# Cathodic Protection of Oil Field Lease Equipment

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## PRINCIPLES OF CATHODIC PROTECTION

### General

A metallic surface that is in physical contact with liquid water is subject to corrosion due to the free energy retained by the metal while it was being reduced from the native ore. Corrosion is simply the return of the metal to its native ore by whatever path is available. Regardless of the process available, the first key step at ordinary temperatures and pressures is always a state of solution of the metal. Cathodic protection is a means of preventing that first key step in the corrosion process.

In oil field lease equipment the metal is nearly always some form of iron, which will be the only metal considered in this paper.

Iron in solution is positively charged; therefore, for an iron surface to suffer solution of iron there must be a discharge of positive current (ions) to the electrolyte. If we can set up circuitry such that the iron surface is receiving positive current from the electrolyte, we have made the surface a cathode by definition and it will not corrode. We call this process cathodic protection. To protect the entire surface, the entire surface must be cathodic, i.e., must be receiving positive current from the electrolyte. The electrolyte can be any water containing substance, such as soil, brine, etc.

### Flow of Current in an Electrolyte

To understand some of the problems with cathodic protection, it is important to understand how current travels in an electrolyte. Current travels in an electrolyte by way of the movement of charged ions which, compared to electrons, are extremely large and heavy, and the electrolyte greatly resists their movement. They are removed from solution at the surfaces of the anode and cathode; therefore, the first requirement is a continuing supply of ions. The second requirement is space so that we do not have to move too many ions per unit area. The third requirement is access to the surface of the anode and cathode by way of the electrolyte. This knowledge is used in the design of effective cathodic protection systems.

### Limitations of Cathodic Protection

Some limitations on cathodic protection are:

1. Cathodic protection does not work well inside of bare, small diameter pipelines; an anode each 5 diameters is a common requirement.
2. It cannot reach the surface of the cathode on the opposite side from the anode unless there is a large electrolyte path around the cathode.
3. It cannot penetrate deposits which stop the flow of ions or move the point of ion neutralization away from the metal surface. Some types of iron sulfide do the latter.
4. It cannot function inside a pipe when the anode is outside the pipe.
5. There is a definite limit to the number of square feet of cathode that can be protected in any given area in high resistivity soil.

### Aids to Cathodic Protection

Some of the means by which we aid cathodic protection are:

1. A coating on the cathode to reduce the surface area and/or to direct the protective current to the desired area.
2. Favorable anode placement.
3. Provide circulation to stagnant areas.

## PRODUCTION AND WATERFLOOD VESSELS

Several types of production and waterflood vessels are internally cathodically protected, such as heater-treaters, water knockouts, 3 phase separators, filters, water tanks, and lease storage tanks. When the electrolyte is not an extremely low tds surface water (containing chlorine perhaps), or does not contain $H_2S$ or low molecular weight organic acids, the cathodic protection is very straight forward. If one of these items is present, cathodic protection design will require all the knowledge of favorable anode placement plus, possibly, some coatings or circulation of static areas and, probably, some trial and error as well.

The economics of cathodic protection of vessels is generally good; it looks much better if the operator does much of his own design and installation work. Almost invariably, local operating and maintenance personnel must be able to do the checking and minor adjustments to have economic feasibility. This factor should be considered in the original design and installation.

## LEASE SURFACE LINES

Cathodic protection of flow lines, injection lines, and gas or water gathering lines is sometimes justified when they are buried. If the lines are coated, cathodic protection can nearly always be justified; bare lines are another matter.

A prediction of the need for cathodic protection can be made by consideration of the life of the project, diameter of the lines and the amount of clay soil, old mud pits, or brine soaked soil the lines pass through.

The most common method of cathodically protecting buried lease lines is to saturate the area of a leak with magnesium anodes. On lines 6 in. and larger, a "hot spot" survey followed by "hot spot" protection is sometimes used if the line passes through clay type soil for a large percentage of its length. Under similar circumstances, lines 4 in. and smaller are sometimes completely cathodically protected by magnesium anodes. It is good practice to protect suspected "hot spots" prior to actual pipe failure if the line passes through a good percentage of clay but not enough to justify either a "hot spot" survey or complete cathodic protection.

## OIL WELL CASING

The most important oil field lease equipment which is sometimes cathodically protected is oil well casing. A wide range of effectiveness is obtained in cathodically protecting oil well casing, varying from 0 to 100%.

### Limiting Factors

It is important to consider some of the limiting factors:

1. Casing is normally installed without coatings; moreover, it is installed in a bore hole in a back-fill in which corrosion protection is seldom a factor in design. If the mud is a type that produces a high current demand and the well is in a highly resistive formation, the pipe is effectively shielded against cathodic protection. Seldom is mud a critical factor in reducing the effectiveness of cathodic protection but certain types of mud or substitutes for mud can be deciding factors in increasing the effectiveness of cathodic protection.
2. Casing is passed through unfavorable zones with no coating and no opportunity for favorable anode placement.
3. Well spacing can be too close and the depth to which casing can be cathodically protected can be severely limited by mutual interference.

### Effectiveness

Considering all the possible adverse factors, it is quite amazing that good results are obtained with cathodic protection of well casings. Good figures are not available on area-wide effectiveness, but it is extimated that effectiveness in West Texas will average about 80%. Cathodic protection is assisted by the fact that seldom does a zone, that cannot be cathodically protected, extend over an entire field and the fact that corrosive zones are rarely very deep with 6,000 ft. being about the limit to date for West Texas-New Mexico.

### Economics

Fig. 1 shows the economics of cathodic protection in a field with the following assumptions:

1. Mud pit ground beds - installations at $400 each.
2. Field too small to install operator owned power lines. Power @ 2.5¢ per Kwh.
3. Fifteen amperes per well - 1 ohm circuits.
4. Pumper-gauger maintenance.
5. Watering at $10 per well per year.
6. Cost of casing repair - $10,000.

Break even point through 20 yr. at 80% efficiency is about 1.75% leaks per year predicted without cathodic protection.

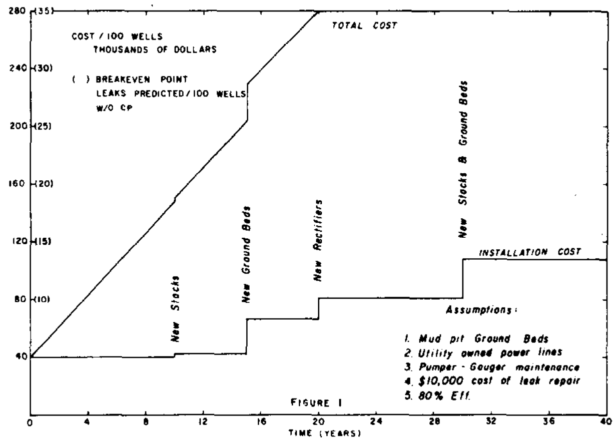


FIGURE 1

Fig. 2 shows the economics of cathodic protection in a field with the following assumptions:

1. Mud pit ground beds and operator owned power lines. Installations at $850 each. Power at 1¢ per Kwh.
2. Fifteen amperes per well - 1 ohm circuits.
3. Maintenance at $20 per well per year.
4. Watering @ $10 per well per year.
5. Cost of casing repair - $10,000.

Break even point through 20 yr. at 80% efficiency is about 1.57% leaks per year predicted without cathodic protection.

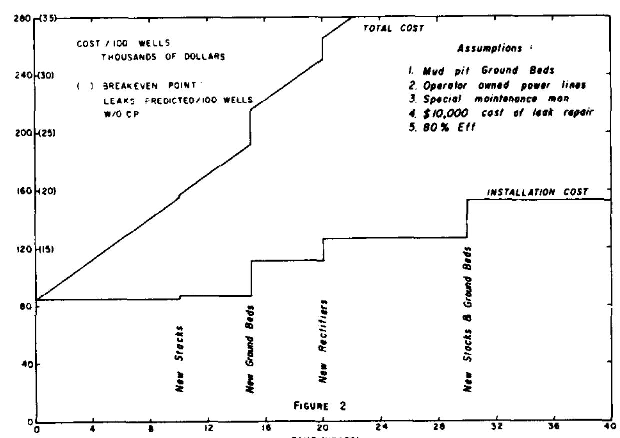


FIGURE 2

Fig. 3 shows the economics of cathodic protection in a field with the following assumptions:

1. Deep well individual ground beds 100 ft. deep and operator owned power lines. Installations at $1,100 each. Power at 1¢ per Kwh.
2. Fifteen amperes per well - 1/2 ohm circuits.
3. Pumper-gauger maintenance.
4. No watering necessary.
5. Cost of casing repair - $10,000.

Break even point through 20 yr. at 80% efficiency is about 1.38% leaks per year predicted without cathodic protection.

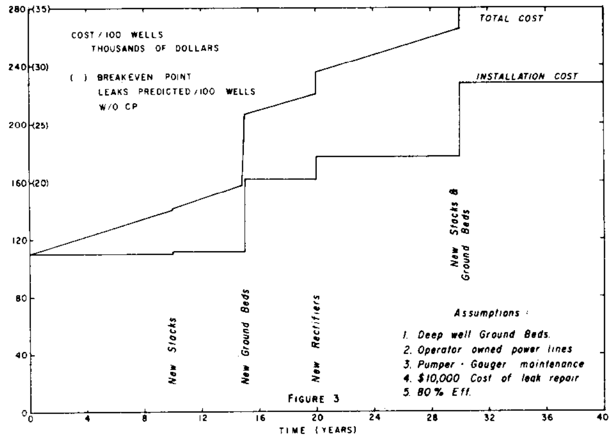
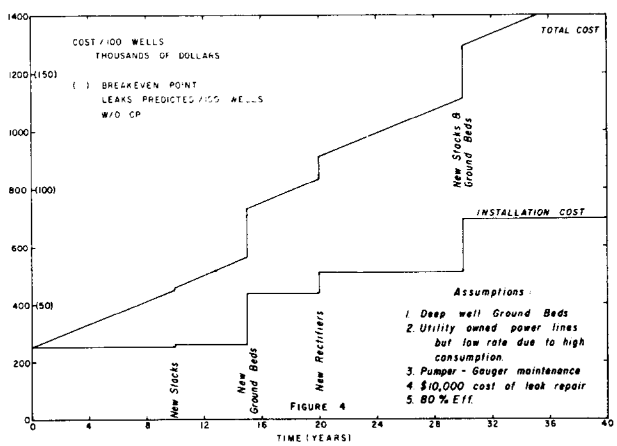



Fig. 4 shows the economics of cathodic protection in a field with the following assumptions:

1. Deep well individual ground beds 200 ft. deep and utility owned power lines. Installations are $2,500 each. Power at 1¢ per Kwh because of the amount used.
2. Fifty amperes per well - 1/2 ohm circuits.
3. Pumper-gauger maintenance.
4. No watering necessary.
5. Cost of casing repair - $10,000.

Break even point at 80% efficiency is about 11% leaks per year predicted without cathodic protection.




Certainly the 4 situations described in Figs. 1 through 4 do not describe all situations that will arise. They were chosen to illustrate several points:

1. Operating cost is very important - perhaps more important than the installation cost.
2. Every situation is different and calls for a special analysis.
3. Several types of installations are available for each situation.
4. The overall economics did not change very much as long as current remained the same but changed by a factor of almost 10 when the current was changed by a factor of 3.33.

An item which greatly affects the economics of cathodic protection is the cost of leak repair. The following table corrects the break even point of Figs. 1, 2, 3, and 4 for the cost of leak repairs.

Break Even Point
Per Cent Leaks Per Year

| | $2,000 per leak | $10,000 per leak | $30,000 per leak |
|---|---|---|---|
| Fig. 1 (15 amps) | 8.75 | 1.75 | .58 |
| Fig. 2 (15 amps) | 7.85 | 1.57 | .52 |
| Fig. 3 (15 amps) | 6.90 | 1.38 | .46 |
| Fig. 4 (50 amps) | 55.0 | 11.0 | 3.67 |

Early detection can prevent a $2,000 squeeze job from becoming a $10,000 liner job or a $10,000 squeeze job from becoming a $30,000 liner job. Therefore, an operator can change the entire economic picture by being alert to the casing corrosion problem.

## Prediction of Leak Frequency

Predicting the leak frequency is extremely important in determining the economics of cathodic protection. The familiar semi-log plot of log cumulative leaks versus time works very well in large fields. Casing inspection tools have been developed which can be used just prior to the time that there are enough points for a semi-log plot. Unfortunately, the sensitivity of these tools is such that casing has to be well corroded to get a response.

In smaller fields, economics dictates that decisions be made on such information as follows:

1. Time until first leak.
2. Offset operator's experience.
3. Information about the general area.

Information about the general area is available for most areas, but it may be difficult to assimilate. To date no one has seen fit to assemble, interpret, and make generally available information about casing corrosion in a state such as Texas, for example, although casing corrosion experience has been obtained virtually throughout the state.

It is ironic that 10% leaks per year can often be more easily shown in a small field than 1 to 2% leaks per year in a larger field. The double irony exists that the extremely severe, strongly localized corrosive areas encompassing a small field or a small part of a large field often do not respond to cathodic protection.

## Geological Comparisons of Corrosive Zones

Geological comparisons have been disappointing to date, probably because trained geologists are not interested in the zones that are corrosive and, conversely, we who are interested are not geologists. In very general terms, to date the most corrosive zones producing failure in 6 months to 5 years contain water, varying from sweet, fresh, almost potable water to heavy, sour brines, and no key corrodent has definitely been established. These zones are highly divided and stratified, non-continuous between offset wells, and with some regularity are found to be electrically shielded from the surface. Zones producing failure in 5 to 20 years commonly contain some type of clay, "red beds", or shale, and contain equally variable waters, but commonly can be correlated well to well.

### The Potential Profile Tool

The potential profile tool is useful in testing for interference, mutual interference, and determining current required for protection. A minimum of 1/2 milliampere per sq. ft. positive slope in the corrosive zone is being used as a criterion by some. On bare casing, the positive slope is a necessary, but not necessarily sufficient, condition for cathodic protection. It apparently works in most cases; but, like the E-log I curves, the profile can be misleading.

### Summary of Recommended Procedures

A summary of recommended procedures for dealing with casing corrosion in established wells is as follows:

1. Operate in such a manner that casing leaks are detected and repaired early.
2. When a casing leak is squeezed, try to get cement on as much of the casing as possible and with as much agitation and cleaning ahead of the cement as possible.
3. If cathodic protection is to be considered, run a potential profile in the field.
   a. If the field is small in area, make sure you do not have one of the highly localized corrosion problems that does not respond to cathodic protection; if the field is large in area, the presence of one of these zones in the test well should not affect the decision of whether to protect or not protect.
   b. Determine current requirement.
   c. Test for mutual interference if spacing is 40 acres or less regardless of current applied, or if current is more than 25 amperes regardless of well spacing. Item "c" does not apply if the formations from 0 to 6,000 ft. are very conductive, such as shales or clays.)
4. If cathodic protection is to be considered, run some E-log I tests. They may prove useful in determining irregularities in the field and may correlate the current requirement. When in doubt, use the profile data.
5. Run an economic study on several different methods of cathodic protection and be sure to include the operating cost in the studies.