.
- 3.149 Selective Corrosion**—The selective corrosion of certain alloying constituents from an alloy (as dezincification), or in an alloy (as internal oxidation).

- 3.150 Slushing Compound**—A non-drying oil, grease, or similar organic compound which, when coated over a metal, affords at least temporary protection against corrosion.
- 3.151 Thermogalvanic Corrosion**—Corrosion resulting from a galvanic cell caused primarily by a thermal gradient.
- 3.152 Throwing Power**—The relationship between the current density at a point on the specimen and its distance from the counter electrode. The greater the ratio of the surface resistivity shown by the electrode reaction to the volume of resistivity of the electrolyte the better is the throwing power of the process.
- 3.153 Undercutting**—See "Creepback."
- 3.154 Underfilm Corrosion**—Corrosion which occurs under films in the form of randomly distributed hairlines (filiform corrosion).
- 3.155 Uniform Corrosion**—Corrosion which appears on the surface of a part and is not associated with joints and is not pitting. See "Cosmetic Corrosion."
- 3.156 Voids**—A term generally applied to paints to describe holidays, holes, and skips in the film. The term "void" is also used to describe shrinkage in castings or welds.
- 3.157 Wash Primer**—A thin inhibiting paint usually chromate pigmented with a polyvinyl butyrate finder.
- 4. Historical Development**—The automotive industry and its supply base have worked together to achieve many unique accomplishments. Some originated as new technology while others resulted from solving customer dissatisfactions. Increasing vehicle durability has been an ongoing customer satisfaction item for the automotive industry with varying degrees of emphasis since the automobile was invented.
- 4.1 Early Galvanized Applications and Electrocoat Priming**—The use of galvanized steel for rocker panels in the late 1950s and early 1960s, and the introduction of electrocoat priming in the late 1960s were two of the most noteworthy and far reaching changes. The steel industry responded to the automotive industry's needs and worked on the development of a minimum spangle, two-side hot-dip galvanized sheet. The application of this product for rocker panels set the stage for other applications. Meanwhile, the chemical and paint industries also responded with the development of an immersion primer system which was supposed to infiltrate into all the hidden cavities and crevices to reduce perforation corrosion.

A "Catch 22" situation was developing since state and local highway departments were also trying to react to their "customers'" demand for better driving conditions and increased the usage of salt to deice the roadways of many northern states. This increased usage of salt accelerated the corrosion of the vehicle bodies.

The automotive industry was developing its own new corrosion problems with the sleek, finned styling associated with the late 1950 and 1960 vehicles. Thinner body materials were used to form these styling designs. These designs were found to be more difficult to assemble and protect with existing sealers, primers, and paints. Another new generation of materials was required.

Galvanized steel became more common, especially for unexposed areas that had been susceptible to poor durability. Minimum spangle hot-dip galvanized steel sheet was modified so that the spangle pattern was appropriate for use in exposed panel applications, such as cowl tops. New manufacturing equipment was necessary for spot welding. New pretreatment chemicals, compatible with zinc coatings, were developed.

Deicing salts continued to be used in increasing amounts in the northern snow belt areas and for dust control (replacing waste oil) for unpaved roads. This created an accelerating corrosion problem since the combination of heat, moisture, and salt resulted in very active galvanic cells with the car bodies being consumed in the salt electrolyte. Automotive engineers became aware of the acceleration of corrosion in many Canadian localities.