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INTRODUCTION

Scope

Corrosion is described as a material's destruction or deterioration as a result of its reaction with its surroundings. Some argue that the term should be limited to metals, yet corrosion engineers frequently have to consider both metals and non-metals when solving an issue. Ceramics, plastics, rubber, and other non-metallic materials are included in this guideline.

Corrosion is defined as the deterioration of paint and rubber due to sunshine or chemicals, the fluxing of a steelmaking furnace's liner, and the attack of a solid metal by another molten metal (liquid metal corrosion). With one important exception, corrosion is a natural and costly process of destruction similar to earthquakes, tornadoes, floods, and volcanic eruptions. While It can only watch as the foregoing processes of destruction unfold, corrosion can be avoided or at the very least controlled.

Regardless of multiple definitions, corrosion is essentially the outcome of interactions between materials and their surroundings. Prior to the 1960s, corrosion was exclusively applied to metals and their alloys, and it did not include ceramics, polymers, composites, or semiconductors.

Corrosion now refers to a wide range of natural and man-made materials, including biomaterials and nanomaterials, and is no longer limited to metals and alloys. Corrosion's scope corresponds to the dramatic advances in material development that have occurred in recent years.

Faraday (1791–1867) made the most significant contributions later, establishing a quantitative link between chemical action and electric current. The first and second laws of Faraday are used to calculate metal corrosion rates. At the turn of the nineteenth century, ideas for corrosion control began to emerge. Corrosion can happen quickly or slowly. Polythionic acid attacks sensitized 18-8 stainless steel in a matter of hours. Railroad tracks usually have minor rusting, but not enough to affect their performance over time.

The famed iron Delhi Pillar in India was built about 2000 years ago and is still in near-new condition. It stands 32 feet tall and has a diameter of 2 feet. However, it should be emphasized that it has largely been subjected to arid circumstances. Metal corrosion can be thought of as extractive metallurgy in reverse. Extractive metallurgy is largely concerned with extracting metal from ore and purifying or alloying it for application. The rusting of steel by water and oxygen produces a hydrated iron oxide, which is found in most iron ores. Although many other metals create oxides when it corrode, rusting is a word reserved for steel and iron corrosion.

GENERAL DESIGN CONSIDERATION

Corrosion is the degradation or disintegration of a material caused by chemical reactions with its surroundings. Some argue that the term should be limited to metals, yet corrosion engineers frequently have to consider both metals and non-metals when solving an issue. Ceramics, plastics, rubber, and other non-metallic materials are included in this book. Corrosion is defined as the degradation of paint and rubber due to sunshine or chemicals, the fluxing of a steelmaking furnace's liner, and the attack of a solid metal by another molten metal (liquid metal corrosion). Corrosion can happen quickly or slowly. Polythionic acid attacks sensitized 18-8 stainless steel very quickly.

Faraday (1791–1867) made the most significant contributions later, establishing a quantitative link between chemical action and electric current. The first and second laws of Faraday are used to calculate metal corrosion rates. At the turn of the nineteenth century, ideas for corrosion control began to emerge. Whitney (1903), based on electrochemical observation, offered a scientific basis for corrosion management.

It was discovered in the seventeenth century that iron corrodes swiftly in dilute nitric acid but is unaffected by concentrated nitric acid. In 1836, Schönbein demonstrated that iron could be rendered inactive. Based on his classical electrochemical theory, U. R. Evans was left to develop a current knowledge of the causes and control of corrosion in 1923.

It made a significant contribution to our current understanding of corrosion. In the reference section at the end of this chapter, the above modern corrosion pioneers have been identified with their famous works. Corrosion science and engineering has been an important aspect of engineering education around the world in recent years. Corrosion is a natural and expensive process of destruction such as earthquakes, hurricanes, floods and volcanic eruptions, with one major difference.

Even though it can only be silent spectators the above crushing process, corrosion can prevented or at least controlled. Several definitions of corrosion have been given and some of them are: Corrosion is the loss of metal surface integrity caused by exposure to reactive conditions.

a) Corrosion is the progressive deterioration of a metal caused by interactions between it and its surroundings.
b) Corrosion is a type of material degradation caused by chemical or biological processes.
c) Corrosion is reverse extractive metallurgy. Hematite, for example, is heated with carbon to produce iron. The life cycle of iron is completed when it corrodes and rusts. Hematite and rust have the same chemical make-up.
d) Corrosion is the degradation of materials caused by chemical reactions with their surroundings (Fontana).

Even though the definition is different, it could be observed that corrosion is essentially the result of interactions between materials and their environment. Until the 1960s, the term corrosion was only limited to metals and their alloys and rightly so does not combine ceramics, polymers, composites and semiconductors in its regime.

The term corrosion now includes all types of natural and man-made materials including biomaterials and nanomaterials, and not limited to metals and mix only. Corrosion scope consistent with revolutionary changes in materials developments witnessed in recent years. Corrosion is the destructive attack of a metal on the surroundings caused by a chemical or electrochemical interaction.

A) Breakdown of Spending in Corrosion

Petroleum, chemical, petrochemical, construction, manufacturing, pulp and paper and transportation (railway, automotive and aerospace industry) is the largest contributor for corrosion removal. Corrosion cost differ from one country to another. For example, in the US, the transportation sector is the largest sectors that contribute to corrosion after public utilities, whereas in oil producing countries, such as the Arab Gulf countries, petroleum and the petrochemical industry is the largest contributor to corrosion expenditure. The highway sector in the US alone covers 4.000.000 miles highways, 583,000 bridges, requiring corrosion remediation treatment.

Annual direct corrosion cost is estimated to be 8.3 billion American Dollars. Transport direct corrosion the sector is estimated at 29.7 billion US dollars. This includes the cost of corrosion of aircraft, transportation of hazardous materials, motor vehicles, carriages and ships.

In the oil sector, drilling pose a serious hazard to the equipment in the form of stress corrosion cracking, hydrogen induced hydrogen sulfide cracking and cracking. In US alone, this sector cost more than 1.2 billion American Dollars. The fees are astounding in the major oil producing countries such as Saudi Arabia, Iran, Iraq and Kuwait. Corrosion direct costs for the aircraft industry exceeds 2.2 billion US dollars.

The effects of corrosion on defense equipment are significant. The rotor blade damage in helicopters caused by desert sand was a severe problem during the Gulf War. The blade thickness was lowered to 2–3 mm in some cases. Corrosion scientists and engineers faced a new issue with desert erosion–corrosion. Defense equipment storage is a severe issue in corrosive settings like Saudi Arabia, Malaysia, and Southeast Asia.

Humidity is the number one killer of military equipment. Defense equipment storage necessitates low humidity, little rain, alkaline soil, no dust storms, no marine environment, and a minimum amount of dust particles. Corrosion appears everywhere, and there is no industry or home where it does not penetrate, as seen by the preceding overview, and engineers and scientists must be prepared to battle this problem.

B) Corrosive Environment

Corrosion cannot be characterized without taking into account the surrounding environment. To some extent, all environments are corrosive. The list of typical corrosive environments is as follows :

1) Air and humidity.
2) Fresh, distilled, salt and marine water.
3) Natural, urban, marine and industrial atmospheres.
4) Steam and gases, like chlorine.
5) Ammonia.
6) Hydrogen sulfide.
7) Sulfur dioxide and oxides of nitrogen.
8) Fuel gases.
9) Acids.
10) Alkalies.
11) Soils.

As a result, corrosion is a powerful force that damages economies, depletes resources, and causes costly and untimely plant, equipment, and component failures. Almost all environments are corrosive to some degree. Some examples is air and humidity; fresh, distilled, salt, and mine water; rural, urban, and industrial atmosphere; steam and other gases such as chlorine, ammonia, hydrogen sulfide, sulfur dioxide, and fuel gases; mineral acid such as chlorides, sulfates, and nitrates; organic acids such as naphthenic, acetate, and formic; alkali; land; solvent; vegetable oil and petroleum; and various food products.

In general, inorganic materials are more corrosive than organic. For example, corrosion of petroleum industry is more caused by sodium chloride, sulfur, chloride, and sulfate acid, and water, rather than oil, naphtha, or gasoline.

Higher temperatures and pressures in the chemical process industries have enabled new processes or improvements to existing ones, such as higher yields, faster speeds, and cheaper production costs. This holds true for all forms of energy generation, including nuclear power, missiles, and a variety of other ways and procedures. Corrosion is more likely to occur at higher temperatures and pressures. Many modern activities would not be practicable or cost-effective if corrosion-resistant materials were not used.

C) Corrosion Science and Corrosion Engineering

The term science includes theory, law, and explanations of phenomena confirmed by intersubjective observations or experiments. For example, explanations of various forms corrosion, corrosion rate and mechanism corrosion is provided by corrosion science. The science of corrosion is knowing why corrosion. The term engineering, as opposed to science, is directed at action for a specific purpose under a set of directions and rules for action and in that well-known phrase is knowing the way. Corrosion engineering is the application of the evolving principles of corrosion the science of minimizing or preventing corrosion.

Corrosion engineering involves designing corrosion prevention schemes and implementation of certain codes and practices. Corrosion prevention measures, such as cathodic protection, designing to prevent corrosion and structural coating included in the corrosion engineering regime. It is keep married to produce new and better protection method over time.

Corrosion engineering is the science and art of preventing or controlling corrosion damage in a cost-effective and safe manner. Corrosion engineers must be familiar in the following areas: corrosion practices and concepts; chemical, metallurgical, physical, and mechanical properties of materials corrosion testing the nature of corrosive environments; material availability and manufacturing; computers and design.

It must also possess the standard characteristics of engineers: a strong sense of human connections, honesty, the ability to think and analyze, an understanding of the necessity of safety, common sense, organization, and, most importantly, a strong sense of economics. Because corrosion effectively inhibits or hinders the activities of metals, plants, and equipment, adequate steps must be taken to reduce function loss or inefficiency.

D) Corrosion Damage

Even catastrophic failures can occur, leading in massive financial losses and human tragedy. Researchers from all over the world have been studying the mechanisms of corrosion and the corrosion resistance qualities of various metals and alloys in order to utilise them in a variety of applications. Attempted to control corrosion at the same time by inventing superior alloys, modifying the microstructure of alloys, applying corrosion-resistant coatings, changing the atmosphere, and so on. Their major purpose is to extend the material's useful life. All of these initiatives are focused at decreasing corrosion's impacts.

- Loss of mechanical integrity, structural failure, or damage to metal components due to reduced metal thickness.
- Serious injury or death as a result of structural failure or damage (eg, airplanes, cars, bridges, etc.).
- Financial losses as a result of industrial plant closures.
- Economic loss as a result of fluid contamination caused by vessel deterioration.
- Pipe leaks causing harmful substances to be released into the environment.
- Solid corrosion products cause mechanical damage to valves, pumps, and other equipment, as well as pipe blockage.
- Additional costs for corrosion-resistant equipment redesign and maintenance of deteriorated components.
- Metals lose technical qualities such as electrical conductivity, surface reflectance, and fluid movement over the surface, among others.

In the next paragraphs, some of the harmful impacts of rusting are discussed. In some circumstances, though, rusting is advantageous or desirable. Chemical machining, often known as chemical milling, is commonly utilized in aviation and other applications. Unmasked parts are exposed to acid, which dissolves any surplus metal. This procedure is used when it is more cost-effective or when the parts are difficult to machine using more traditional methods. Anodizing aluminum is another positive corrosion procedure that provides a better and more uniform appearance as well as a corrosion-protective coating on the surface.

1. Appearance

Because rusting surfaces are unattractive, automobiles are painted. Corroded and rusty plant equipment would provide a negative impression on the observer. It would be cheaper to make the metal thicker in the first place (corrosion allowance) than to apply and maintain a paint layer in many rural and urban environments. Building outside surfaces and trim are frequently made of stainless steel, aluminum, or copper for aesthetic reasons. Restaurants and other commercial facilities are no exception. These are cases where cost versus service life is not the deciding issue.

2. Maintenance and Operating Cost

The use of corrosion-resistant construction materials can result in significant cost reductions in a variety of operations. In this regard, one example is timeless. A chemical facility saved over $10,000 per year by simply changing the bolt material on some equipment from one alloy to another that was more robust to the conditions. This change was really inexpensive. In another case, a waste acid recovery plant was forced to operate in the red for several months until a significant corrosion issue was resolved. This factory was designed to address a significant waste disposal issue. Cathodic protection can reduce leak rates in existing underground pipes to almost zero, resulting in significant cost savings.

In many cases, close collaboration between the corrosion engineer, process and design professionals before the plant is completed can eliminate or significantly decrease maintenance expenses. Small adjustments in the process can occasionally lessen the corrosiveness of plant liquors without impacting the process itself, allowing less expensive materials to be used. These modifications can typically be done after the facility is up and running, but proactive steps are preferable. Corrosion problems may often be engineered out of equipment, and the best time to do it is during the plant's initial design.

3. Plant Shutdown

Plants are frequently shut down or portions of processes are halted due to unforeseen corrosion failures. These shutdowns are sometimes induced by corrosion with no change in process conditions, but can also be triggered by modifications in operating practices that are mistakenly thought to be incapable of worsening the corrosive conditions. It's amazing how often a small adjustment in technique or the addition of a new element may drastically affect corrosion properties. One example is the manufacture of a critical chemical molecule for national defense.

The temperature of the cooling medium in a heat-exchanger system was lowered to boost production, and the time required each batch was reduced. Lowering the cooling medium's temperature, on the other hand, resulted in more severe thermal gradients across the metal wall. As a result, the metal experienced increased strains. The plant was shut down and production was delayed due to stress corrosion cracking of the vessels.

Plant corrosion monitoring can assist prevent unexpected corrosion failure and plant shutdown. This can be accomplished by inspecting corrosion specimens that are continuously exposed to the process or by employing a corrosion probe that continuously records the corrosion rate. Equipment inspections during scheduled downtimes can assist prevent unplanned shutdowns.

4. Contamination of Product

In many circumstances, a product's market worth is directly proportional to its purity and quality. In the production and processing of transparent polymers, pigments, foods, pharmaceuticals, and semiconductors, contamination control is critical. A little quantity of corrosion, which introduces particular metal ions into the solution, can produce catalytic decomposition of a product in some instances, such as in the manufacture and transportation of concentrated hydrogen peroxide or hydrazine. When it comes to product contamination or degradation, the equipment's life is usually not a major consideration. Ordinary steel can last for many years, but more expensive materials are chosen since corrosion is undesirable in terms of product quality.

5. Loss of valuable products

Because sulfuric acid is such a cheap material, minor leaking to the drain is not a major worry. However, if a material worth many dollars per gallon is lost, immediate action is required. Minor uranium compound or solution losses are dangerous and expensive. In such instances, a more expensive design and superior building materials are fully justified.

6. Effect on Safety and Reliability

Handling hazardous materials such as: such as toxic gases, hydrofluoric acid, concentrated sulfuric acid and nitric acid, explosive and flammable substances, radioactive substances, and chemicals at high temperatures and pressures require the use of construction materials which minimizes corrosion failure. Stress corrosion on separating metal walls the fuel and oxidizer in the missile can cause premature mixing, which can resulting in millions of dollars in losses and personal injury.

Failure minor components or controls may result in complete failure or destruction structure. Equipment corrosion can cause some quite dangerous compounds be explosive. No construction material savings desirable if safety is at stake. Other health considerations are also important such as contamination drinking water.

Corrosion products can make equipment sanitation more difficult. An interesting example here involves milk and other dairy products plant. Straight chromium stainless steel satisfies in old factory where most of the equipment is disassembled and sanitized with "pans" technique. The new plant uses cleaning and sanitizing where it is needed: more corrosive chemicals, especially those associated with chloride and ions hole. This solution is circulated through the system without fetching it separated thereby saving a lot of man-hours.

This progress requires more usage pit-resistant stainless steels, such as type 316 containing nickel and molybdenum. Corrosion also plays an important role in the medical metals used for the hip joints, screws, plates, and heart valves. Reliability, of course, is very important. An unusual experience emphasized important safety considerations. A large carbon steel vessel was cleaned, washed, and put in for maintenance. A worker experiences shortness of breath and die because the air becomes deprived of oxygen (approximately \% 02) the situation created by rapid rust of empty steel vessels. If the second hole has been opened, the natural wind will change the air.

7. Product Liability

There is a significant and alarming trend in the country to shift the blame and legal liability for every item or piece of equipment that fails due to corrosion or for any other reason on the manufacturer or manufacturer. According to reports from the US Department of Commerce, product liability claims have surpassed inflation and are reaching medical mall levels. Practice of insurance claims.

All of this means that a product's manufacturer or producer must ensure that it is made of appropriate materials, under strict quality control, and to a design that is as safe as feasible, with thorough inspection. The corrosion engineer must be certain that failure will not occur in the real world, as well as be aware of the legal implications. The passage of time is not a deciding factor; lawsuits were filed after a bridge that had been in use for nearly 40 years failed.

E) Functional Aspects of Corrosion

Metals, plants, and equipment may be seriously harmed by corrosion in the following ways:

1) Impermeability: Environmental constituents must not be allowed to enter pipes, process equipment, food containers, tanks, etc. to minimize the possibility of corrosion.

2) Mechanical strength: Corrosion should not affect the capability to withstand specified loads, and its strength should not be undermined by corrosion.

3) Dimensional integrity: Maintaining dimensions is critical to engineering designs and should not be affected by corrosion.

4) Physical properties: For efficient operation, the physical properties of plants, equipment and materials, such as thermal conductivity and electrical properties, should not be allowed to be adversely affected by corrosion.

5) Contamination: Corrosion, if allowed to build up, can contaminate processing equipment, food products, drugs and pharmaceutical products and endanger health and environmental safety.
6) Damage to equipment: Equipment adjacent to one which has suffered corrosion failure, may be damaged.

Recognizing that corrosion can effectively block or damage the operations of metals, plants, and equipment, adequate precautions must be taken to reduce function loss or inefficiency. To understand corrosion engineering properly, keep in mind that the choice of a material is influenced by a variety of elements, including its corrosion behavior.

Figure 1 depicts some of the characteristics that influence structural material selection. Although, mostly concerned with the corrosion resistance of various materials, other factors frequently influence the ultimate decision. In architectural applications, however, appearance is frequently the most significant factor. Fabricability must be examined as well, which includes the ease of forming, welding, and other mechanical operations.

Even if the material is chosen for its corrosion resistance, the mechanical behavior or strength is important in engineering applications and must be considered. Finally, the availability of many extremely resistant materials, such as gold, platinum, and some super-alloys, is sometimes a deciding factor in whether or not it will be employed. The delivery time for some of the unusual metals and alloys is often prohibitive. The importance of corrosion resistance engineering cannot be overstated. Platinum or glass can provide complete corrosion resistance in almost all media, but these materials are not practicable in most situations.

It is impossible to overstate the importance of corrosion resistance engineering. Platinum or glass can provide complete corrosion resistance in almost all media, but these materials are not practicable in most situations. The spontaneous direction of a reaction is determined via thermodynamic studies and computations. Thermodynamic simulations can establish whether or not corrosion is theoretically possible in the instance of corrosion.

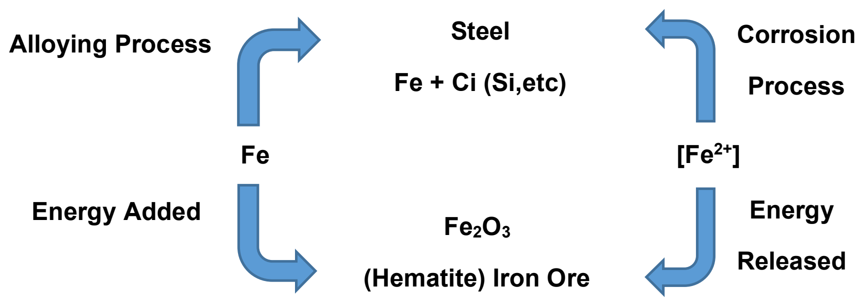

Figure 1 : Corrosion Cycle

DEFINITIONS

Aluminium - is a chemical element with the symbol Al and atomic number 13. Aluminium has a density lower than those of other common metals, at approximately one third that of steel.

Aluminium Corrosion - Aluminum has a very high affinity to oxygen. When a new aluminum surface is exposed in the presence of air or any other oxidizing agent, it quickly develops a thin, hard film of aluminum oxide (or hydrated oxide in non-stagnant water).

An alloy - is a mixture of chemical elements of which at least one is a metal. Unlike chemical compounds with metallic bases, an alloy will retain all the properties of a metal in the resulting material, such as electrical conductivity, ductility, opacity, and luster, but may have properties that differ from those of the pure metals, such as increased strength or hardness.

Anodic protection (AP) - otherwise refer as Anodic Control is a technique to control the corrosion of a metal surface by making it the anode of an electrochemical cell and controlling the electrode potential in an zone where the metal is passive.

Atmospheric - An atmosphere (atm) is a unit of measurement equal to the average air pressure at sea level at a temperature of 15 degrees Celsius (59 degrees Fahrenheit).

Atmospheric Corrosion - Atmospheric corrosion is the degradation of materials caused by air and the pollutants contained in the air. It can be precisely defined as an electrochemical process which depends upon the presence of electrolyte which may be rain, dew, humidity or melting snow.

Beryllium - is a chemical element with the symbol Be and atomic number 4. It is a steel-gray, strong, lightweight and brittle alkaline earth metal. It is a divalent element that occurs naturally only in combination with other elements to form minerals.

Beryllium Bronze - Copper-based alloy with 0.4 to 2.1% beryllium, optionally alloyed with lower levels of cobalt, nickel, or silicon, and client specific alloys with other elements. Otherwise, with typical impurities.

Beryllium copper (BeCu) - is also known as copper beryllium (CuBe), beryllium bronze and spring copper, is a copper alloy with 0.5–3% beryllium, but can contain other elements as well. Beryllium copper combines high strength with non-magnetic and non-sparking qualities.

Cadmium - is a chemical element with the symbol Cd and atomic number 48. This soft, silvery-white metal is chemically similar to the two other stable metals in group 12, zinc and mercury.

Cast iron - is a class of iron–carbon alloys with a carbon content more than 2%.[1] Its usefulness derives from its relatively low melting temperature.

Cathodic protection - is a technique used to control the corrosion of a metal surface by making it the cathode of an electrochemical cell.[1] A simple method of protection connects the metal to be protected to a more easily corroded "sacrificial metal" to act as the anode.

Chromite - is a mineral composed of natural oxide of ferrous iron and chromium, with varying amounts of magnesium and aluminum substituting for the iron and chromium.

Coating - is a covering that is applied to the surface of an object, usually referred to as the substrate. The purpose of applying the coating may be decorative, functional, or both.[1] Coatings may be applied as liquids, gases or solids e.g. Powder coatings.

Conductor - conducts electricity since it offers little or no resistance to the flow of electrons, thus leading to a flow of electrical current. Typically, metals, metal alloys, electrolytes and even some nonmetals, like graphite and liquids, including water, are good electrical conductors.

Cooling tower - is a device that rejects waste heat to the atmosphere through the cooling of a coolant stream, usually a water stream to a lower temperature. Cooling towers may either use the evaporation of water to remove process heat and cool the working fluid to near the wet-bulb air temperature or, in the case of *dry cooling towers*, rely solely on air to cool the working fluid to near the dry-bulb air temperature using radiators.

Corrosion - Corrosion is a natural process that converts a refined metal into a more chemically stable oxide. It is the gradual destruction of materials (usually a metal) by chemical or electrochemical reaction with their environment.

Corrosion Engineering - is the field dedicated to controlling and preventing corrosion.

Corrosion fatigue - Corrosion fatigue occurs when a metal fractures prematurely as a result of simultaneous corrosion and repeated cycle loading at lower stress levels than would be required in the absence of a corrosive environment.'

Copper - is a chemical element with the symbol **Cu** (from Latin: *cuprum*) and atomic number 29.

Copper corrosion - is the corrosion of materials made of copper or copper alloys. When exposed to the atmosphere, copper oxidizes, causing normally bright copper surfaces to tarnish.

Crevice Corrosion - This is a localized form of corrosion, caused by the deposition of dirt, dust, mud and deposits on a metallic surface or by the existence of voids, gaps and cavities between adjoining surfaces.

De-aluminfization - is the specific process of the leaching of aluminum in aluminum-bronze (or other Cu-Al) alloys. Aluminum bronze is commonly used in seawater or brackish water applications because of its good resistance to corrosion and erosion.

De-nickelification - refers to an occurrence of corrosion where nickel is extracted by leaching from its alloys. This process occurs in copper-nickel alloys that have undergone significant exposure to seawater or other aquatic environments.

Dezincification - is a form of de-alloying. As the phenomenon was first observed in brass in which zinc separated by dissolution from copper, the term dezincifications still used.

Distillation - or classical distillation, is the process of separating the components or substances from a liquid mixture by using selective boiling and condensation.

Electron - Electrons belong to the first generation of the lepton particle family, and are generally thought to be elementary particles because they have no known components or substructure.

Erosion corrosion - is a degradation of material surface due to mechanical action, often by impinging liquid, abrasion by a slurry, particles suspended in fast flowing liquid or gas, bubbles or droplets, cavitation, etc.

Fretting - is a phenomenon of wear which occurs between two mating surfaces subjected to cyclic relative motion of extremely small amplitude of vibrations. Fretting appears as pits or grooves surrounded by corrosion products.

Galvanic corrosion - occurs when two metals with different electrochemical potentials or with different tendencies to corrode are in metal-to-metal contact in a corrosive electrolyte.

Graphite - is a crystalline form of the element carbon. Graphite occurs naturally and is the most stable form of carbon under standard conditions.

Gold - is a chemical element with the symbol **Au** (from Latin: *aurum*) and atomic number 79, making it one of the higher atomic number elements that occur naturally. It is a bright, slightly orange-yellow, dense, soft, malleable, and ductile metal in a pure form.

Heat exchanger - is a system used to transfer heat between a source and a working fluid. Heat exchangers are used in both cooling and heating processes.

Hydrogen damage -is the generic name given to a large number of metal degradation processes due to interaction with hydrogen atoms. Note that molecular gaseous hydrogen does not have the same effect as atoms or ions released into solid solution in the metal.

Insulation - is a general term used to describe material that creates barriers for transmission of electricity, heat, moisture, shock or sound between insulated surfaces of adjacent bodies. These materials could be insulating heat, cold, electricity, sound or radiation.

Intergranular Corrosion - It has been defined commonly as a form of localized attack on the grain boundaries of a metal or alloy in corrosive media, which results in the loss of strength and ductility.

Iron - It is a metal that belongs to the first transition series and group 8 of the periodic table. It is, by mass, the most common element on Earth, right in front of oxygen (32.1% and 30.1%, respectively), forming much of Earth's outer and inner core. Chemical element with symbol **Fe** (from Latin: *ferrum*) and atomic number 26.

Manganese - is a chemical element with the symbol **Mn** and atomic number 25. It is a hard, brittle, silvery metal, often found in minerals in combination with iron. Manganese is a transition metal with a multifaceted array of industrial alloy uses, particularly in stainless steels.

Metal - is a material that, when freshly prepared, polished, or fractured, shows a lustrous appearance, and conducts electricity and heat relatively well. Metals are typically malleable (they can be hammered into thin sheets) or ductile (can be drawn into wires).

Monel - is a group of alloys of nickel (from 52 to 67%) and copper, with small amounts of iron, manganese, carbon, and silicon. Monel is not a cupronickel alloy because it has less than 60% copper.

Nickel - is a chemical element with symbol **Ni** and atomic number 28. It is a silvery-white lustrous metal with a slight golden tinge. Nickel is a hard and ductile transition metal.

Nickel silver - also known as German silver, Argentann, paktong, new silver, nickel brass, or alpacca (or alpaca), is a copper alloy with nickel and often zinc.

Oxygen - is the chemical element with the symbol **O** and atomic number 8. It is a member of the chalcogen group in the periodic table, a highly reactive nonmetal, and an oxidizing agent that readily forms oxides with most elements as well as with other compounds.

Phosphor bronze - or tin bronze, is a bronze alloy that contains a mixture of copper with 0.5-11% tin and 0.01-0.35% phosphorous. Phosphor bronze alloys are primarily used for electrical products because they have superb spring qualities, high fatigue resistance, excellent formability, and high corrosion resistance

Phosphor - is a substance that exhibits the phenomenon of luminescence; it emits light when exposed to some type of radiant energy.

Pitting corrosion or pitting - is a form of extremely localized corrosion that leads to the random creation of small holes in metal. The driving power for pitting corrosion is the depassivation of a small area, which becomes anodic (oxidation reaction) while an unknown but potentially vast area becomes cathodic (reduction reaction), leading to very localized galvanic corrosion.

Platinum - is a chemical element with the symbol **Pt** and atomic number 78. It is a dense, malleable, ductile, highly unreactive, precious, silverish-white transition metal. Its name originates from Spanish *platina*, a diminutive of *plata* silver.

Red Brass - is 85% copper and 15% zinc. Red brass is a single phase alloy with Face Centered Cubic structure, ductile and nearly the color of gold.

Stress corrosion - also known as stress corrosion cracking, is a type of corrosion that occurs due to the simultaneous action of a corrodent and a sustained tensile stress. This mechanism is characterized by corrosion in the microscopic granular composition of a metal's surface.

Tin - is a chemical element with the symbol **Sn** (from Latin: *stannum*) and atomic number 50. Tin is a silvery-coloured metal.

Titanium - is a chemical element with the symbol **Ti** and atomic number 22. Found in nature only as an oxide, it can be reduced to produce a lustrous transition metal with a silver color, low density, and high strength, resistant to corrosion in sea water, aqua regia, and chlorine.

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