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CORROSION CONTROL COST REQUIRES CORROSION EDUCATION

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Abstract: An overview of corrosion problems and corrosion control cost is made. The importance of corrosion education for all kind of engineers is presented. According to importance of knowing and dissolving corrosion problems for every engineer, the course for corrosion education is presented. This program allows planning the structure of a particular course in an open way, depending on the students, the degree and the range of the education. Based on three main modules, the course is constructed specifically for different kind of students focusing on corrosion practice. The methodology is thought to stand on experiences in order to allow the students to acquire knowledge on corrosion.

Keywords: corrosion, corrosion protection, higher education

1. Introduction

Corrosion, Figure 1, is a naturally occurring phenomenon commonly defined as the deterioration of a substance (usually a metal) or its properties because of a physicochemical reaction with its environment.

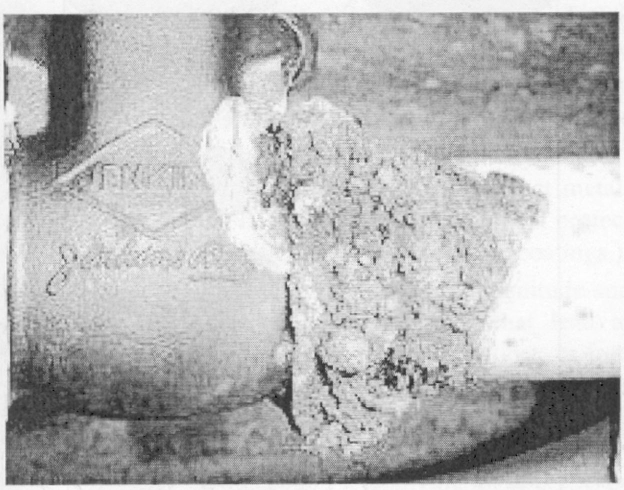

Figure 1. Galvanic corrosion.

Like other natural hazards such as earthquakes or severe weather disturbances, corrosion can cause dangerous and expensive damage to everything from automobiles, home appliances, and drinking water systems to pipelines, bridges, and public buildings.

Over the past 22 years, the U.S. has suffered 52 major weather related disasters - including hurricanes, tornadoes, tropical storms, floods, fires, droughts, and freezes - including total normalized losses of more than $380 billion (averaging $17 billion annually) [1]. Unlike weather-related disasters, however, corrosion can be controlled, but at a cost.

2. Economic Effect of Corrosion

Because the United States and Japan are two of the most developed industries in the world, here some facts about his corrosion damages are presented.

The corrosion problem in the United States:

- A 2001 study published by NACE International identified the total direct cost of corrosion in the United States as $276 billion per year (Figure 2a), or about 3.1% of the Gross National Product (GNP). In Figure 2b the estimated economic cost of corrosion is given [2].
  Note: The manufacturing sector includes "Mining" and "Agricultural, Forestry, and Fishing" categories.
- Indirect corrosion costs are conservatively estimated to be equal to direct cost, giving a total cost of $552 billion per year.
- Over $121 billion is spent each year on corrosion control chemicals, coatings, and other protective systems.

The first report on the cost of corrosion in Japan had been published at 1977 [3]. The report estimated that the corrosion loss in Japan which did not include indirect loss was 1-2 percent of Gross National Product (GNP) at that time. Since then, almost two decades have passed and the industrial structure has drastically changed. Corresponding to this situation, the Committee on the Cost of Corrosion in Japan was organized at 1999 jointly by the Japan Society of Corrosion Engineering (JSCE) and the Japan Association of Corrosion Control (JACC). The project was funded by the National Research Institute for Metals (NRIM) as part of the Ultra-Steels (STX-21) Project. The costs for 1997 were between 3,938 ÷ 5,258 billion yen, which is respectively 0.77% ÷ 1.02% of the GNP of Japan. However, the total cost including the direct and indirect costs is likely to be more than 2 times larger.

Although corrosion is inevitable, its cost can be considerably reduced. For example, an expensive magnesium anode could double the life of a domestic hot water tank.

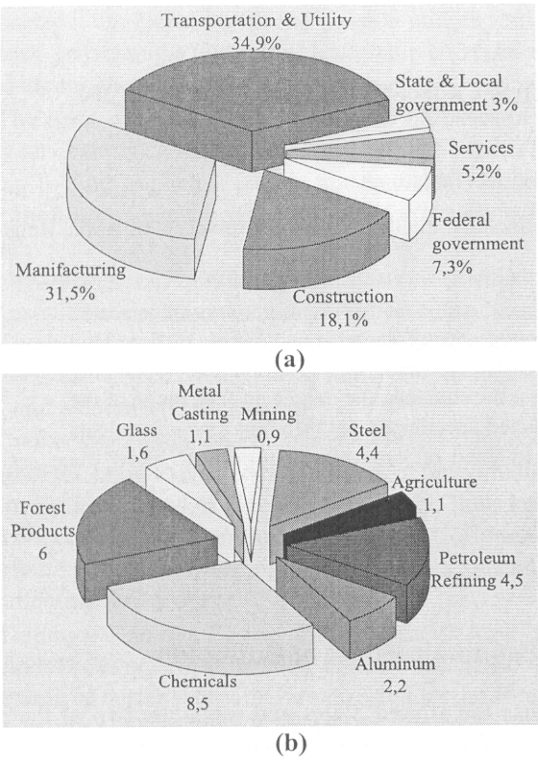

Figure 2. Cost of corrosion by sector according NACE report: **(a)** For 2001, **(b)** Estimated economic cost of corrosion to industries of the future in billion dollars per year [2].

Washing a car to remove road deicing salts is helpful. Proper selection of materials and good design reduce costs of corrosion. A good maintenance painting program pays for itself many times over. Here is where the corrosion engineer enters the picture and is effective - his or her primary function is to combat corrosion.

3. Corrosion Education

Corrosion education at the University could be differentiated between design engineers (mechanics, civil, electronics) and specialists in materials (metallurgists, chemical engineers, material engineers, etc.). The first group is material users, while the second group is responsible for new materials development and their implementation in the engineering systems. So that, Corrosion Science is the study of the chemical and physical processes that occur during corrosion and Corrosion Engineering is the design and application of methods to prevent corrosion.

Ideally, science should be married to engineering so as to invent new and better methods of prevention and to apply existing methods more intelligently and efficiently. Normally, courses in corrosion science and engineering are designed for undergraduate engineers who will likely work in industry and encounter problems of design, materials selection and failure analysis due to environmental effects on engineering materials. Therefore, corrosion is often perceived as a discipline we have to endure helplessly and it is a shock to many to learn that there are many ways to prevent and control this natural force.

The multidisciplinary character of the corrosion science and engineering has involved important problems for University lecturers. Very different requirements are needed for students of dissimilar degrees such as: chemical engineering, materials engineering, electrical engineering, chemists, architects, etc.

4. Corrosion Course

The course (Figure 3) is taught in three main sections or modules, which are divided into different sub modules. The methodology is based on training with problem solving.

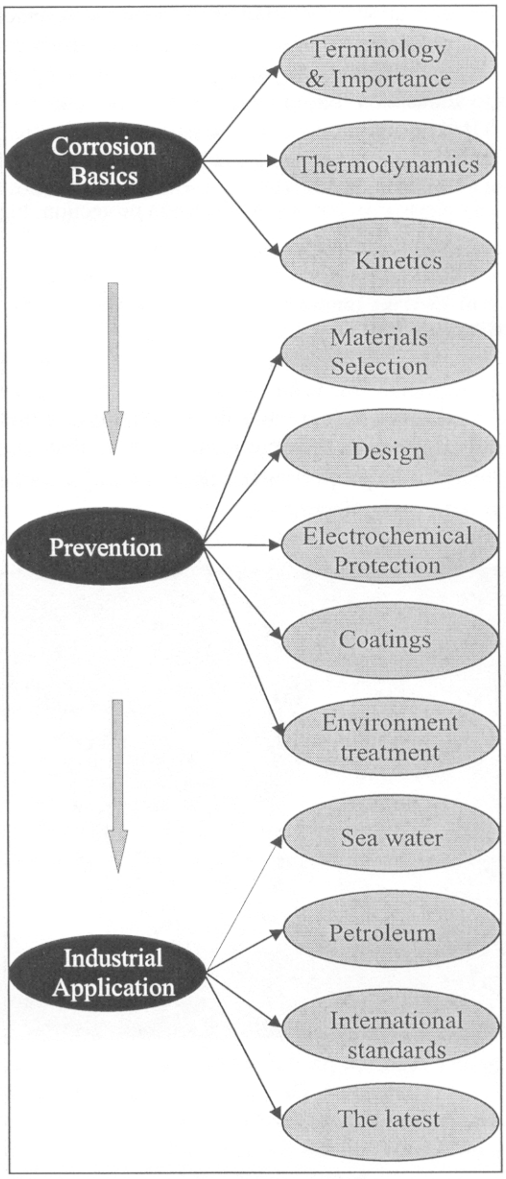

Figure 3. Scheme of a Corrosion course.

The first module: **Corrosion Basics** is the fundamental section and the students approach corrosion through basic definitions and essential measurements of when and how fast corrosion propagates on a metallic surface and medium.

The second module: **Corrosion Prevention and Control** comprises the most common ways to prevent corrosion phenomena. The section allows the students to become involved in design of protection systems under various conditions.

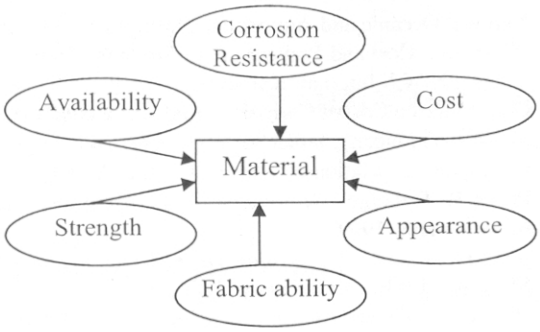

Figure 4. Criteria for selection of materials [5].

Some of the most important accent here are:

- *Selection of Materials.* It has to be made according to criteria presented on Figure 4.
- *Design.* If the metal has to be protected, make provision in the design for applying metallic or nonmetallic coatings or applying anodic or cathodic protection. Avoid geometrical configurations that facilitate corrosive conditions.
- *Contact with other materials.* Avoid metal-metal or metal-nonmetallic contacting materials that facilitate corrosion such as:
  - Bimetallic couples in which a large area of a more positive metal is in contact with a small area of a less noble metal;
  - Metals in contact with absorbent materials that maintain constantly wet conditions or, in the case of passive metals, that exclude oxygen;
  - Contact with substances that give off corrosive vapors (e.g., certain woods and plastics).

    (Exception: in some cases the contact metal-metal can be used for electrochemical protection by sacrificial anode or metallic coatings.)
- *Mechanical factors.* Avoid stresses (magnitude and type) and environmental conditions that lead to stress-corrosion cracking, corrosion fatigue, or fretting corrosion.
- *Coatings.* If the metal has a poor resistance to corrosion in the environment under consideration, make provision in the design for applying an appropriate protective coating.
- *Environment.* Make environment less aggressive by removing constituents that facilitate corrosion; decreasing temperatures decreases velocity; where possible prevent access of water and moisture (e.g., for aqueous corrosion remove dissolved O_2). When they can not change environment the inhibitors can be used.

The third module: **Industrial Application** is the most flexible one; it puts all of the above material together by describing different corrosion problems in industrial situations. It is meant to be developed in the form of practical cases in which the students may apply the knowledge and skills acquired on corrosion.

This part has to contain information about corrosion testing and monitoring. It is very important especially when there is no information on the behavior of a metal or alloy or a fabrication under specific environmental conditions (a newly formulated alloy and/or a new environment). Monitor composition of environment, corrosion rate of metal, interfacial potential, and so forth, to ensure that control is effective. That very question can be assimilating by experimental practice.

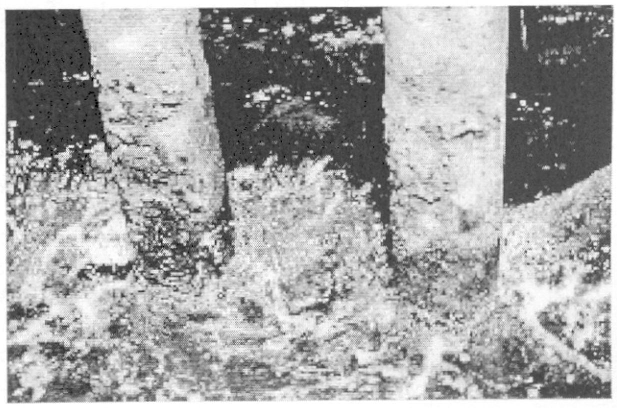

Figure 5. Corroded columns at water line.

Industrial examples such as sea water (Figure 5) and pipeline corrosion (Figure 6) ones of the most dangerous cases have to be presented.

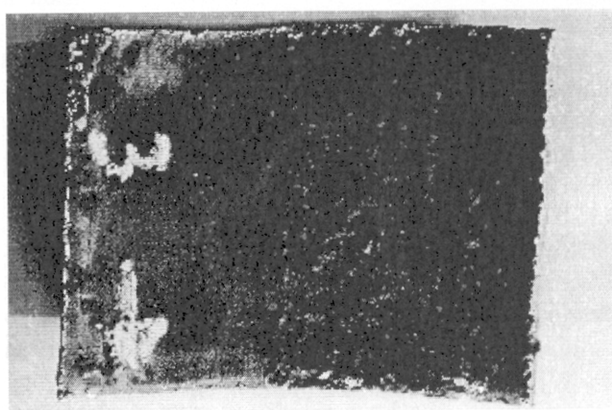

Figure 6. Internal corrosion of a crude oil pipeline.

It is important to know how they make supervision and inspection of existing corrosion protection methods. For example: ensure that the application of a protective coating (applied in situ or in a factory) is adequately supervised and inspected in accordance with the specification or code of practice.

Here is the place of international standards, such as ISO 8044 [6]. The main objective of this European Standard is to provide definitions and that can be understood to have the same meaning by all concerned. Some corrosion terms in present use have developed through common usage and are not always logical.

5. Conclusion

Corrosion engineering is the application of science and art to prevent or control corrosion damage economically and safety.

In order to perform their function properly, engineers must be well versed in the practices and principles of corrosion: the chemical, metallurgical, physical, and mechanical properties of materials; corrosion testing; the nature of corrosive environments; the availability and fabrication of materials; computers; and design.

We recommend a course of corrosion to be included to tuition of students from English language faculty of engineering in Technical University of Sofia.

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