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PHENOMENON OF CORROSION AND THE INDUSTRIAL SAFETY

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ABSTRACT

The problem of corrosion has taken nowadays a considerable importance considering the great use more and more of metals and alloys in our modern life. From the economic point of view and safety, the corrosion is a real thread. The replacement of corroded material composes for the industrie a financial burden which is very high. I taws estimated that more than 100 milliards of dollars constituting the yearly lusts caused by the corrosion in the American economy. The corrosion also can be translated by a modification and weakening of mechanical properties of corroded materials, consequentially it can’t fill in all safety its functions to which it is distinated. The aim of this study is to evident links which existed between corrosion and safety of materials and persons.

Keywords : corrosion, economy, industry, safety, investigations.

INTRODUCTION

The phenomenon of corrosion is a problem area or more precisely the interface between a metal and a corrosive liquid or gas. In the absence of industrial pollution, the atmosphere is composed mainly of moist air containing carbon dioxide and sometimes dissolved sodium chloride in suspension under these conditions metallic materials including iron and most commonly used properties are deteriorating and will be subject to corrosion (Battle Institute, 1980). The corrosion phenomenon has a multidisciplinary character, knowledge of chemical, electricity and materials science is essential to fully understand and therefore predict. In this work we want to show the close relationship between corrosion and safety of property and persons, to give the phenomenon of corrosion his well-deserved place in the Science of Risk.

PRINCIPLE OF CORROSION

All materials degrade at a rate more or less. Table 1 gives an overview of the usual extreme corrosion rate.

Table 1: Speeds comparative corrosion (Battle Institute, 1980).

Conditions	Corrosion rate
Stainless steel in air	nm / year
Stainless steel in freshwater	µm / year
Stainless steel in seawater	mm / year
Stainless steel in hydrochloric acid	cm / year

The reactions that occur between a material and its environment are essentially 3 types:

a. Corrosion of metals in aqueous (wet corrosion).
b. Oxidation of metals in a gaseous medium dry, often at high temperature (drycorrosion).
c. Chemical reactions that cause degradation of plastics and ceramics. This latter type of corrosion is not addressed in this work.

Wet corrosion

The corrosion of metals in aqueous media is essentially an electrochemical phenomenon of nature, in that it involves reactions between ions and electrons. When plunging a metal (eg iron) in an acid that contains no dissolved oxygen, there occurs a reaction between iron and hydrogen ions from the acid solution and the reaction can be written

$$Fe + 2H^{+} \longrightarrow Fe^{2+} + H_2 \uparrow \qquad (1)$$

We can decompose reaction (1) in 2 separate reactions

$$\text{Anodic reaction} \quad Fe \longrightarrow Fe^{2+} + 2e \qquad (2)$$

$$\text{Cathodic reaction} \quad 2H^{+} + 2e \longrightarrow H_2 \uparrow \qquad (3)$$

Figure 1 shows schematically the process of dissolution of iron in acid medium. A metal subjected to such an attack is called dual electrode, because it is simultaneously the seat of an anodic and a cathodic reaction.

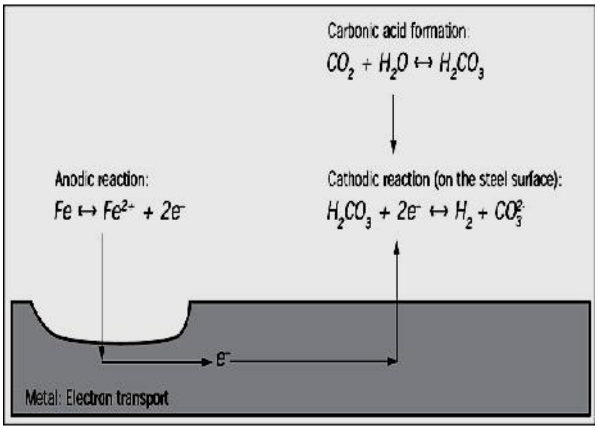


Figure1 : Schematic of dissolution of iron in acidic

All anodic reactions are of the form of reaction (2) :

$$M \longrightarrow M^{n+} + ne \quad (4)$$

Depending on the environment in which corrosion occurs, ie the type of electrolyte, its concentration of hydrogen ions (or pH) and dissolved oxygen, several cathodic reactions can take place, which are the main data below Acidic (pH <7) deaerated

$$2H^+ \longrightarrow 2e + H_2 \quad (5)$$

Acidic (pH <7) containing dissolved oxygen

$$O_2 + 4H^+ + 4e \longrightarrow 2H_2O \quad (6)$$

Neutral or alkaline (pH 7) containing dissolved oxygen

$$O_2 + 2H_2O + 4e \longrightarrow 4OH^- \quad (7)$$

Reduction of metal ions

$$M^{n+} + ne \longrightarrow M \quad (8)$$

Dry corrosion

The dry corrosion causes the metal back to their natural state, as the case of oxides and sulphides

$$M + O_2 \longrightarrow \text{oxides} \qquad (9)$$

$$M + S_2 \longrightarrow \text{sulphides} \qquad (10)$$

The dry corrosion of metals is a reaction between them and the gas around them. This reaction is an oxidation. In most cases, the oxygen in the air combines with the metal atoms to form oxides, sulfur oxidizing atmospheres (SO2) by cons, the corrosion products are sulphides. Finally, ataque may also be due to halogens (Cl, Br and I) and combustion atmospheres (CO, CO2, H2O, etc..). This type of corrosion causes problems including serviceability at temperatures well above room temperature.

ANALYSIS AND DISCUSSION

This section is devoted to a detailed analysis of various examples of industrial accidents caused mainly by corrosion, in order to highlight the relationship between corrosion and industrial safety.

Case1

In 1975, there’s been an explosion in a foundry in Scunthorpe in England Appleby-Frodingham Steelworks,(Scunthorpe, England ,1975). Figure 2 shows a general view of the molding shop devastated by the explosion, the picture is taken 60 hours after the incident.

Result: 12 dead over huge property damage

Cause: Corrosion

To understand the incident, we must describe the entire process: By Blast furnace top (Figure 5), we introduce iron ore, fluxes and coke. It blows hot air (950 °C - 1000 °C) inside through the nozzles (Fig. 6), the nozzles are cooled by circulating cold water. On leaving the blast furnace hot metal reaches the mold shop located a few meters in large ladles on the car, dubbed "Torpedo" (figure 3 and figure 4). It is in the cooling system of nozzles that there has been a failure due to corrosion. The buffer (Figure 8) brass (an alloy of Cu-Zn) screwed to the nozzle assembly 13 No.2 (Figure 7) has corroded, leaving hundreds of liters of water escape inundated for the entire workshop. Half of the 175 tons of liquid iron (at a temperature of 1500° C) already paid in the Torpedo 35 m long and 5 m internal diameter, exploded after coming into contact with son chemin à l'intérieur de la poche et en contact avec le métal liquide, l'eau s'évapore et créant ainsi une pression énorme à l'intérieur de la poche qui s'éclate.

CONCLUSIONS AND RECOMMENDATIONS

The corrosion of the buffer (Figure 8) was produced by brass dezincification; phenomenon that occurs when the Zn content exceeds 15%. In this case, the piece becomes poorer in Zn from the surface, giving a mass of copper porous, brittle and weak. The brass (up to 33% Zn) containing arsenic (0.04%) are known for their resistance to this type of corrosion. The Cupronickel (70% Cu - 30% Ni) are even more resistant to corrosion by pitting.

Figure 2 : Overview of the Molding workshop devastated by the explosion, photograph 60 hours after the incident

Case 2

A catastrophic failure occurred in 1984 in a refinery in the USA (C.M.Schillmoller, 1986), has resulted in an explosion, caused by the rupture of an amine absorber.

Result: 17 dead more property damage exceeding $ 500 million.

Cause: stress corrosion.
The cause of this incident, after investigation, has been attributed to stress corrosion under the action of the amines. These are used to remove acids from

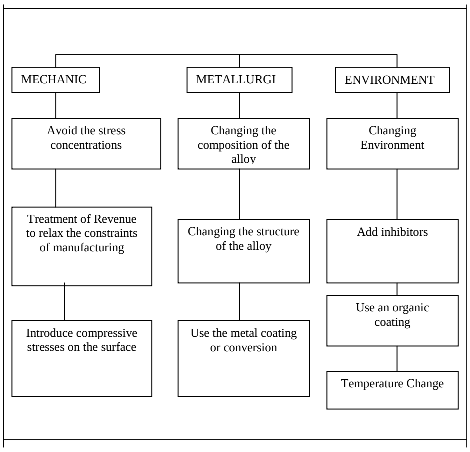
hydrocarbons, the alkanolamines were used to remove hydrogen sulfide H_2S and carbon dioxide CO_2 (which are acids) of oil since the 50s, Figure 9 illustrates a typical process of desulfurization. The canister has been in service for 14 years before the explosion. The elimination of these gases is Undesirable hydrocarbon absorption in a basic solution (15% monoethanolamine, MEA). The pure amine solutions (without caustic) does not cause stress cracking. But when additions of diluted caustic, used to prevent contamination of MEA by organic acids are made, they cause stress corrosion. Figure 10 shows the relationship between temperature and the concentration of NaOH to cause cracking. Note how a concentration of 30% to 135 degrees F (57 ° C) is more susceptible to stress corrosion cracking than 5% at 200 º F (93 ° C), or 15% to 180F(82°C). .

The conditions in the absorber was broken, probably contributed to the cracking of hydrogen as the main cause of the disaster rather than cracking the amino alkaline solution at temperatures below 135° F (57° C). Metals these techniques constituted absorbers, regenerators, etc.., operating in such conditions are susceptible to hydrogen embrittlement. It penetrates into the steel to form atomic broadcast, creating cracks.

Remedies

Table 2 summarizes us the steps to the control of stress corrosion. It is also recommended to keep the concentration of caustic under 5% - 10% and temperature of steam in the boiler below 300° F (149°C). The cracks due to stress corrosion are difficult to detect with ultrasound and penetrating. For this, it is advisable to inspect areas of welds by magnetic particle method.

Table 2: The control of stress corrosion



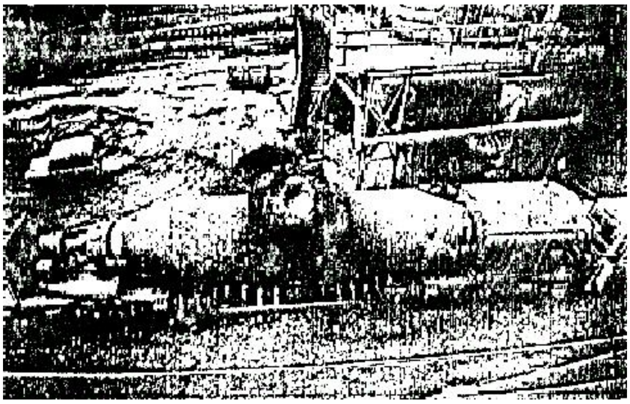


Figure 3: The Torpedo ladle in operation before the break

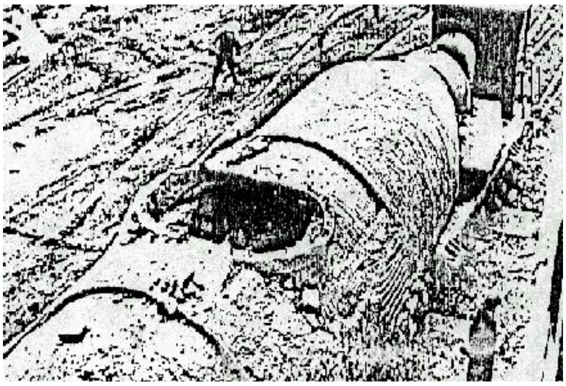


Figure 4: The Torpedo photographed just after the explosion

The stress corrosion results in the appearance of cracks under the effect of stress and environment are not necessarily aggressive in the absence of this constraint. It still is, for each system, associated with the presence of a specific corrosive environment, Table 3 gives us different environments can cause stress corrosion.

Table 3: Examples of environments that can cause stress corrosion (Perry, 1982; Turner,1989)

Metal / Alloy	Environment / Effect
Al and Light Alloys Brasses (Cu-Zn) Carbon Steels Steels Al alloys Magnesium alloys Titanium Alloys Mild steel Pb	Water with or without chlorine ions Ammonia solution and the mercurous nitrate embrittlement due to the presence of caustic (NaOH) Media containing chlorine ions And hot concentrated alkaline solutions Solutions of Pb acetate

The media containing chloride ions, even at trace levels are dangerous, just a concentration of 5 × 10-6 NaCl in water at 80 ° C to cause corrosion of 18 / 8 (steel stainless containing 18% Cr 8% Ni) subjected to a voltage not exceeding 15 N / cm ². A stainless steel is very effective against attack by hydrogen, but in a caustic environment, it can crack under stress at temperatures above 250 ° F (121° C) with concentrations of 30% to 300° F (149° C) for more dilute systems.

Case 3

In 1985, the roof of a pool of 200 tons (in Switzerland) collapsed killing 12 people. After review, it was found that the disaster was the result of stress corrosion of stainless steel brackets supporting the roof. All conditions were ripe for the stress corrosion, the action of stress since the hook is turned on and the action of specific corrosive environment. In this case, it is the chlorine ions in the atmosphere from the pool certainly treated water from the pool (Battle Institute, 1989)

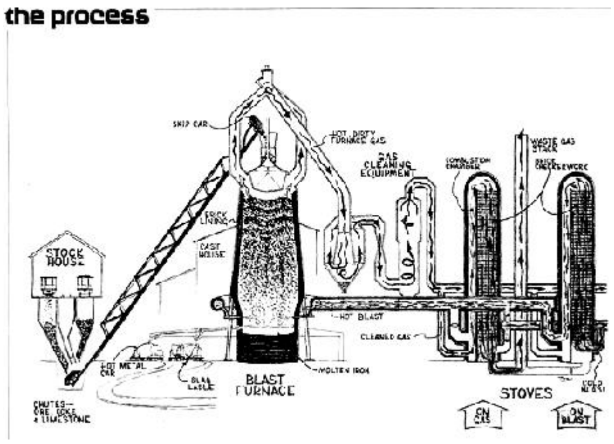


Figure 5: Diagram illustrating the Blast Furnace and its auxiliary facilities

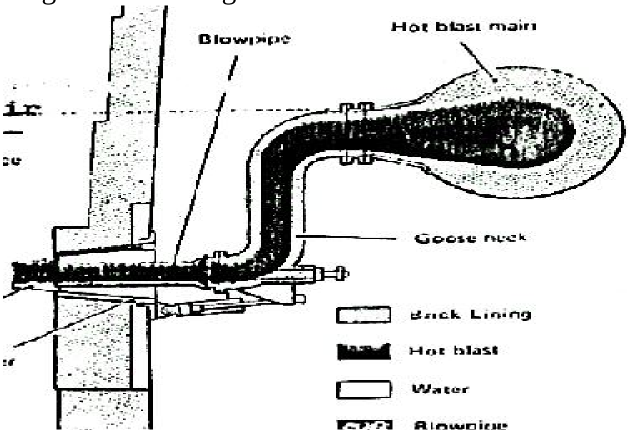


Figure 6: A section of the Blast Furnace showing the nozzle of the hot air system Coo

Case 4

In 1967 (December 15), the Bridge "Point Pleasant" in Ohio, s "collapse. The investigation indicates that the cause of this accident is once again stress corrosion (Highway accident report 1971)A crack of 2.5 mm depth was developed after a bar of the bridge structure. The incident has caused the death of46people. Dorlot and al. (1986) showed that defects in the material could act as stress concentrators and thus amplify the local stress, it can then reach value equal to the theoretical value without the value of the applied stress is very high. In this case, the crack of 2.5 mm has played the role of stress concentra

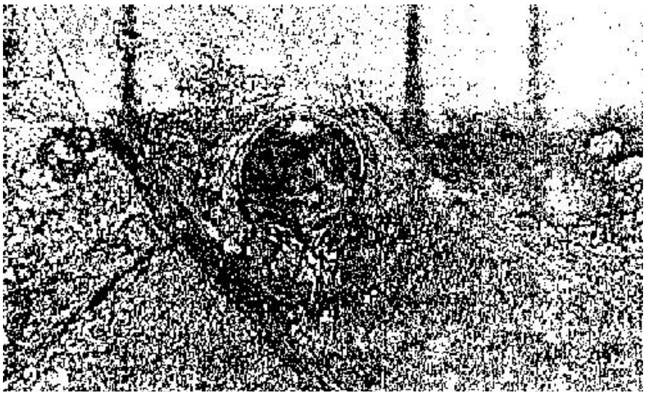


Figure 7: Section showing the nozzle orifice through which water had escap

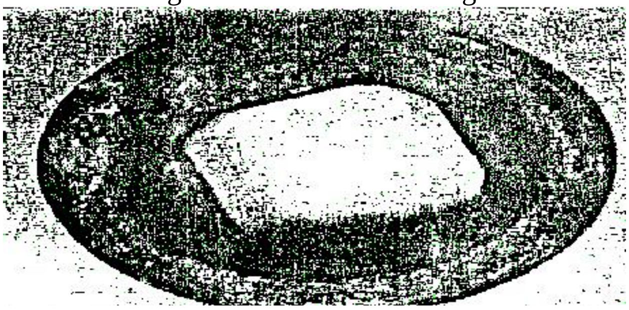


Figure 8: Tampon brass corrodes causing leakage of water from the cooling sy

Case 5

In 1988, corrosion was responsible for damage caused to a Boeing 737 Tawainnais. The aircraft was used for transporting fish in plastic bags containing seawater. Salt water is very corrosive, it had done its work, one of the doors of the aircraft affected by corrosion is depressurized and the plane crashed.

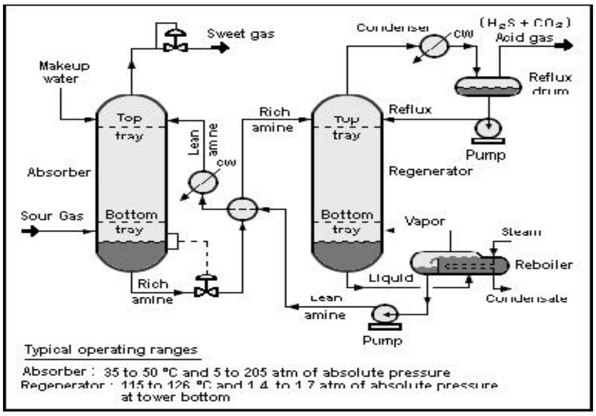


Figure 9: Typical process for removing acid gases from hydrocarbons

Case 6

A leak of 80 000 liters of isobutane to an underground pipe 250 mm in diameter occurred in Lake Charles (Louisana, USA) in 1968. The said pipe passing through a alkylation unit and 2 storage tanks, the valve line was located in a pit below. The bolts for the valve were severely corroded by fumes escaping from a line of sulfuric acid located in the vicinity. A small leak had developed in the valve due to corrosion, but it has not been noticed because the pit was filled with mud and rainwater. When the valve had been completely lacking, a large amount of isobutane was released, forming a vapor cloud covering 5 acres. The steam was detonated with a force equivalent to 10 tons of TNT, killing 7 people. The fire had burned for 2 weeks.

Case 7

4 people are killed and 5 others seriously injured in a nuclear power station in Britain when a cable suspended from a cabin of an elevator in which they were weakened by corrosion and lack of lubrication (Battle Institute, 1981).

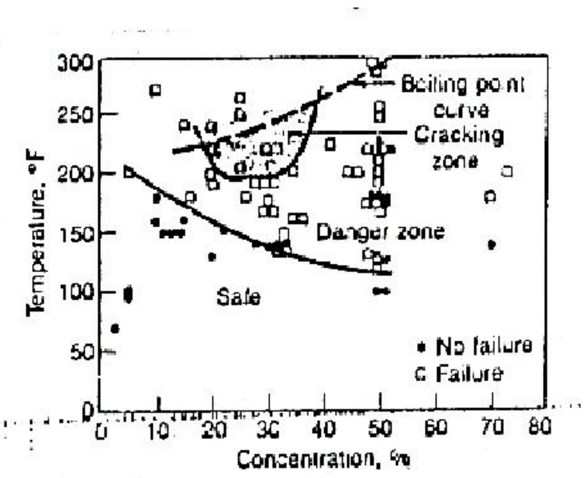


Figure 10: Temperature and concentration of NaOH to cause cracking

CONCLUSION

It can be seen through these examples, no branch of industry is immune to the corrosion phenomenon, it affects all areas of industry, ranging from steel to oil industry. There is a close relationship both between corrosion and safety of property and a second between corrosion and safety, as every incident is accompanied by loss of life.
Numerous studies of incidents occurring at industrial sites and whose investigation of the causes highlighted first and foremost a failure of materials and their behavior because the behavior of materials in general vis-à-vis the technical implementation shaped during their service and depends mainly on their structural state

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