Cathodic Protection Of Oil Well Casings

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One of the largest investments in petroleum equipment today is the steelcasing of the many oil, gas and water wells located throughout the country. The cost per pound of the steel in place in these casings is certainly very high. The annual cost of failures of casings due to external corrosion reaches into astronomical figures when the cost of the casing, lost production and damage to producing sands are all considered. It is the purpose of this paper to review the present state of the art in the application of cathodic protection to oil well casings for control of corrosion on the external surfaces.

A. The causes of casing corrision.

1. *Flow Line Currents*

Probably one of the most common forms of casing corrosion is caused by current being carried to the casing from the flow lines and other equipment on the surface. In some instances one well will flow current into another. This current flow is relatively easy to measure by breaking the flow line and inserting an ammeter and measuring the current flow. This measurement can also be made by taking an IR drop in a measured length of the flow line. The measured current flowing into the well casing is discharged by the casing at some subsurface level. By Faraday's law we know that this results in a loss of approximately 20 lbs. of steel casing per ampere per year. This amount of metal may not be of any particular significance when spread over several thousand feet of casing; however, these currents can be discharged at some narrow salt water sand or other low resistivity stratum. This type of corrosion can be eliminated with very little cost and operational difficulty by the installation of insulated unions or flanges inserted in the flow lines. All metallic connection to the casing must be broken, and where electrical systems are used the neutral, and in some instances the lightning grounding circuit, must be changed. Without a doubt this is the greatest bargain in all the field of corrosion.

2. *Corrosion Cells*

These cells are formed by anodic and cathodic areas produced on the surface of the casing, principally as a result of differences in the surface of the metal and differences in the surrounding electrotype. This is the most commmon type of corrosion leading to failures in oil field casings. Although there are any number of ways that corrosion cells may be set up along the casing, by far the most commmon is caused by differences in conductivity of the different formations as they appear along the surface of the casing. This type of cell action can also be caused by mixing two types of metal in the casing string.

3. *Anerobic Bacteria*

The third and probably the most acute type of casing corrosion is that caused by sulfate reducing anerobic bacteria. This type of corrosion is the most difficult to detect and can only be completely verified by analysis of fluid produced by the failure or by pulling the casing.

This type of corrosion is experienced in many of the fields in West Texas and is detectable in almost any producing area, although it may be confined to certain fields in the area. Past experience has shown that this type of corrosion may be dormant or non-existent for many years and then suddenly become troublesome.

The corrosion function of the bacteria is principally that of a depolarizer; however, the resulting sulfides are corrosive agents also.

B. Detecting Casing Corrosion.

Generally speaking the operator will know when he has casing leaks; however, there may be considerable doubt as to the cause of the failures. There are several ways to determine the nature of leaks. These are (1) the use of calipers inside of the casing, (2) analysis of fluid produced by the leak, (3) a potential profile or down-the-hole survey to determine whether or not an anodic area of sufficient magnitude appears at the leak area, and (4) pulling the casing for visual inspection. When many leaks appear opposite the same formation, it may reasonably be assumed that the corrosion is external.

C. Corrosion Mitigation.

As mentioned above, the elimination of flow line currents is possible by proper insulation of the flow line; however, the other types of corrosion offer somewhat more of a problem. The application of cathodic protection to a well casing consists of applying the proper amount of current drain to the casing from a location which will give the proper distribution of the protective current to effectively eliminate the gross anodic areas from the casing. This application of cathodic protection is analogous to "hot spot" protection as applied to pipe lines and should eliminate 85 to 95 percent of the casing failures due to external corrosion. The effect of the drainage of current from the wellhead is to cause all current to flow onto the casing, thereby making it cathodic and in a non-corroding state. The action of cathodic protection on anerobic bacteria is indirect, in that as the metal surface plates out hydrogen the pH at the surface is raised to the point of inactivating the bacteria. Laboratory tests have shown that many strains of bacteria are made dormant at pH 9 and above. All strains seem to be controlled above pH 11.

Consideration will now be given to the specific business of placing a lease under cathodic protection.

First, after determination of the presence of external corrosion, a determination of the proper amount of current for cathodic protection must be made. There are two methods for determining the required current:

1. *The Current - Potential Break Method*

This method consists of drainage of increasing amounts of current from the well for short periods of time, and after each period of time the circuit is broken and the potential as referred to a half cell located in remote earth is read. The location of the temporary ground bed used to obtain the test current should be approximately the same as the proposed permanent groundbed location. The instrument for reading these potentials should be of a high independence type and accurate to three places. Success in using this method requires very careful instrumentation, good technique and proper interpretation. The current is plotted versus casing potential to remote earth on semi-log paper, with current shown as the log function. The break formed in the curve is considered to indicate that current which is the minimum for starting polarization of that amount of casing which is being "seen" by the electrode. Although this method is relatively fast and inexpensive when compared to the down-the-hole or potential profile method (see below), it is limited by several factors and should be confirmed by at least one down-the-hole survey for correlation for a given field. Good practice calls for testing 10 - 20 percent of the wells in a given field to establish that the potential breaks indicate similar current requirements. Otherwise, more extensive down-the-hole studies will be required.

2. *The Potential Profile or Down-the-Hole Method*

This method consists of taking IR drops along the inside of the casing to determine the amount of current and direction of flow along the casing. Thus, it is possible to locate the anodic and cathodic areas and evaluate their severity. The application of current from a temporary groundbed at the time of the second run of the instrument will determine amount of current required to eliminate the gross anodic areas. This method is somewhat limited by the effect of variations in the weight of pipe and by any resistance in the casing collars. Proper and careful interpretation of these logs will usually clearly outline the location of trouble areas as well as the amount of current to eliminate the gross anodic areas to a given depth. Several impressed current runs may have to be made before the exact results desired are obtained and final selection of optimum cathodic protection drainage current is made.

There are two generally accepted methods of obtaining the desired current for cathodic protection of oil well casings. (1) Magnesium anodes, and (2) Rectifier-graphite anode systems.

Determination of which method will be used is usually governed by soil resistivity, which limits the possible output of magnesium anodes, and power availability. In West Texas the soil resistivities are generally high, and the current requirements on most of the wells are such as to rule out the use of magnesium anodes. A soil resistivity survey will also show the voltage requirements of the rectifier and the number of graphite anodes necessary to furnish the required protective current. Careful interpretation of the resistivities as determined by a Megger or Virboground is necessary. In some instances these readings are not completely reliable for groundbed design, due to the heterogeneous nature of the soil, and installations must be "tailored" in the field.

Inasmuch as most of the wells being placed under protection will have a long projected life, the performance and life of the cathodic protection equipment used is of prime importance to prevent the creation of still another operating problem. The best quality of equipment and workmanship obtainable is indicated. Magnesium anodes are usually installed for either ten or fifteen year replacement life, while a rectifier-installation is usually rated for fifteen year life.

Location of small individual rectifiers and groundbeds, or magnesium anode groups, at each well eliminates most of the interference with other structures, such as flow lines, foreign wells, etc. Good design is important, and experience is a prime factor in attaining good design. In the final check-out of the protective system, interference tests should be made and resistance bonds installed as necessary to eliminate any interference effects on foreign structures.

The average turnkey cost of installation of a cathodic protection system will vary from $275.00 to as much as $500.00 per well, according to the number of wells, current requirements per well, and the resistivities of the soils encountered. These estimates are based on fields where power is available at the wellhead or reasonably close to it. As a general rule, the cost of repairs of one or two casing leaks in a lease will pay for the installation of a well designed cathodic protection system with fifteen year life for all well casings in the lease.