Corrosion Control In Pumping Equipment

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The primary objective of this paper is to stress the importance of a systematic, organized corrosion control program. In order for us to see the great problem at hand and fully realize the importance of such control practices, we must have some understanding of the basic fundamentals of corrosion.

Since corrosion is not limited to pumping wells, the basic fundamentals should apply to all types of oil well corrosion and its control from a general point of view. Specific problems must be dealt with individually, but in most instances, information gained throughout the industry from all its phases of corrosion control places a wealth of time and money saving control practices at our disposal. We are no longer groping around in complete darkness as was the case only a decade or so ago.

Some fundamentals of corrosion: Corrosion is a term often used to denote or indicate a chemical change in which a metal passes from the elementary to the combined state. Actually corrosion is natures means of undoing the master pieces of man's making in the metal world. The laws of corrosion follow certain definite rules and patterns and reactions in the corrosion process should form an essential division of chemical kinetics. In the process of corroding, a metal eventually passes from a state of some degree of purity (i. e. the elementary state) to a combined state in which a decrease in the free energy of the metal concerned takes place. The most stable or lowest free energy state of the metal marks the end of the corrosion cycle. Corrosion produces, or rather the reaction products of metals in which a change from the elementary to the combined state which commonly occur in nature, are rust or hydrated iron oxide (the combination of iron and oxygen) and scale formation of iron oxide. (Of course iron as the corroding metal.)

Corrosion, however, is not always detrimental. In some cases it is brought about intentionally in industry in order to produce some valuable commercial product. An example of intentional corrosion is the manufacture of white lead for the paint and related industries.

Corrosion of metals may be divided into several classes. e. g. (1) Corossion by oxidation. (2) Corrosion by liquids. (3) Corrosion by the atmosphere. (4) Corrosion by an external electromagnetic force. In the first three classes, a protective film may be formed which acts as a barrier or inhibitor for the corrosive action of whatever agent is the cause. For example, when an oxide film is formed, the rate of oxidation is necessarily decreased because of the resistivity of the film to oxygen penetration. This film may give varying degrees of protection, depending on the environment in which the metal is in, such as temperature, whether in air or liquid, etc. Since most metallic oxides are sparingly soluble in water, the rate of attack on the heavier metals by pure water would be expected to be slow. This is generally the case, but in some instances, the fact that a discontinuous film is sometimes formed, localized attack in the form of pitting may occur.

In the presence of salt water, general attack may increase appreciably because of the added danger of electrochemical attack and because of the increased solubility of the oxide film in salt water. As anodic or cothodic products, the film may fail to form in the beginning, thus leaving the surface of the metal exposed to direct attack.

In liquids, corrosion may progress much the same as in the atmospheric oxidation type of corrosion. Hydrogen sulfide attack may tend to form a continuous film which will give protection against any localized action. In cases where velocity of fluids is great in the presence of other corrodents, the attack may become increasingly severe and tend to erode away the film or to form secondary corrosion products. For instance, where soluble corrosion products are formed such as in carbon dioxide and organic acid attack, the metal may be exposed without the protection of any film of corrosion product. Where the protective film is not kept continuous and intact, localized or general attack may become evident. In atmospheric oxidation as in liquids, the presence of sulfur compounds accelerates the attack by creating defects in the latice of the scale. Fuels containing sulfur compounds cause metal wastage much more than cleaner fuels. A good example of corrosion in air is copper in the presence of hydrogen sulfide. The same sequence of film formation is observed as when copper is heated in pure air.

Corrosion by electrolysis presents another view of the behavior of metal, such as iron in a corrosive environment. The metal undergoing corrosion is made the anode in an electrolytic cell and is supplied with current from a source possibly far removed from the zone of actual attack. An example of this type of corrosion may be found in oil well casing, tubing, flow lines and pipe lines. The source of current may possibly be another line near by or even another section of the same line. Usually circuit resistance or current carrying capacity of the soil in which the line is buried, or type of water or resistance of certain zones a casing may be set in, governs to a great extent the rate of corrosion of this type. Type of attack is governed largely by pH of the electrolyte (soil, water, etc.) in that anodic action does not always lead to attack. Low pH valves usually finds the iron passing into solution as a soluble salt, but in alkaline solutions a protective film is generally formed which causes the metal to become "passive" and corrosion ceases.

Concentration of corrosion attack in small areas greatly increases damage in the form of pitting or localized attack and usually occur under conditions intermediate between that of general corrosion and complete imunity from corrosion. By this token an inadequate protective coating may actually increase pitting attack, eventually leading to perforation of pipe, tanks or other containers, whereas if the corrosion were generally spread over the survace, it may take years to corrod through the surface of the container.

Metals subjected to static stresses may develop intergranular cracking leading to failure in these metals, since the surface or boundaries of the grains are more susceptable to corrosion than are the interiors. Disorganized matter produced along slip planes may be most susceptible to corrosion rather than the intergranular boundaries when subjected to alternating stresses and strains in a corrosive environment. In this case we have "corrosion fatigue."

Another ever present corrosion accelerator in pumping equipment is known as corrosion-erosion. In this type of corrosion, velocity of fluids passing through the system determine the rate of attack on metal equipment. As a protective film of corrosion product is laid down on the metal surface, fluids passing over the film remove it at the rate of formation, thereby keeping the metal surface exposed to the corrosive elements present in the well fluids. This type of corrosion may be more noticeable around pumps, rod collars and other sections where turbulence is greatest.

Preliminary steps in corrosion mitigation: The first step in corrosion mitigation should be to determine or clarify the problem at hand. Find out by careful analysis of corrosion products just what type of corrosion you are facing in your wells. Analysis should give an indication as to whether your equipment is being corroded by presence of oxygen, hydrogen sulfide, carbon dioxide or combinations of two or more of these corrosive elements. The next step should be to run coupon surveys or in the case of carbon dioxide corrosion, iron counts or caliper surveys should be made. To more fully analyze the problem a combination of coupon surveys and iron counts should be run.

Coupon surveys and iron counts do not necessarily tell the whole story as to what is actually happening down hole, but at present, it is the most practical method from a cost standpoint and also from the ease of testing view point.

From data obtained in the fore going testing procedures, along with normal knowledge of production of the well such as water-oil ratio, total production, number of days produced, etc., treating procedures can be set up with some degree of precision.

In treating for corrosion the foregoing steps in determinining corrosion rates and types of corrosion are essential to a successful mitigation program.

At the out set of production, well equipment is generally protected against corrosive attack by the natural inhibiting properties of the oil, but as production continues over a period of time, the water phase generally increases and becomes more and more corrosive. As the oil phase decreases, generally the corrosion rate will steadily increase with increasing water volume. This may be explained partially by the fact that since all corrosive substances such as carbon dioxide and hydrogen sulfide are dissolved in the water phase and as the ration of water increases, there is naturally a greater quantity of corrosive substances in contact with metal equipment; however, there are certain exceptions to this rule. In many areas the highest rate of equipment loss to corrosion is in wells in which only very small or trace amounts of water is produced. In this instance, we may assume that the small quantity of water present contains a rather high concentration of acidic substances, such as dissolved carbon dioxide and organic acids. As previously stated, however, corrosion generally reaches its peak when the volume of water produced is high or within the range of 40-100% of the produced fluids.

A partial explanation of increasing corrosiveness of a well with age, quite possibly may lie in the fact that all crude oils possess varying degrees of natural wetting and inhibiting properties within the oil itself. Certain polar molecules are present in all crudes to a greater or lesser degree and by this virtue are natural inhibitors against corrosion. Now there are only a few loop holes to this statement. Many oil wells, though producing highly corrosive waters, fail to show any appreciable corrosion, if any at all, because of the natural protection provided by the crude oil. Other wells, however, under the same conditions, are extremely corrosive; thus, indicating that the crude give little or no protection against the corrosive brines. Usually when a well is produced over several years time, it becomes more corrosive which may be due, in part, to the gradual loss of the protective ability of the crude and, or, increase in water produced. It is a well established fact that the opportunity to corrode is governed by the factors which permit the steel equipment to be wet by the corrosive brines. As already pointed out, the relative amount of brine present and wetting ability of the crude oil will generally determine the amount of severity of corrosion. Velocity of well fluids may well prove to be a deciding factor also, as to the rate at which well equipment corrodes by the fact that erosive action may act as an accelerator as previously pointed out.

To properly evaluate the corrosiveness of a pumping well and set up a proper program of treatment, a number of factors should be reviewed and steps taken to remedy.

1. Keep an accurate and up to date pulling record. In every case, rate type of failure, where it occurred and most logical cause of failure. It may or may not be due to corrosion.

2. If at all possible when completing a well in a known corrosive area, steps should be taken to permit treatment with a minimum of additional cost when the well does become corrosive. For example, flow lines and well head eqquipment should be such that would permit coupon installation and treatment with inhibitor. Some wells are completed and all equipment installed with no provision made for a corrosion treating program in known corrosive areas and when treatment does become necessary, quite a lot of expense is incurred in making necessary changes. This should be avoided if possible.

3. The system should be kept air free in every instance where at all possible. Oxygen generally accelerates corrosion and when only traces are present, a marked increase in corrosion rate usually is evident.

4. If batch treatment of inhibitor is to be made, steps should be taken to provide well fluids for proper flushing of inhibitor into casing annulus; or if continuous treatment by chemical injection pumps is to be used, the proper type of pump should be carefully selected to insure proper treatment. In batch treating a period of several hours circulation of well fluids will insure better protection by giving a uniform distribution of inhibitor throughout the system. Treating intervals should be governed mainly by the volume of fluids pumped and relative corrosiveness of the particular well.

5. In the case of vapor space corrosion, there are three practical methods of control. First, the corrosion inhibitor may be flushed into the annulus whereby a film of inhibited oil covers the surface of the casing and tubing; however, this method has several drawbacks e. g. possible incomplete coverage, etc. Second, a packer may be set and the annular space filled with inhibited oil. This method has been used successfully in several West Texas Areas. Last, but not least, is the injection of anhydrous ammonia gas periodically into the annular vapor space; extensive work has been done in the ammonial field and to date, very promising data have been obtained.

6. Extremely high fluid level wells in which the water leg is high sometimes fail to respond properly to the ordinarily oil soluble inhibitors, but water soluble or dispersible inhibitors have shown improved protection. These inhibitors may be had both in liquid and solid (pellet) form of which the solid form will insure bottom hole treatment and from present data, the pellet form shows much greater efficiency.

7. Where external casing corrosion is expected to be a problem or if the problem has already been established as being severe, measures should be taken to insulate all flow lines by use of insulating flanges. By insulating in this manner, the danger of electrochemical attack may be lessened, or in many instances, completely eliminated.

8. Rod parting sometimes is the direct result of excessive stresses and strains in a corrosive environment and whipping may cause pre-mature parting. This may be eliminated somewhat by slowing down the pump cycle to within the capacity of the rod string and should also help to eliminate the ever present erosion corrosion factor.

In order to treat corrosive wells with some degree of success, a general knowledge of the mechanism and type of corrosion as already briefly explained, should be had by the persons responsible for carrying out the corrosion control program. A lack of knowledge as to the importance of treating procedure and techniques can easily determine the success or failure of a well designed program of treating. A corrosion engineer, if well informed, should be able to set up a treating schedule with minor adjustments that will best serve a particular well or field, but if his instructions are not carried out by men in the field, a state of general confusion and costly repairs will be the result sooner or later. Treating schedules are most important, even though a number of things may cause a man to want to omit a treatment now and then. Only a pint or quart of inhibitor may seem to be quite unimportant in the weekly or daily treatment, but many years of experience and millions of dollars worth of lost equipment has proven the value of the inhibitor treatment and also the strict schedule.

Numerous instances of equipment failure, because of inadequate adherence to a strict treating program, are in our files at present. As an example of indifference of some field personnel to treating schedules set up by the corrosion engineer, one of our field representatives was called in to explain why in a certain field the frequency of pulling jobs had suddenly increased (our inhibitor was being used in treatment of course). A check around the field revealed that the inhibitor drums were still rather full, even though at the rate of prescribed treatment, they should have been about empty. This immediately indicated that chemical had not been used as recommended and measures were taken to insure proper treatment immediately. As soon as the wells were back on the original treating schedule, pulling jobs returned to their normal frequency.

We have another instance on record where a pumper, by adhering to proper treating schedules, reduced time spent on pulling jobs to almost zero. Before getting on schedule the pumper was averaging a pulling job once or twice a week, while an adjoining lease rarely ever had a pulling unit on location. This was a puzzling situation to the pumper, but in discussing his problem it was learned, that in his pulling troubles he just didn't find time to treat regularly, while on the adjoining lease a rigid treating program was maintained. After pointing out the importance of such a program the man began regular treatment and as would normally be expected, his pulling time was cut eventually to that of his neighbors.

These examples are given in order to stress the importance of regular treatment with inhibitor when once a program is under way. I'm sure that there are hundreds of similar examples that never come to the attention of the proper individuals and in the process of time a very good inhibitor may be blamed for it's lack of protection, when it is not the inhibitor at all. The human element in the process of treating oil wells for corrosion control, is a very great and important factor in determining whether or not a given inhibitor is worthy of continued use, or whether millions of dollars worth of eqquipment will be lost due to corrosion, simply because of the prejudice of one or two individuals toward a given inhibitor.

Corrosion rate with age: A common misunderstanding of corrosion of equipment has led many in the field to believe that a given inhibitor will perform for a certain period of time, then fail and at that point another inhibitor will perform better and so on. For this reason, many inhibitors have been discontinued after several months or years use after failures become more frequent, in preference of some other inhibitor which in many cases may be less effective.

Because of an apparent parabolic increase of failure due to corrosion, the Bureau of Mine conducted an extended testing campaign for 15 years. This test program was set up to establish what, if any, was the relationships of the corrosion of metals in various soils with time. After compiling all data, the final analysis gave a general equation for the rate of failure of mild steel, which was generally represented by the equation, cumulative failures equals K to the nth power where K is constant and n is greater than one.

It is a well known fact, that commonly used irons and steels including low-alloy steels, corrode at approximately the same rate when totally immersed in ordinary natural waters. This fact was proven as much as 30 years ago in laboratory tests, in which it was shown that the rate of corrosion in soft water is governed by the dissolved oxygen content more than by small variations in metal composition. The Bureau's tests also established that regardless of type of ferrous metal, whether steel, ancient iron or wrought iron, all show the same rate of attack by corrosion in soils of various types and fresh or sea waters. The soils tests closely approximated the conditions which would be present in sea waters.

From the great wealth of data obtained in the Bureau of Standards tests and subsequent data obtained by the numerous oil companies, it has been very definitely established that because of the time relationship in corrosion rates, it is essential that one be very careful in a mitigation program. It is imperative that closely controlled tests be made and should be run over a period of several months time and in a great number of wells if concrete data is to be obtained.

Elimination of haphazard testing and careful analysis of all data obtained, will produce a clearer more dependable picture of the problems at hand and what may be expected in the future for a corrosive field. Corrosion mitigation is at best, time consuming and expensive, but a program worth carrying out is worth doing well if money is to be saved through corrosion control.