Cathodic Protection of Oilfield Vessels and Other Production Equipment

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Cathodic Protection Service

Corrosion of steel in contact with brine results from the creation of anodic and cathodic areas by reason of differences in the electrolyte and/or differences in the surface of the metal caused in manufacture or fabrication.

In the anodic areas current leaves the surface of structure and enters the electrolyte causing loss of metal or pitting action. In the cathodic areas current flows from the electrolyte onto the surface of the structure and no corrosion occurs.

The principle of cathodic protection is based on forcing direct current to flow from the electrolyte onto all exposed surfaces of the structure so that the steel becomes cathodic and in a non-corrosive state.

Severe corrosion is frequently caused by depolarization of areas along the surface of the metal by action of sulfate-reducing bacteria. Under cathodic protection a highly alkaline film is built up on the cathodic surface which arrests the action of the bacteria.

Current for applying protection to oil lease equipment is obtained by one of three methods:

(1) The use of galvanic current furnished by magnesium, aluminum and zinc anodes. The anodes are dissipated and must be replaced from time to time.

(2) The use of rectifiers with impressed current type anodes. This is a more permanent system and does not require frequent changes of the anodes; however, it requires an external source of power.

(3) Thermoelectric generators can be used to furnish the current required for cathodic protection by burning gas from the lease and converting the heat directly into electricity These units have proven to be a reliable source of cathodic protection current and are used with impressed current anodes.

Cathodic protection of tanks, treaters, gunbarrels, filters and other vessels which contain brine can result in the prevention of corrosion on that portion of the metal which is below the water level. Field tests have shown that protection even in bacterial environments is practical both from an economic and operating standpoint.

Cathodic protection of oil field saltwater handling equipment has become generally accepted in the last 10 years in fields where corrosion has been a major problem. Many examples of outstanding savings in operating costs have been obtained. Unfortunately, however, in many instances the misapplication of cathodic protection has allowed this form of corrosion mitigation to get a bad name. In most of these installations, disregard for some of the basic rules of cathodic protection has been the major cause of the trouble. In many instances the difficulty in being able to get a reference electrode into the vessel to measure the extent of protection has caused the design to be oversimplified, and the use of current density as a criterion has been adopted in untested areas. It is the purpose of this discussion to review cathodic protection of vessels and well casings.

DETERMINATION OF CURRENT REQUIREMENT IN VESSELS

In order to be valid, the current requirement must be determined inside the vessel to be protected. The general procedure is to provide a controllable source of current at the proposed normal anode location. A reference electrode or zinc reference should be located in one of the least favorable potential locations. Current is impressed until an acceptable potential is obtained at the reference point. Often it is possible to install the permanent anodes to be used in the final installation and adjust the current drain by use of a through-the-wall reference electrode.

LOCATION OF THE ANODES

The ideal anode situation would be a point type anode located at the center of the compartment, equidistant from all metal surfaces. Since the ideal condition would almost never occur, the anodes must be located as near to the ideal design as possible. When the anode is located too near the vessel wall or other metallic structures a low resistance path can occur and uneven attack on the anode can result due to high anode current density. This type of anode attack leads to very low anode efficiency, i. e., shortened anode life.

When locating the anode, experience has shown that the current from the anode will travel in nearly straight lines. In other words, the current from the anode will protect what it can see and cannot be forced onto the back side of baffles or for any distance through small holes.

SELECTION OF THE TYPE OF ANODE

Galvanic Anodes

Galvanic anodes offer the advantage of not having to have an outside source of power.

Magnesium Anodes—Magnesium anodes are consumed at the rate of 17 lb/amp yr under ideal conditions. As a general rule the smallest anode which will give the required current will be the most efficient. Magnesium anodes in heater treater applications may be restricted to about 75 per cent of their normal output without excessive local cell attack and its resulting lower anode efficiency.

Zinc Anodes — Zinc anodes with their lower driving potential have been used in the protection of vessels for some time. These anodes are consumed at the rate of 26 lb/amp yr. The weight of zinc makes the through-the-wall heater treater type of anode require internal support. One of the major drawbacks to the zinc anode is its tendency to reverse its polarity to steel at elevated temperatures. This can occur as low as 140°F. in some cases and in most electrolytes at 180° F. If these anodes must be used at such elevated temperatures, they should be checked for reversal in the particular environment where they are to be used.

Aluminum Anodes — New alloys of aluminum have recently been developed which offer great promise as anodes in the field of saltwater handling vessels. Tests have shown efficiencies up to 70 per cent in hot brines with consumption rates as low as 8 lbs/amp yr. A typical aluminum alloy heater treater type of anode weighs 42 lbs. Tests now being conducted in the field should give practical field data within a few months.

Impressed Current Anodes

Graphite Anodes — The "specially treated" graphite anode has been the principal impressed current anode used in vessels for a number of years. It has the advantage of long life and does not require frequent replacement. These anodes are treated with an oxidizing oil which fills the pores of the graphite so that gas will not form within the anode material and cause breaking away of small amounts of graphite near the surface. In some installations where the anodes are located near a firebox the heat will cause the oil in the anode to ooze out, with resulting local attack on the anode surface. This attack can cause premature failure of the anode or very poor anode efficiency at best. For this reason the anodes should be located as far as possible from the firebox in a treater, or other types of vessels with heaters.

In most applications graphite anodes which have been properly treated can be operated satisfactorily at current levels in brine of four amperes for a 3 in. x 60 in. anode.

Durichlor D-51 Anodes—These anodes have the advantage of low consumption rates and are without anode current limitations. Common consumption rates in the range of 1.6 lbs/amp yr are to be expected. The greatest disadvantages are their weight and the brittle nature of the cast metal.

Miscellaneous Impressed Current Anodes — The smaller, noble-metal types of anodes, including platinum, platinum-titanium and platinum-tantalum, have the common difficulty of being subject to coating by electrophoresis of suspended material in both the oil emulsion as well as the separated brine. The principal offender in the way of material subject to this mode of deposition is wax; however, some of the anodic inhibitors as well as emulsion breakers result in the same difficulty. This problem is commonly noticed because of the refusal of the anode to discharge current. In some cases it is possible to reverse the polarity momentarily and reverse the process. This seems merely to confirm the difficulty rather than offer a cure. In many instances larger anodes with their lower anode current density will not be subject to coating by electrolytes which coat smaller anodes. In some cases increasing the voltage will remove the coating. The only true test is to try the anodes in an actual vessel.

The platinum-titanium anode is subject to overvoltage damage at about 12 volts. This voltage must be measured peak-to-peak rather than the RMS value read by the meters of a rectifier's pulsating DC. The ability of the titanium to resist the flow of current from its surface is dependent on the formation of TiO_2 on the surface by oxidation of the very active titanium. This coating offers high resistance to the flow of current at low voltages; however, when the critical voltage is exceeded, the coating will be destroyed and the base metal will go into solution.

SYSTEM DESIGN CONSIDERATIONS

The first step in the design of a cathodic protection system is to determine the area which an anode must protect. All of the exposed surface must be considered.

The next step is to determine the size and material of the anode. Consideration must here be given to the anticipated life of the installation.

If the brine is not saturated, or nearly so, it may be desirable to determine the resistance of the anode to the brine. These resistances may be approximated on the following basis:

Anode Size	Factor
3" x 60"	R=.0043
3" x 30"	R=.0072 g
2" x 60"	R= .005 g
1½" x 60"	R= .006 g

R=Anode resistance to brine

g=Resistivity of brine in ohms/cm³

Size the rectifier voltage by Ohm's Law. Allowances should be made for the following:

(1) Back e.m.f. of the anode material to steel - - generally allow two volts.

(2) The resistance of the total circuit should be very low; therefore, driving potential should be provided for wiring and control circuit resistance.

(3) Allow at least 25 per cent additional voltage for aging of the stacks and high levels of polarization of the vessel. Generally speaking, for small vessels a minimum of 12 volts is provided. If several compartments are operated from a single rectifier, a control box with individual controls for each anode is utilized to advantage.

SPECIAL CONSIDERATIONS FOR VESSEL INSTALLATIONS

In some oilfield brines when sulfides are present, current densities above 15 ma sq ft seem to increase hydrogen blistering; however, no increase was observed at lower current densities.

When vessels are coated, the only assurance of not damaging the coating is by checking the potential. No potentials above one volt to a calomel electrode should be allowed on well coated vessels, especially those newly in service.

When vessels are filled after making an installation, the anodes may become coated with heavy crude which tends to remain in place after the anode is submerged in brine. When such coating makes the anodes passive, a reversal of polarity for a short period of time will tend to remove the oil. In other cases, high voltages of the correct polarity will remove the oil film.

CATHODIC PROTECTION OF WELL CASINGS

One of the greatest losses of steel to corrosion in the oil field is caused by the corrosion of well casings. As cathodic protection has now become generally accepted in many locations, a review of the general procedures is in order.

Probably the first consideration should be given to the location of the corrosion. Inspection of tubing and internal caliper surveys are helpful in making this determination. One must consider that both internal and external corrosion can occur in the same well.

In many fields a number of leaks may occur opposite the same formation, giving a clue to the external nature of the corrosion.

Casing potential profile surveys may show gross anodic areas opposite saltwater sands and other formations. These conditions would point to an external mechanism of corrosion.

The most reliable method of determining the nature of corrosion is to inspect the casing if it is possible to do so. In some instances when wells are abandoned and scrapped, investigation of the casing when it is pulled will give a good idea of the condition of the remaining wells in the field.

The eddy current tool, originally developed by Shell research, measures metal loss along the casing. It will not determine the location of the metal loss. In some locations these instruments have been run in conjunction with an internal caliper to give internal or external corrosion data.

Current Requirement Surveys

Two methods of determining the current requirement for cathodic protection of well casings are in common use, and when they are run with good procedure they will often confirm each other.

The Potential Profile Survey - The potential profile survey is conducted by contacting the casing internally with a known spacing between two sets of contacts and measuring the IR drop. This method gives the amount of current flowing in the casing, its direction, and the locations of the areas where current is entering or leaving the pipe. This survey is effective where large anodic areas are present but offers little help where small concentrated cells are caused by anerobic bacterial attack. To determine the current requirement for protection of the well the survey is rerun with different amounts of current being drained from the wellhead. By this method the minimum amount of current drain required to eliminate the gross anodic areas can be obtained.

When the corrosion mechanism is other than gross anodic areas, the impressed current is increased until all parts of the casing have current entering the pipe in quantities adequate to eliminate the offending depolarizer.

To run the potential profile survey the well must be killed with either oil based mud or oil. The unit will work in a dry casing.

E log I Current Requirement Surveys-This method requires that the well be insulated from all external lines and a temporary groundbed be used to impress current on the well in order to start polarization. Small increments of current are drained for short, accurately timed periods, after which the current source is removed and the potential is measured to a remote electrode. The minimum current considered to be adequate to protect the well is that current reading at which the potential becomes a straight-line function of the log of the current. A number of variations of this procedure have been used with success. Of the large number of casings which have been placed under cathodic protection, the largest number of current requirements have been determined by the E log I method.

As galvanic anodes will seldom produce enough current to protect a well casing the installations are primarily the rectifier-impressed anode type. The costs of these installations can vary considerably depending on the availability of power, the current requirement and soil resistivity. When quantities tend to lower overhead costs, the cost per well varies from some $350 to as much as $3,500 per well. The average cost would probably be in the range of $450 to $500 per well.