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Construction Concerns: Galvanic Corrosion
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"Galvanic corrosion" is damage caused when two dissimilar metals are joined in the presence of an electrolyte. The electrolyte can be one of many liquids, including plain water, acids, sea water, or salt water. When the two metals are joined in the presence of the electrolyte, one becomes the anode and corrodes faster than it would by itself. The other metal becomes the cathode and corrodes more slowly than it would by itself.

This action, the basis for wet-cell and gel-cell batteries, was first demonstrated by Alessandro Volta in 1800.

This action is also the basis for the sacrificial corrosion of one metal to protect another by use of sacrificial anodes or cathodic protection. This sacrificial corrosion is used in the protection of underground steel tanks and steel pipelines, boilers, and water-heating appliances, using magnesium or aluminum sacrificial anodes. This action was first demonstrated by Sir Humphry Davy and Michael Faraday a few years later.

A small electrical current flows between two dissimilar metals in contact in a conductive or corrosive environment. This current flow results in the increased corrosion of the least corrosion-resistant (most active) metal and in the decreased corrosion of the more corrosion-resistant (most inactive) metal. The least corrosion-resistant metal is gradually destroyed by this process, causing weakness and eventually failure of the metal.

<u>Galvanic Series Table</u>			
<u>Electrolyte: Sea water</u>			Tables vary with electrolytes
Anodic – Most active – Most easily corroded		12	Stainless Steel
1	Magnesium	13	Tungsten
2	Zinc	14	Brass
3	Beryllium	15	Bronze
4	Aluminum	16	Copper
5	Cadmium	17	Molybdenum
6	Tin	18	Monel
7	Lead	19	Titanium
8	Steel	20	Silver
9	Cast Iron	21	Gold
10	Nickel	22	Graphite
11	Chromium	**Cathodic – Least Active –**	
	(Excerpts from MIL-STD-889 1997)		**Noble - Least easily corroded**

The Galvanic Table lists metals in order from the most active (Anodic, or most easily corroded) to the least active (Cathodic, or least easily corroded, or "noble"). This excerpt from one of these tables, based on sea water as the electrolyte, lists some of these metals:

Note: Monel is a nickel-copper alloy that also contains small amounts of iron, manganese, carbon, and silicon; with high tensile strength and resistance to corrosion.

The rate of corrosion is related to the distance between the metals in the Galvanic Table. Metals farther apart in the table will corrode more rapidly than metals that are adjacent to each other. Due to their relative positions on the galvanic table, aluminum is more easily corroded than steel when they are in contact with each other. The rate of corrosion of the aluminum will be increased in the presence of a corrosive electrolyte like road salt, whereas the corrosion of the steel will be reduced or stopped.

Galvanic corrosion does not always occur while the metals are submerged in a conductive or corrosive liquid. It can also take place in the atmosphere, where the rate of corrosion is dependent on the amount of moisture and oxygen present, the conductivity of the connection between the metals, and the temperature. This can explain why corrosion continues from exposure to salt of an aluminum-body fire apparatus even during a dry summer. If some salt remains in contact with both the steel and aluminum, and if the steel and aluminum are in contact with each other, the corrosion continues.

The corrosion rate of dissimilar metals also depends on the amount of each metal present at the connection. Aluminum rivets or screws will corrode quickly when used to join steel panels to steel frames, causing rapid failure of the connectors. Aluminum panels will corrode quickly when connected to steel frames with steel screws or rivets, causing rapid failure of the panels at the connections.

Manufacturers and materials engineers consider these points when joining dissimilar metals:

- Avoid placing a small amount of an active metal in contact with a large amount of an inactive metal.
- When connecting two pieces of the same metal, use fasteners of the same metal.
- When the metals being connected are structural or load-bearing, use fasteners of the proper grade and strength, with the proper coatings to reduce the potential for corrosion.
- When fasteners are not available of the same material as the metals being fastened, use fasteners of a material as close as possible to the material being fastened in the galvanic corrosion chart.

These points apply to buildings and structures as they do to vehicles and fire apparatus. If galvanic corrosion is not prevented during the construction of a building, its structural components or fasteners may fail early in the building's life. One common challenge in building high-rises is the connection of an aluminum-framed glass curtain wall to structural steel framing.

When dissimilar metals must be in contact, a non-porous insulator must be used between them. Examples of this include the hard plastic strips that are often installed between steel truck frames and aluminum truck bodies; and like the non-compressible plastic tapes that are installed between steel or stainless steel door hardware and aluminum compartment doors. All surfaces of both metals must be primed and painted. This is especially important for the more active metal, like the aluminum body of a fire apparatus with a steel frame.

Galvanic corrosion can also explain some of the electrical problems that occur during the 20 to 30-year life of a fire apparatus, especially when the apparatus' aluminum body is joined to a steel chassis. In the past, the aluminum apparatus body was electrically bonded (grounded) by copper wires to the steel chassis to complete the circuit for lights, warning lights, sirens, and other equipment. Steel is more active in corrosion than copper; and aluminum is more active than steel. The corrosion at both ends of the copper ground wires loosened connections and increased resistance to current flow. The corrosion products are also less conductive than the metals on which they are based. Either of these related conditions resulted in electrical malfunctions.

Modern vehicles and fire apparatus are equipped with two-wire circuits for each light, siren, or other accessory; and no longer depend on chassis and frame bonding to complete electric circuits. However, there are still many older fire apparatus that depend on this older bonding method for the operation of lights and accessories.

Galvanic corrosion follows the laws of physics and chemistry. We cannot assume that we or our project are so special that these natural laws will be suspended. If we do so, we, or our fire apparatus, or our building under construction, will develop problems that will be difficult to remedy. Problems caused by galvanic corrosion probably will not show themselves until after the project is complete and the warranties have expired.

For a more complete discussion of this topic, search the Internet for “galvanic corrosion” and “galvanic table”.

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