Introduction to Aircraft Corrosion

Carl E. Locke, Jr.

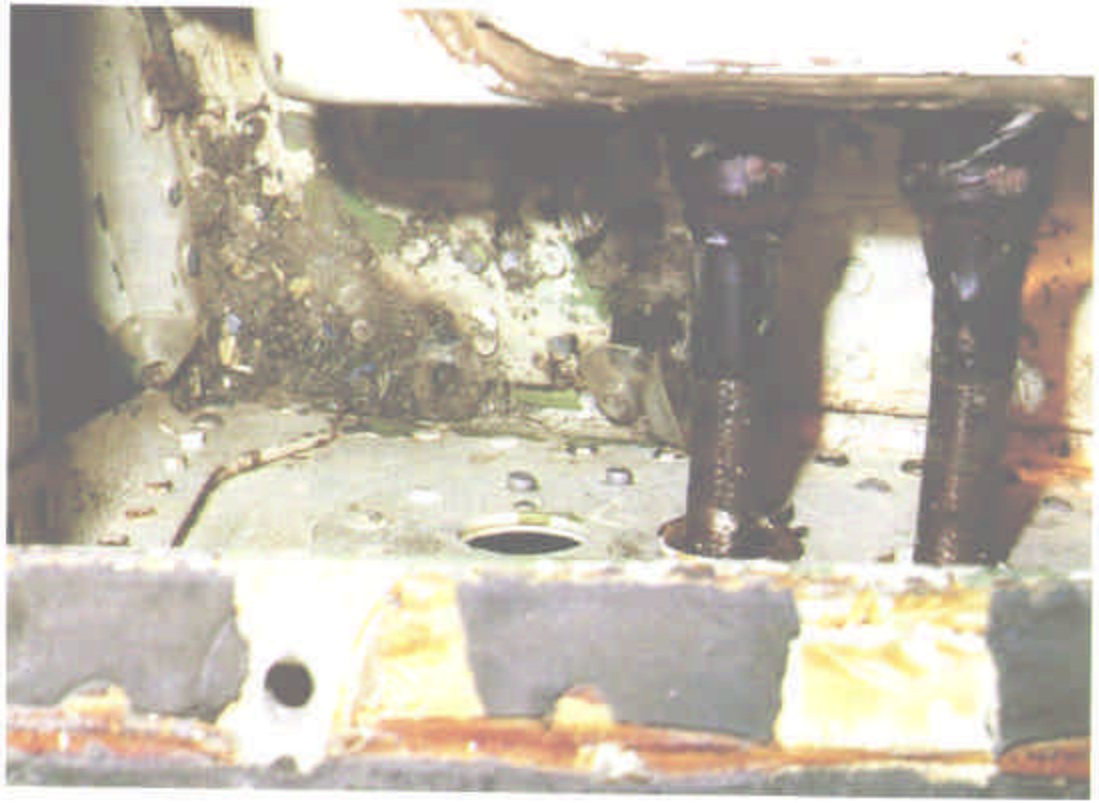
University of Kansas

CORROSION ON 727

Corrosion of a No. 3 cargo door forward frame lower sill on a Model 727.

DRAINAGE CAUSED PROBLEM

The results of blocked drainage tubes at Butt Line 40, Body Station 2360 pressure dome, on a Model 747.



Lap Joints - Possible Problems

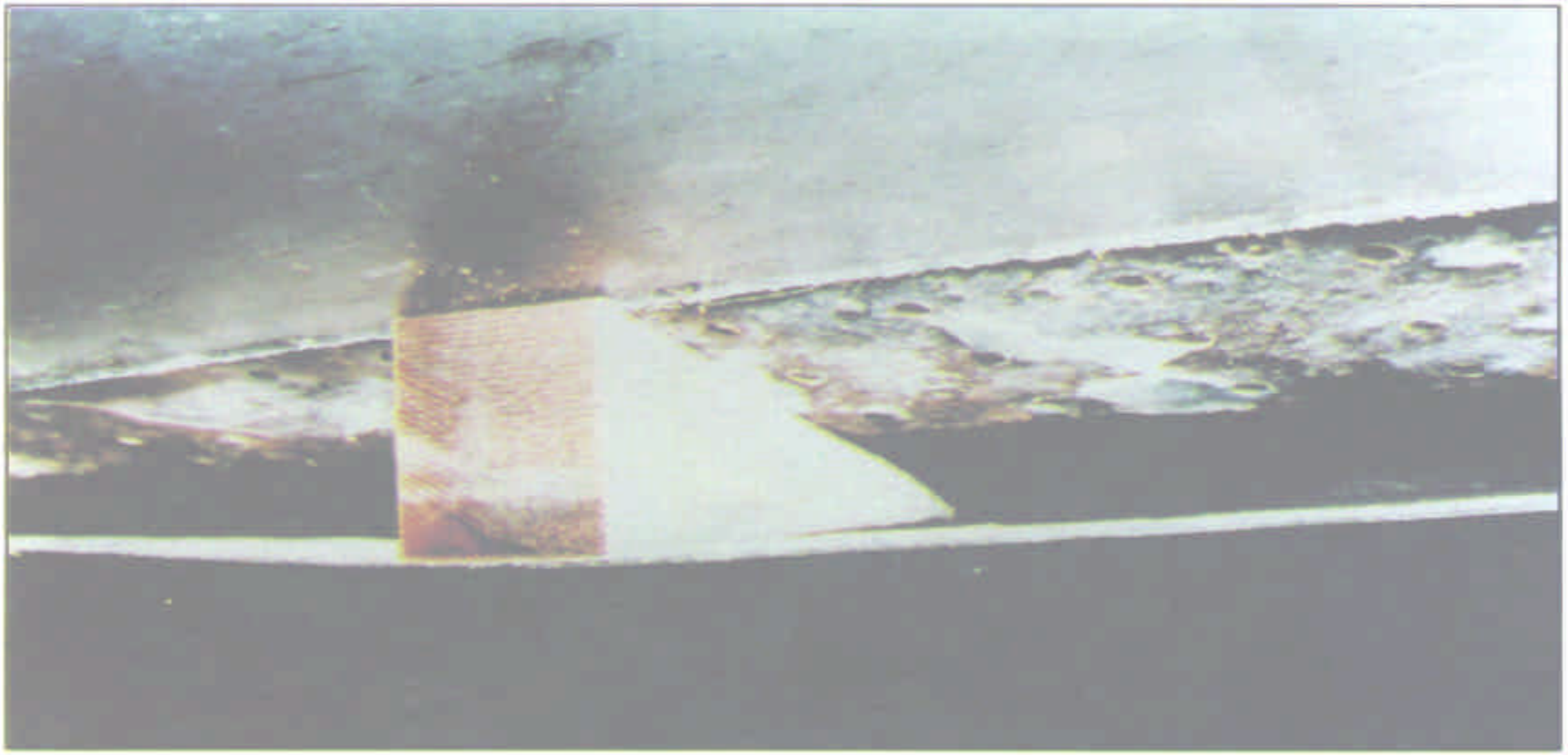


FIGURE 4-14. CLOSEUP VIEW OF A CORRODED LAP JOINT

Corrosion Products Cause Problems

FIGURE 4-12. SKIN BULGING AROUND FASTENERS

Introduction

- Definition of Corrosion
- Why Corrosion is Important
- Corrosion Electrochemistry
- Corrosive Environments
- Types of Corrosion
- Corrosion Control Techniques

Definition of Corrosion

- Destructive Attack of Metal by Reaction with the Environment
  - Does not include non-metals
  - Some Reactions with Environment are Helpful
    - Dry Cell
    - Alumnium Oxide - Anodizing
    - Cathodic Protection

Why Corrosion is Important

- Economics
- Safety
- Conservation

Economics of Corrosion

- Total Cost to Country
  - 4% of GNP ==> > $200 Billion
- Cost to Army
  - $2.8 Billion in 1986 (1989 Tri-Service Corrosion Conference)

Safety

- Aloha Airlines 737
- Piper PA-18 & PA-22 Strut Problems
- Jet Landing Gear Failure

Conservation

- Non-Renewable Resources
- Source of Metals - Non- USA

Electrochemistry of Corrosion

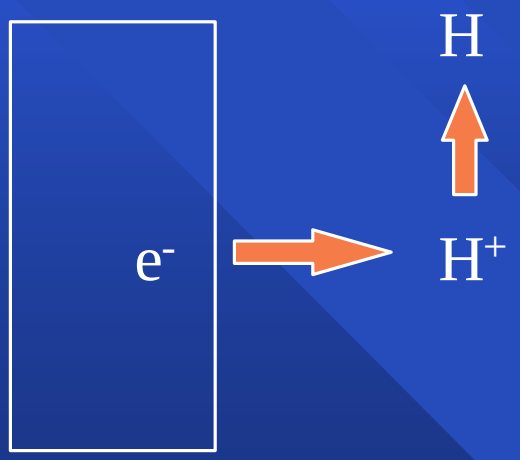
- Reactions - Oxidation and Reduction
- Electrochemical Cell - What is Needed
- Energy Producers (Batteries & Fuel Cells)
- Substance Producers
- Energy Waster & Substance Destroyer

Corrosion Reactions

- Reduction Reaction
  - $2H^+ + 2e^- \Longrightarrow H_2$
- Oxidation Reaction
  - $Fe \Longrightarrow 2e^- + Fe^{++}$

Reduction Reaction

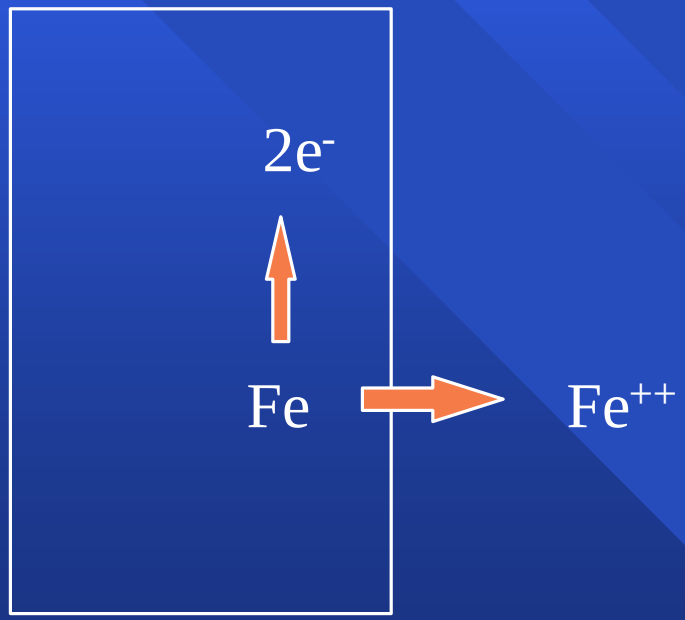
- Electron Added to Species



$H + H \Rightarrow H_2$

Oxidation Reaction

- Electrons Given by Species



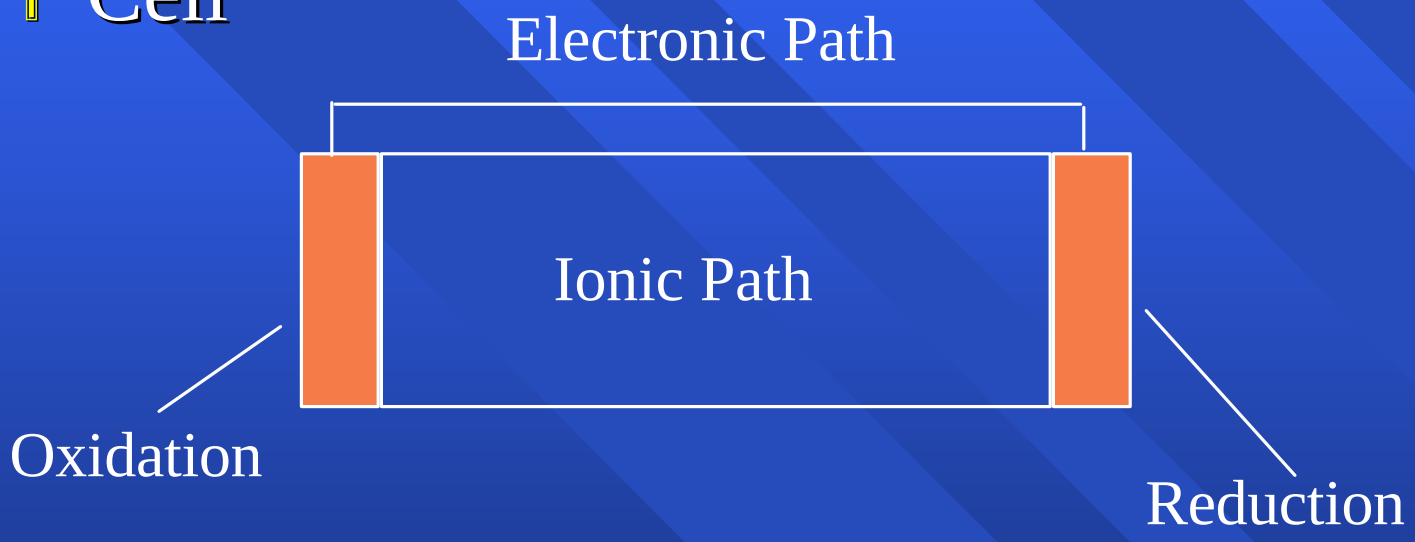
Ionic Form is
Water Soluble

Electrochemical Cell - What is Needed

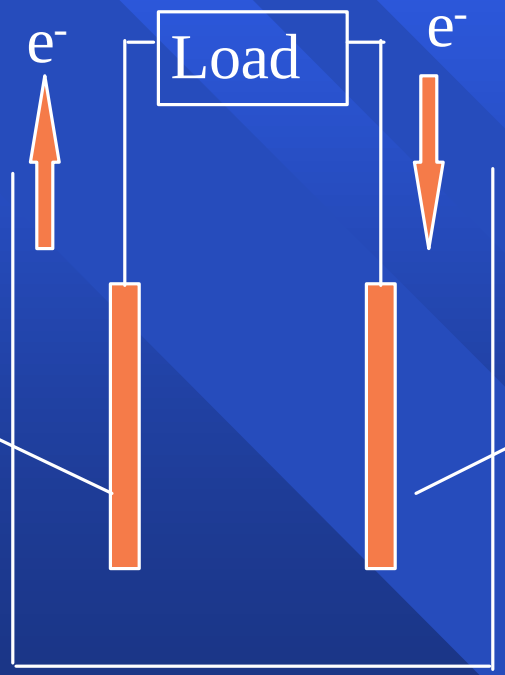
- Site for Reduction Reaction
- Site for Oxidation Reaction
- Electronic Path
- Ionic Path

Electrochemical Cell

- Cell



Energy Producer (Battery/Fuel Cell)



Oxidation Reaction

ANODE

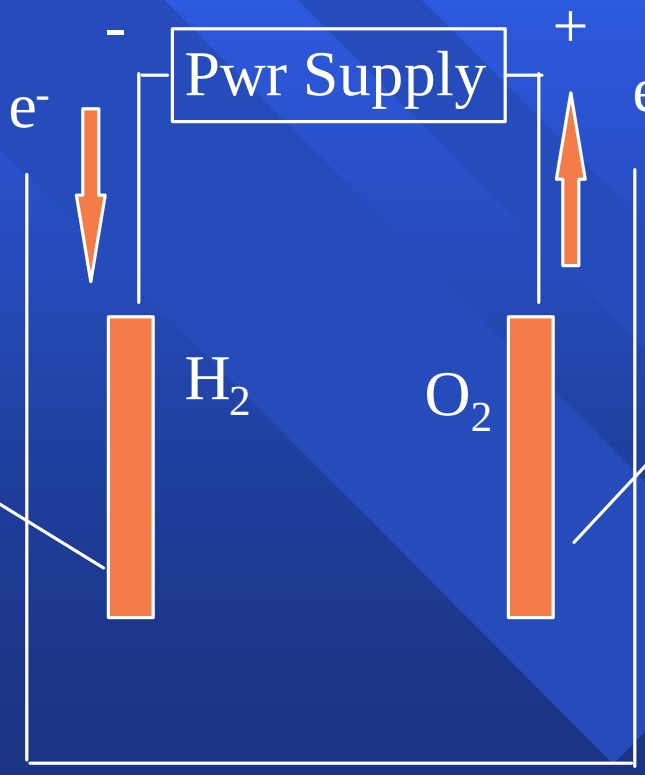
Reduction Reaction

CATHODE

Substance Producer

$2H^+ + 2e^- \Rightarrow H_2$

$2OH^- \Rightarrow 1/2O_2 + H_2O + 2e^-$



Reduction Reaction

CATHODE

Oxidation Reaction

ANODE

Tendency to Corrode

- Half Cell Potentials
- Galvanic Series

Half Cell Potentials

- Hydrogen Reaction Defined as 0 Volts
- Pure Metals in Solution of Ions, Unit Activity
- Example from Series
  - $Mg^{++} + 2e^{-} ==> Mg$ -2.38 V
  - $Al^{+3} + 3e^{-} ==> Al$ -1.66 V
  - $Fe^{++} + 2e^{-} ==> Fe$ -0.44 V
  - $Cu^{++} + 2e^{-} ==> Cu$ -0.34 V
  - $Ag^{++} + 2e^{-} ==> Ag$ 0.80 V

Galvanic Series

- Alloys and Metals in Same Solution
- Different Relationships with Different Solutions

Galvanic Series (Cont.)

- Examples from Metals in Sea Water
  - Platinum
  - 18-8 Stainless Steel (passive)
  - Brasses
  - Steel
  - 2024 Aluminum
  - Pure Aluminum
  - Magnesium

Corrosive Environments

- Environmental Factors
  - Rates increase with increasing temperature
  - Rate Dependent upon specific ions
  - Solution conductivity required
  - System Pressure - little influence on rate
- Atmospheric Environments

Atmospheric Environments

- Marine/Coastal
  - High Humidity/Salt
  - Rates 400-500 times greater than in dry atmosphere
  - Condensed water - bad problem
- Industrial - Chemical
  - Localized Areas, dissolved gases, ions control rates

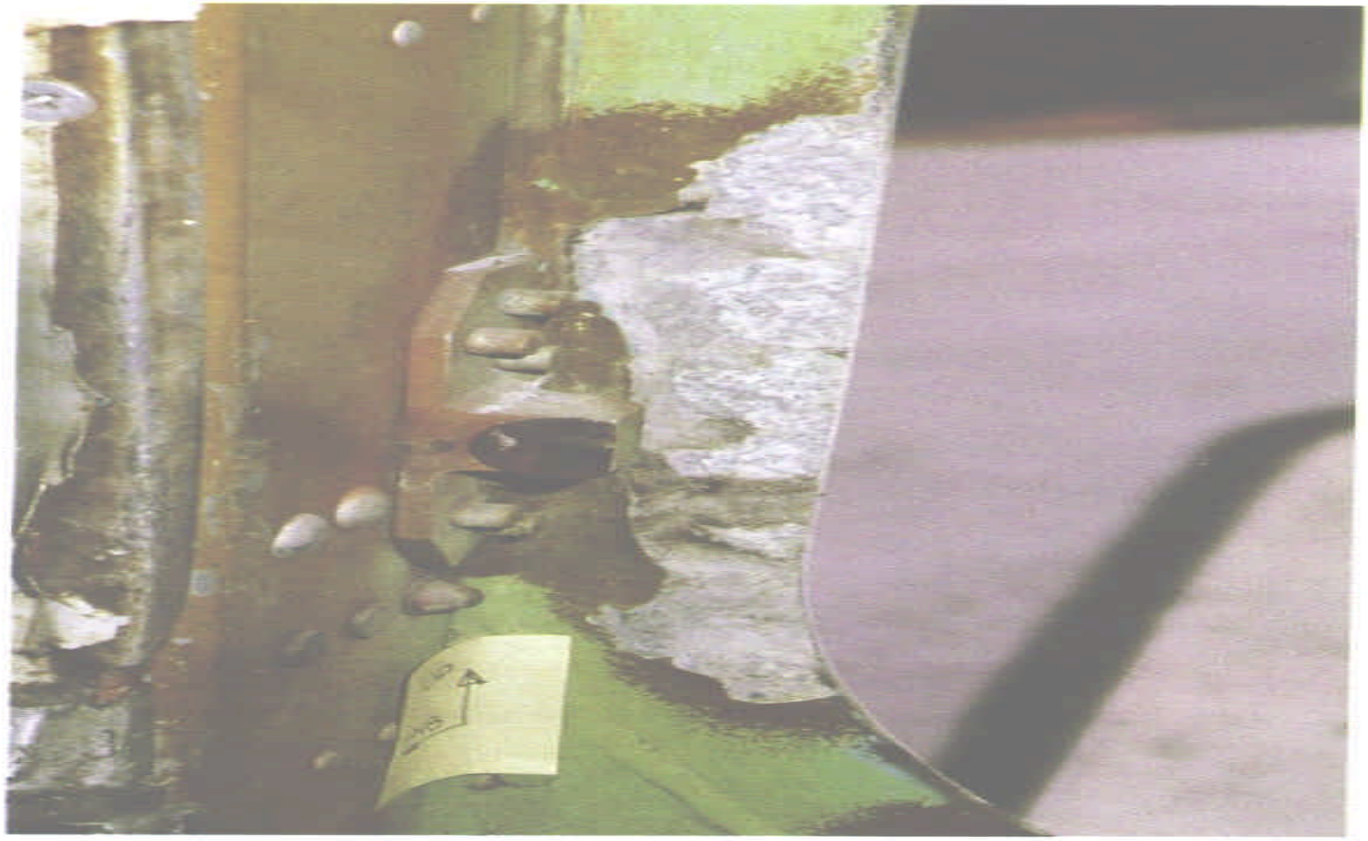
Atmospheric Environments (Cont.)

- Rural - Urban
  - Time of Wetness controls
- Enclosed Atmospheres

Types of Corrosion

- General
- Pitting
- Crevice
- Filliform
- Stress Cracking
- Exfoliation
- Fretting
- High Temperature Attack

Exfoliation Corrosion



Corrosion of an overwing escape hatch forward frame of a Model 720.

Stress-Corrosion Cracking

FIGURE 2-12. STRESS-CORROSION CRACKING OF 7079-T6 FITTING

SSC Magnified

FIGURE 2-13. STRESS-CORROSION CRACKING STARTING AT A PIT IN CRES MATERIAL

Filliform Corrosion

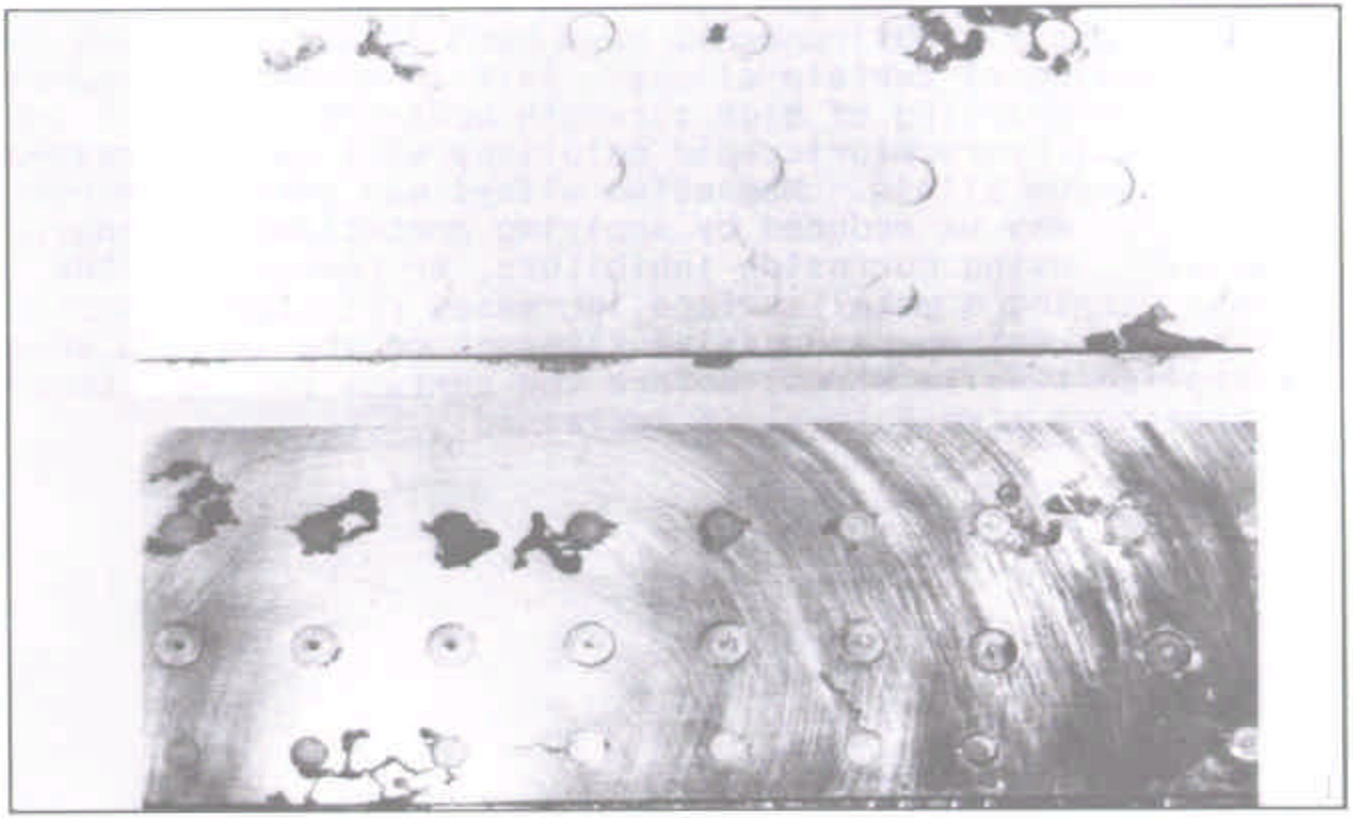


FIGURE 2-11. FILIFORM CORROSION BEFORE AND AFTER PAINT REMOVAL

Corrosion Control Techniques

- Coatings
  - Metallic
  - Organic
- Inhibitors
  - Electrochemical
  - Film Formers
- Materials Selection
- Design Factors

Control of Aircraft Corrosion

- Selection of Materials
  - Al Alloys
  - Clad Aluminum
- Design
- Inhibiting Compounds
- Inspection

Aluminum Alloys Used

- 7075
- 7178
- 2000 Series
- Clad Aluminum
- Heat Treatment is important
- T-73 and T-76 Widely Used

Design

- Avoid Galvanic Couples
- Drain Holes
- Inspection Access
- Wet Assembly

DESIGN FOR CONTROL

- SEVERAL TECHNIQUES FOR CORROSION CONTROL HERE

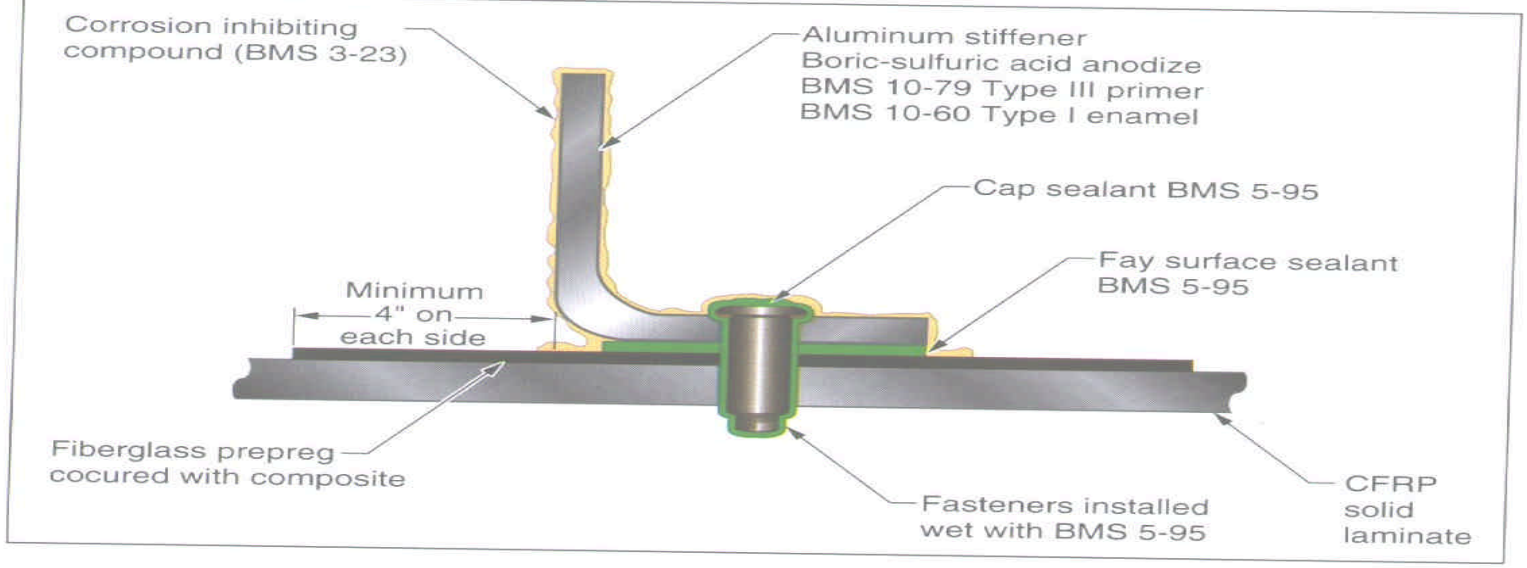


Figure 3. Designers paid extra attention to isolating aluminum from the CFRP solid laminate structure. This separation prevents galvanic corrosion of dissimilar materials.

Design for Corrosion Control

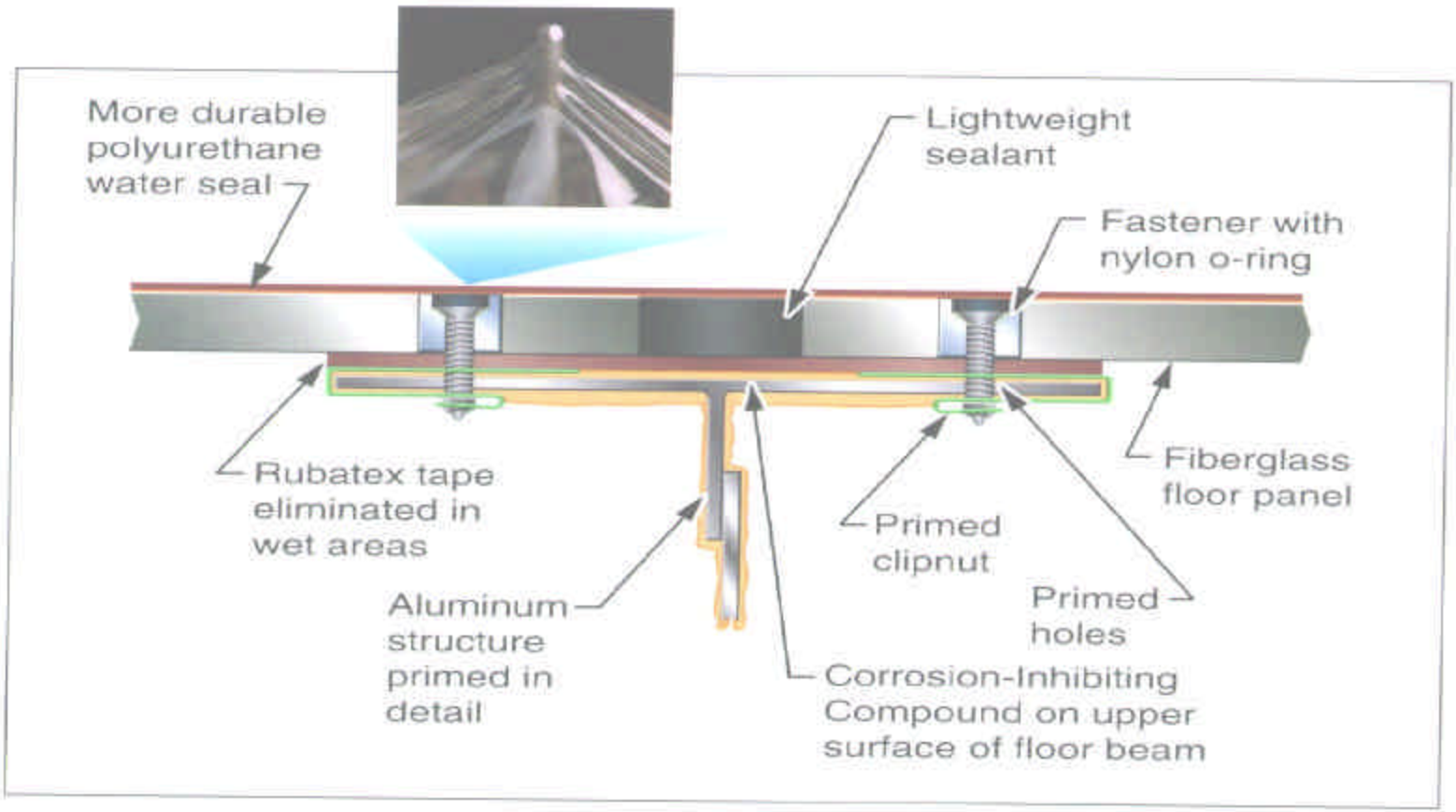


Figure 5. To avoid corrosion, many design improvements have been incorporated to passenger floors, especially in the galley and lavatory areas. One of the latest improvements is a polyurethane moisture barrier (inset photo), which forms a durable water seal.

Inhibiting Compounds

- During Maintenance Procedures
- During Manufacture
- Compounds Available

Steps to Control Corrosion

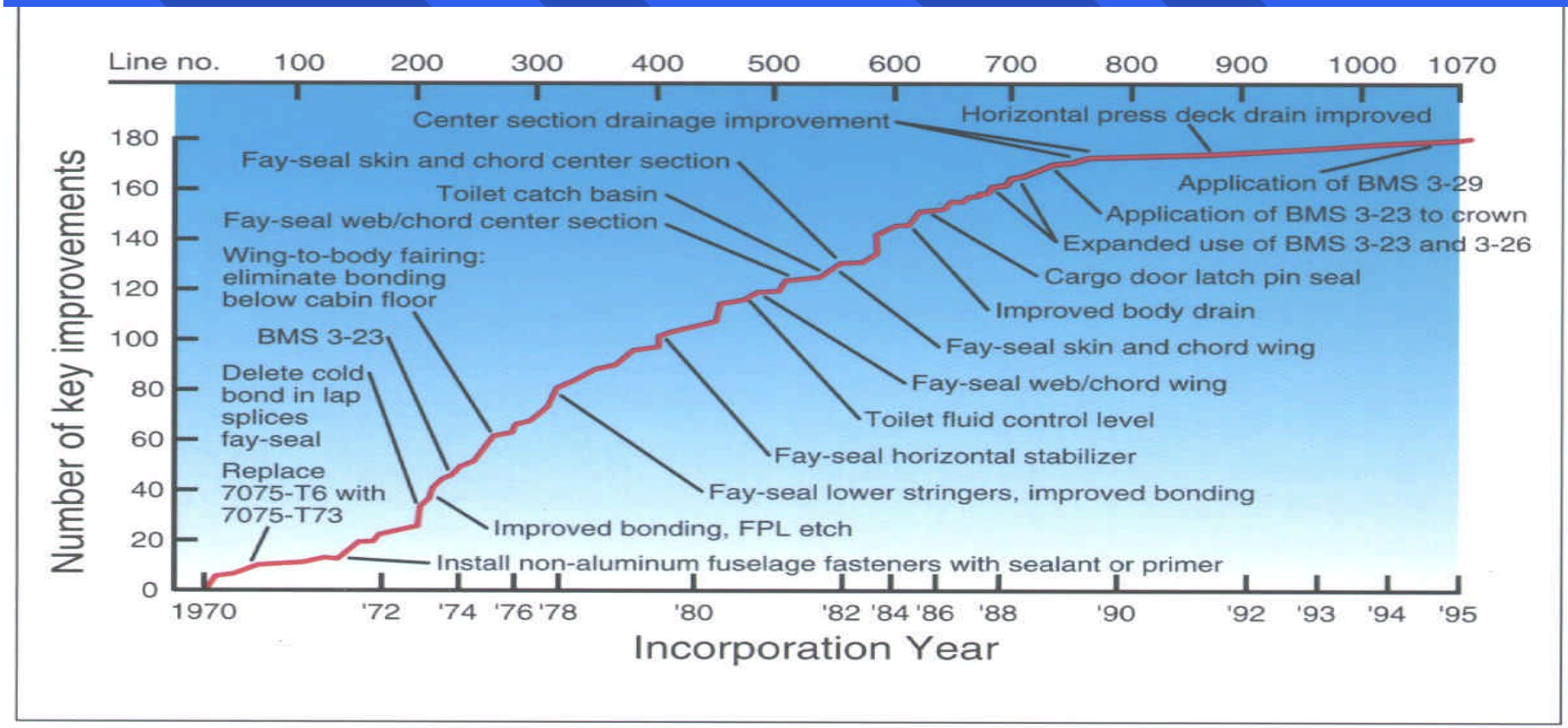


Figure 4. Boeing has made a continuous effort to improve airplane design. The example chart shows corrosion prevention improvements incorporated into the 747 production line.

Inspection

- Aging Aircraft Program
- Levels of Corrosion
- Extent of Corrosion

Inspection Methods

- Visual
- Ultrasonic
- X-Ray
- Eddy Current
- Dye Penetrant
- Magnetic Flux

Conclusions

- Corrosion is a problem in Aircraft
- Must have a program to minimize effect