A review of the use of typical metals and plastics for the construction of Ex equipment in areas of highly corrosive agents

In many petrochem and offshore facilities which present a danger of explosions due to the presence of explosive gases, also involve corrosive agents that can be harmful to the equipment and be a source of deterioration of electrical and non-electrical components. With this in mind, it is important for engineers and designers to pay particular attention to the specific corrosive agents in which the equipment will be utilized.

In the table below are listed some chemical substances and the compatibility/incompatibility of some ferrous and non-ferrous metals, some plastics materials and the borosilicate glass to these substances. The table should be considered as a basic guideline as it will not and cannot be exhaustive for all the possible variations of concentrations of corrosive elements and materials.

	Aluminum (ENAB 44100)	AISI 304 Stainless Steel	AISI 316L Stainless Steel	Brass alloy	Bronze	Cast Iron Alloy	Carbon steel	Polycarbonate	Polyester	Borosilicate glass	Teflon	EPDM	Nitrile	Neoprene	Silicone
Acetylene	Green	Green	Green	Yellow	Orange	Green	Green	Green	Green	Green	Green	Green	Green	Yellow	Yellow
Acetone	Green	Green	Green	Green	Green	Green	Green	Red	Yellow	Green	Green	Green	Red	Red	Red
Fatty Acids	Green	Orange	Green	Orange	Orange	Red	Orange	Black	Black	Black	Green	Orange	Yellow	Yellow	Yellow
Acetic Acid	Green	Orange	Yellow	Green	Orange	Red	Red	Green	Green	Green	Green	Yellow	Yellow	Red	Yellow
Boric Acid	Green	Black	Green	Yellow	Orange	Black	Black	Green	Black	Black	Green	Green	Green	Green	Green
Carbonic Acid	Green	Green	Yellow	Black	Orange	Red	Red	Black	Black	Black	Green	Green	Yellow	Green	Green
Hydrocyanic acid	Green	Yellow	Green	Red	Black	Orange	Black	Green	Green	Green	Green	Red	Red	Black	Black
Citric acid	Orange	Green	Green	Orange	Orange	Red	Orange	Green	Green	Green	Green	Green	Green	Green	Green
Hydrochloric acid	Red	Black	Yellow	Red	Red	Red	Red	Yellow	Orange	Yellow	Green	Orange	Red	Red	Red
Hydrofluoric acid (anhydrous)	Red	Red	Red	Red	Orange	Red	Red	Yellow	Red	Red	Green	Green	Red	Red	Red
Phosphoric acid	Red	Yellow	Green	Red	Orange	Red	Orange	Green	Yellow	Yellow	Green	Yellow	Red	Red	Orange
Formic acid	Green	Green	Yellow	Yellow	Yellow	Red	Yellow	Green	Black	Black	Green	Green	Red	Red	Yellow
Lactic acid	Yellow	Green	Green	Red	Orange	Red	Orange	Green	Green	Green	Green	Green	Green	Green	Yellow
Nitric acid (10-30%)	Red	Red	Yellow	Red	Orange	Red	Orange	Green	Black	Black	Green	Red	Red	Red	Red
Hydrogen sulfide	Green	Black	Green	Orange	Black	Black	Black	Green	Green	Green	Green	Green	Green	Green	Orange
Sulphuric acid	Yellow	Yellow	Yellow	Red	Red	Red	Orange	Yellow	Yellow	Yellow	Green	Green	Red	Orange	Red
Sea water	Orange	Green	Green	Orange	Yellow	Red	Red	Yellow	Yellow	Green	Green	Green	Green	Green	Green
Fresh water	Yellow	Green	Green	Green	Green	Red	Red	Green	Green	Green	Green	Green	Green	Green	Green
Ethyl alcohol	Green	Green	Green	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green
Methyl alcohol	Green	Green	Green	Yellow	Green	Yellow	Yellow	Green	Green	Green	Green	Green	Green	Green	Green

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Propyl alcohol															
Anhydrous ammonia															
Moist ammonia															
Ammonium nitrate															
Ammonium sulfate															
Carbon dioxide (dry)															
Sulphur trioxide (dry)															
Sulphur dioxide (dry)															
Gasoline															
Benzene															
Butane															
Kerosene															
Chlorine dry gas															
Liquid chlorine															
Colophony															
Exane															
Ethane															
Formaldehyde															
Freon															
Glycerin															
Aromatic hydrocarbons															
Hydrogen															
Sodium hydroxide															
Methane															
Methyl ethyl ketone															
Naphtha															
Oxygen															
Oxygen gas (cold)															
Oxygen gas (hot)															
Pentane															
Turpentine															
Urea															

	No aggression, excellent behavior
	Aggression light, good behavior
	Moderate aggression, unsuitable
	Aggression strong, not suitable
	Data not available

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Borosilicate glass

From the technical point of view, the most important chemical property of the borosilicate glass is the chemical inertness towards acidic or alkaline solutions. The only chemical compounds which may give rise to corrosion phenomena are hydrofluoric acid, concentrated solutions of sulphuric acid and combinations of caustic solutions with high pH and high temperatures.

Aluminum

Halogenated hydrocarbons in the presence of water can decompose giving rise to the corresponding acids (e.g. hydrochloric acid), which attack the natural oxide film destroying it. It's also possible the development of complex reactions starting from aluminum halides. The trend to reactivity is related to the stability of the halogen-bond organic radical. In each case, the corrosion problems occur at elevated temperatures, such as those of boiling of chemical compounds.

Stainless steel

Stainless steel AISI 304 and AISI 316L which are non-magnetic and are resistant to most organic and non-organic chemical attacks are the most commonly used in petrochemical environments.

Elements	**AISI 304**	**AISI 316L**
Amyl acetate	Good resistance	Excellent resistance
Benzoic acid	Very low resistance	Good resistance
Hydrobromic acid	Very low resistance	Very low resistance
Butyric acid	Low resistance	Good resistance
Chloroacetic acid	Very low resistance	Very low resistance
Fluorosilicic acid	Good resistance	Good resistance
Trichloroacetic	Acid Very low resistance	Very low resistance
Turpentine	Excellent resistance	Excellent resistance
Acetic anhydride	Very low resistance	Good resistance
Phthalic anhydride	Excellent resistance	Excellent resistance
Bauxite	Good resistance	Excellent resistance
Benzedrine	Good resistance	Good resistance
Sulfur Dioxide	Good resistance	Good resistance
Bromobenzene	Good resistance	Good resistance
Sodium cyanide	Excellent resistance	Excellent resistance
Chlorobenzene	Good resistance	Good resistance
Dry chloroform	Good resistance	Low resistance
Aluminum chloride	Very low resistance	Very low resistance
Ethyl chloride (dry)	Low resistance	Excellent resistance
Hydrogen chloride	Low resistance	Low resistance
Magnesium Chloride	Very low resistance	Low resistance
Phenol	Good resistance	Excellent resistance
Sodium phosphate (tribasic)	Excellent resistance	Excellent resistance
Aluminum hydroxide	Good resistance	Good resistance
Ammonium nitrate	Low resistance	Good resistance
Ethylene Oxide	Excellent resistance	Good resistance
Hydrogen peroxide	Low resistance	Good resistance

Propane	Excellent resistance	Excellent resistance
Sodium hydroxide	Low resistance	Low resistance
Carbon disulphide	Good resistance	Excellent resistance
Elements	**AISI 304**	**AISI 316L**
Toluene	Excellent resistance	Excellent resistance

Surface treatment of ferrous and non-ferrous metals

Materials that are usually used in petrochemical plants except for the stainless steels, which do not need further protective treatments, if properly selected for their installation, may require the need of surface treatment suitable to the type of possible corrosion present at the place of installation. Aluminum, for example, may require anodizing or other surface treatments to be protected against aggressive agents or painting treatments. Carbon steel, commonly indicated as "Iron", may require protective surface treatment such as electrolytic galvanizing, if the aggressiveness is slight and if the material will be installed in confined areas; hot-dip galvanized if installed in highly aggressive and outside areas, or require coating systems like electrostatic powder coatings.

Conclusions

The variables that could occur in the various cycles of the production process are many and not always predictable, certainly during the engineering phase of the project. Therefore it is critical to properly anticipate the particular corrosive agent(s) you may find at an early stage in the design process to maximize the longevity of the equipment selected and to maintain a safe working environment for the plant operators with regards to Ex equipment.