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A Study on Optimization Solutions and Causes of Corrosion in Water Reservoirs

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ABSTRACT

Considering the role and significance of the matter of supplying drinking water consumed by different groups of people in different cities and rural areas of the country, and increasing the level of utilizing pure drinking water resources on one hand; and on the other hand, reducing the processing problems of water facilities and buildings, and increasing the lifetime of preparation, transfer, distribution, treatment and reservoirs facilities of drinking water, have a significant importance. One of the major concernsindustrialists and consumers of the country is maintaining water facilities and infrastructures, which a great amount of money has been spent for building and utilizing them, and in the utilization phase, optimized maintenance of water is significantly important.

In the present study, considering existing records and previous experiences, efforts have been made to have an overview on the discussion of corrosion of concrete and metal drinking water reservoirs. Corrosion of reservoirs is environmental. The compounds present in water such as sulfur, hydrogen, carbon dioxide and otherimpurities are very effective in accelerating the process of corrosion.

Keywords: *Optimization, reinforcement, corrosion, dual corrosion, reservoirs' corrosion*

INTRODUCTION

Nowadays, vital currents and its necessities are the keys to advancement and growth of humans, however, the occurrence of major problems such as natural disasters, environmental damages such as corrosion, cause deficiencies and defects in utilizing them. In this study using ABFA Company's experience, another investigation has been conducted on the problem of corrosion and the efficiency of the existing maintenance methods.

DRINKING WATER RESERVOIRS

Reservoir tanks that due to different workings conditions should be designed and built with different safety coefficients, considering their usage, have different structures. In the country's water industry, we are witnessing an extensive usage of concrete and metal and compound material reservoirs that we will discuss the corrosions that has taken place in these type of reservoirs. These types of reservoirs are made with metal or non-metal materials (composites) and or a combination of these materials, which

at least their design be done with the least cost and materials used, and building them often has complicated construction and design phases. The reservoirs should have the ability to tolerate static, dynamic loads and weariness under different environmental conditions and at times when damages have been made.

All Metal Reservoirs

Although the type of used alloy and also the design stresses in these type of reservoirs has not been determined in the standard, however these type of steel, aluminum or compound concrete reservoirs have to pass efficiency tests. These tests are necessary for ensuring the sufficient amount of resistance of these reservoirs towards weariness and corrosion. The safety of these reservoirs with different destruction and non-destruction test such as hardness, hydrostatic pressure test and etc. is for determining CrMo.

Hoop Wrapped Reservoirs

These reservoirs are made with steel, aluminum or compound concrete, which have been reinforced with composite fibers and FRP or different types of geo-membranes in radial direction. Except for two first and ending parts of the reservoir that are usually made out of glass fibers, carbon or armid or resin, the used composites in reservoirs is mostly epoxy or polyester isophthalic resin.

Fully Wrapped Reservoirs

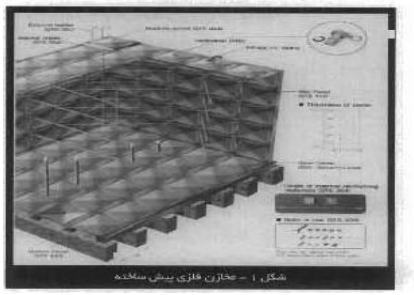

Figure1. *Pre-fabricated Steel Reservoirs*

These reservoirs are made out of steel or aluminum or concrete compound, which are reinforced with composite fibers in radial and axial directions. Reinforcing these reservoirs with composite fibers in to directions, has made these reservoirs stronger in tolerating more load pressure compared to the second type of reservoirs, and these reservoirs are also more lightweight than the second type. Although, in the combined type, due to the varied loads that have been taken into consideration, more effectiveness has been taken into consideration.

All Composite Reservoirs

Similar to the third type of reservoirs, these reservoirs are reinforced with composite fibers in radial and axial directions, with the difference that the wall used in these reservoirs is made out of polyethylene polymer material. The load bearing of these reservoirs has been done accordant with the reinforcement and in the cross sections they have more tolerance compared to steel and concrete reservoirs and the unreinforced.

Armed Concrete Reservoirs

These reservoirs are made of all concrete with an inner dual layer of metal and covering. The lifetime of these reservoirs is more than other reservoirs and they are very appropriate for southern regions of the country, but due to execution problems, they are non-executable in cold regions.

Stone Reservoirs

These reservoirs were made in regions where appropriate materials were not accessible and the existing stone in the base location could be very suitable. Corrosion and destruction in these reservoirs is strongly depended upon the quality of the used stone and materials and mortar.

Reservoirs Utilization Conditions

The utilization conditions for these reservoirs are very different and based on the region, climate, water quality, manner that was built, usage situation and loading and unloading conditions, they vary.

Problems Occurred Due to Water Quality

The transfer and reserve of water or any other fluid is depended upon controlling its composition and quality. Generally, if the water composition flows in the pipelines accordant to the special regulations, reserving it should have no problem. Carbon dioxide, oxygen and sulfur (H1S) are among the effective factors in corrosion and damages in reservoirs, especially concrete reservoirs without covering. In regards to sulfide hydrogen, the ranges have been specified and as its amount is higher, the amount corrosion that would occur is more. The effect of water quality and other indices in the transfer and reserving lines will be reviewed separately.

Water

When water meets the reservoirs' body, other than those materials that water does not destroy them, it will cause problems for other composed materials. During winter time, corrosion decreases. When water sits inside the pipelines and reservoirs, the possibility of this problem occurring increases. The presence of water can cause corrosion and development of alkaline compounds.

Carbon Dioxide

The carbon dioxide presents in the water that is reserved in steel and concrete reservoirs that are also exposed to water, escalates corrosion.

Depending on the pressure, temperature, amount of iron carbonate, concentration and resistance of the reservoir's body and cover composing materials, the speed of corrosion is variable and flexible. Corrosion could only be limited to those parts where water has just sat and the upper part of the reservoir surface may have no damage; however, due to the dew and water evaporation phenomenon, sometimes the damages in the upper parts might be even more because of the presence of air.

Hydrated Compounds

As the pressure inside the reservoirs increases, hydrates may form in temperatures above zero degrees (meaning that in cold regions, this matter occurs less). This matter can cause blockage in pipes, valves, pressure regulators, drainage basins, fire valve and safety valves. For this purpose, usually an allowed range is defined for the amount of water present in the reservoirs. The concentration of the corrosive compounds in water should be so little that its freezing temperature under pressure should be 5 degrees centigrade lower than the lowest local temperature. This means that the allowed amount is 10 to 50 milligrams per cubic meter.

Hydrogen Sulfide

In the case where hydrogen sulfide was present in the water, it can be appearing as acidic hydrogen sulfide compounds and cause an increase in corrosion and brittleness of the metal. Experiments have shown that the amount of corrosion depends on the amount of hydrogen in the environment.

Sulfur

Since sulfur has a low solubility in water, not much corrosion occurs with its presence.

Mercaptan

This odorous substance solves in water at a very low level and therefore does not cause much corrosion.

THE EVENT OF CORROSION

In engineering science, corrosion is one of the most important matters that in addition to creating economic, environmental, and technical and safety problems, it also dedicates a significant part of industrial researches and studies to itself. The increase in the price of energy, human resources, pressures, high temperatures, and more corrosive and complicated environments in industrial processes, leads to progressive increase in economic damages in the years to come. The significance of corrosion in industries increases when its adverse effects directly threatens the safety of users. In service facilities such as transfer pipelines and water reservoirs, corrosion causes reduction in the utilization lifetime and increase in reservation and maintenance costs.

Crevice Corrosion

The most common type of corrosion in water reservoirs is crevice corrosion. This occurs on the crevices and regions on the reservoir's surface where corrosive solutions are still in these parts. Crevice corrosion starts in the contact point of rubber and metal and then its progresses. In order to prevent impaction of fluids under the retaining belts, gaskets should not be used under the retaining belts of the reservoirs.

Pitting Corrosion

In pitting corrosion, a small surface of the metal due to certain defects such as defect in covering, becomes exposed to the corrosive environment and corrosion occurs intensively. This type of corrosion is severely localized and intensive, which causes pitting of the metal or composite.

The pits usually grow in the direction of gravity. Pitting occurs through anauto-catalytic anodic reaction. The used reservoirs should be protected from corrosive factors, which this matter is done through appropriate covering (resin covering or two-layered compound zeolites along with sea cement).

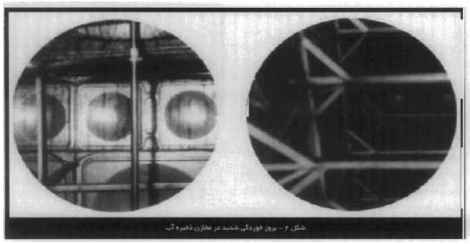

Figure2. *Intense Corrosion Occurring in Water Reservoirs*

Inter-Granular Corrosion

The border between granules are high energy areas and are chemically more active. For this purpose, when the surface of a metal or compound materials are exposed to a corrosive substance, corrosion occurs a bit faster in the borders between granules than their surface.

As we know, alloys exist in two different states of homogeneous and heterogeneous. Homogeneous alloys are more resistance towards corrosion,

because in these type of alloys, there is no galvanic state. Therefore, in order to form a homogeneous alloy in building reservoirs, its constituting elements should be controlled.

Considering the chemical combination of the above-mentioned steels as use materials for building reservoirs, we will discuss this resistance mechanism towards corrosion in these types of alloyed steels. Chrome (Cr) as an alkaline base metal, plays the role of a victim in protecting iron from corrosion. In this way that through the effect of oxygen infestation to the surface of the metal, a great amount of iron oxide is created, but due to chrome's combination inclination with oxygen, a small amount of chrome oxide substitutes iron and the sticky layer of chrome on the surface creates a resistant layer; and chrome creates a barrier against oxygen penetration on the surface of the iron oxide compound; and this way the metal is protected.

Galvanic or Two Metal Corrosion

The electrical potential difference between two heterogeneous metals that are in contact with each other causes the establishment of electron current between them and causes galvanic corrosion. In this corrosion environmental effects such as temperature, humidity and surface effect, the coefficient of anode and cathode surface, have an important role in the speed of corrosion.

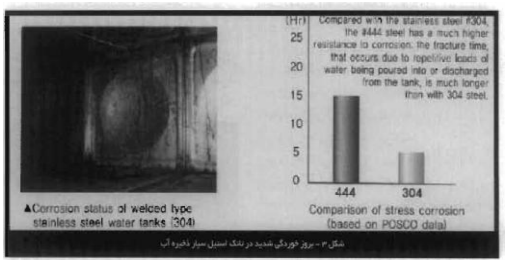

Figure3. *Intense Corrosion in Stainless Steel Mobile Water Tank*

Figure4. *Localized Destruction of Inner Body Due to Corrosion in Reservoir*

By protecting the steel body of metal reservoirs in direct contact with aluminum, corrosion will less likely occur and the lifetime of reservoirs will increase. This method is also applicable in concrete reservoirs. This note should be considered that in choosing parts and fitting for the water system, the type of material should be carefully selected. In fittings, instead of gaskets and metal attachments, compound materials, plastics and polyethylene should be used in order to reduce corrosion in reservoirs.

Stress Corrosion Cracking

The result of simultaneously applying tension stresses, chemical solution combination, is stress corrosion cracking of the corrosive environment on the metal. Important factors in the chemical combination of metal or composite used in the reservoir, is the stress and structure of the metal. One example of these stresses can cause compaction in one area and lack of compaction in other area; which this matter leads to the creation of a cell,and in those areas having low compaction become a conductive anode for corrosion in the environment; while those areas with atomic compaction work as protection cathode, therefore, acidic rains cannot be established, because these acids do not have the sufficient strength for the SCC process.

Solution

Those reservoirs that are covered with fiberglass should not come in contact with acids. Batteries should not be kept near these reservoirs. These batteries can easily tip over and sulfuric acid spill from them.

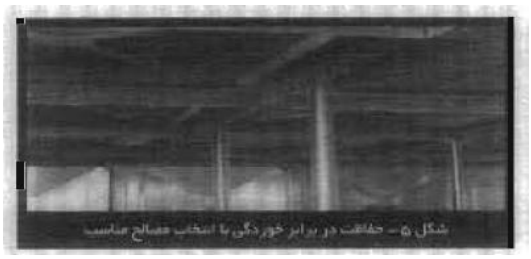

Figure5. *Protection against Corrosion by Using Appropriate Materials*

Also, these batteries produce sulfuric acid vapors that may sit on the reservoirs. Make sure that the battery of vehicles is within a safe distance from composite reservoirs that covered with fiberglass.

Pre-Fabricated Water Reservoirs and their Applications

Considering the natural limitations of water in our country, lack of balanced rainfall, natural phenomena of drought, decrease in quality of existing water sources, increasing trend of population growth and consumption, advancement in industries and agriculture, which have designated a major share of quality waters to themselves; require planning and systematic management in reducing its effects and attention to precise reservation of water.

Capabilities of Pre-Fabricated Water Reservoirs

Pre-fabricated reservoirs have more advantages and different capabilities compared to in place reservoirs.

- They can be reinforced differently against corrosion with the type of substance.
- They are resistant against environmental effects.
- Pre-fabricated water reservoirs are completely made with nuts and bolts, thus can be easily assembled, disassembled and moved.
- As far as shaped and mechanical strength, they have a detailed design and are under ISO standard.
- They are available with different dimensions and volumes from 25 to 1175 cubic meter and with the least number of personnel and in a short time, they can be installed anywhere desired.
- They prevent water evaporation at 90 to 95% and prevent the growth of algae, due to the presence of air float floating sheets inside the reservoirs or the genaroof or air top silo roof covering on the reservoirs, which also prevent the entrance of dust and insects inside the reservoirs.
- They have an excellent tension strength.
- They have high resistance against length variation due to heat.
- They are resistant towards severe winds.
- They have sufficient resistance against artificial airing in sewage treatment projects and fish and shrimp breeding.
- Using the maximum amount of space possible, in order to reserve water in different volumes, even in indoor halls.
- The quality and quantity of water in these reservoirs are easily measurable and controllable on a daily basis.
- In order to reserve water in regions with high erosion degrees, the tanker sheets are coated on both sides, therefore they are resistant against erosion for 30 years, even in salt marsh regions.
- Different types of aquatex coverings, accordant with the climate conditions, from cold to tropical regions with high UV degrees and for different agricultural and gardening and industrial uses, have been anticipated in a specialized manner.

Pre-Fabricated Water Reservoirs Application

- Suitable for reserving drinking water in different parts of the country; holder of international standards of ATA, KIWA and ISO 9001.
- Suitable for reserving different industrial fluids in a safe manner in order to prevent oil or fuel or chemical substances' leakage to the outside of the reservoir and protecting the environment.
- Suitable for industrial breeding of fish and shrimp in developing plans.
- Suitable for reserving rain water and other waters to be use in agriculture, gardening and irrigation in different parts of the country.
- Suitable for reserving water in parks, sport grounds and city squares.
- Suitable for temporary reserving petroleum.
- Consumer groups: construction, industry, environmental, …

Disadvantages of Concrete Reservoirs compared to Pre-Fabricated Water Reservoirs

Concrete reservoirs are more expensive compared to pre-fabricated galvanized reservoirs.

The installation of concrete reservoirs need more time and after they are built, they cannot be immediately used, because concrete requires hardening, whereas pre-fabricated reservoirs are not like this.

Pre-fabricated water reservoirs can be disassembled and moved, but concrete reservoirs are not like this, therefore, galvanized reservoirs are more flexible.

Concrete reservoirs require a heavier foundation compared to galvanized reservoirs.

Because of the presence of hydrogen sulfide in city and rural sewage water that causes the concrete to break, using concrete reservoirs in this regards are not suitable.

Concrete cracking, especially during winter time in concrete structure of water reservoirs, sewage treatment plants, water transfer pipelines and distribution networks, is significantly important.

Figure6. *Fast Implementable and Corrosion-Resistant Reservoirs*

Concrete reservoirs unlike pre-fabricated water reservoirs, have time (season) and built place and installation limitations.

Although concrete is a popular and commonly used substance in building materials, however, it has weaknesses such as low tension resistance and plasticity, low energy absorption, concrete contraction and compaction and consequently leading to cracking in concrete, and finally, the cracks are due to inappropriate treatment and hardening of concrete.

CONCLUSION

One of the controversial issues in studying reservoirs is the different types of corrosion and methods for controlling it. In this study, after reviewing the different types of corrosion, in order to prevent this unwanted phenomenon, reservoirs must be built that are covered with fiberglass and that are not near acidic materials and compounds.

Different experiments such as testing in acidic environment, testing reservoir under saltwater conditions have been conducted, however, most of them have been also offered by other creditable standards such as ISO, 11439 standard base. By reviewing the tests, it was observed that pre-fabricated reservoirs should go through special conditions compared to reservoirs under regular pressure.

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