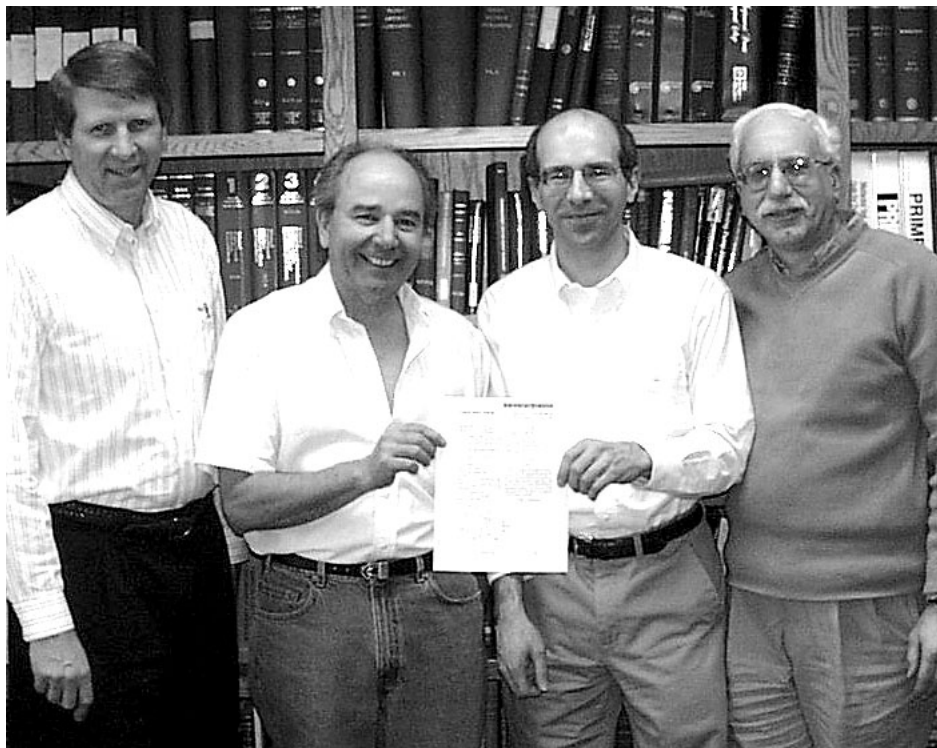


Tech Talk



Co-inventors Jerry Lorenc, Butch Henyan, Ken Hauenstein, and Gene Sabini show off their patent certificate.

Patented Technology: Future Foundation for Control Solutions

Gene Sabini

Director - Research, ITT Industrial Products Group

"Apparatus and Method For Controlling a Pump System," Patent Number US 6,464, 464 B2 was granted on October 15, 2002 to Industrial Products Group co-inventors Eugene Sabini, Jerome Lorenc and Oakley Henyan.

The patent covers all of the control algorithms for flow and pressure as well as all of the fault tolerance features and alarms on the original PumpSmart® device.

1. Loss of performance due to wear
2. Dead head protection/alarm
3. Low Flow protection/alarm
4. Closed Suction Valve protection/alarm
5. Thermal alarm
6. Over pressure alarm
7. Npsh protection/alarm

The highlight of the patent is the control algorithm which eliminates the need for "tuning" and "re-tuning" PID (Proportional, Integral, Differential) circuits found with traditional drives. PID circuits are known to

become unstable when system changes occur. We teamed with another colleague on "Method and System for Determining Pump Cavitation And Estimating Degradation in Mechanical Seals," Patent Number US 6,487,903 B2 was granted on December 3, 2002. Co-inventors this time were myself, Jerome Lorenc, Kenneth Hauenstein and Oakley Henyan.

This is a device which indicates when cavitation, due to insufficient NPSHa, occurs. When cavitation occurs in pumps with open seal chambers, the seal chamber evacuates leaving the mechanical seal to run dry. It only takes a few seconds for the seal faces to heat up have damage occur. Repeated exposure to cavitation causes the seals to fail prematurely. The patent proposes a technique to estimate remaining seal life.

The PumpSmart PS300 constantly compares the npsha versus the pumps' npshr and protects against cavitation damage by slowing the pump speed down until the cavitation is eliminated or by alarming. This requires loading in fluid properties and sets of npshr versus capacity tests run at 4 to 5 different speeds. The Cavitation Detector eliminates the need to load or run npshr data as it always detects when cavitation occurs regardless of fluid pumped and pump type. This technology is being incorporated into the PS200 product. ■

Material Matters

Galvanic or Dissimilar Metals Corrosion (Part 2)

Stephen Morrow

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Polarization

The potential produced by a galvanic cell often changes with time, due to the flow of current and corrosion reactions. The extent of corrosion is directly proportional to the current generated. As corrosion proceeds, reaction products and corrosion products accumulate at the cathode and anode respectively. This causes a polarizing effect, which controls the rate at which galvanic corrosion proceeds.

Since electrons flow between dissimilar metals in a galvanic couple, the current flow between anode and cathode causes potential shifts, as the electrical potentials of the metals coupled tend to approach each other. That is, the potential of the anode drifts towards that of the cathode and vice versa. This change or shift in potential is called polarization – anodic polarization (shift is from negative to positive) at the anode and cathodic polarization (shift is from positive to negative) at the cathode. The build-up of a hydrogen layer and increased electrons at the cathode surface is an example of cathodic polarization. The build-up of corrosion products and decrease of electrons at the anode surface is an example of anodic polarization.

To understand this polarization effect it is helpful to think about the negative electrode or anode becoming more positively charged, and shifting towards the positive electrode or cathode as electrons leave the metal. At the same time the positive electrode (cathode) becomes more negatively charged, and shifts towards the negative electrode (anode) as electrons collect or move into the metal. The corrosion current (I_{corr}) and corrosion potential (E_{corr}) is measured where these polarization curves intersect, as illustrated in Figure 4.

The magnitude of the potential shift is dependent on the environment, as well as the material's initial potential. When the potential shift of the anodic metal moves in the direction of the cathode, electron or current density flow is reduced as illustrated in Figure 4, so the galvanic corrosion is not as severe as would otherwise be expected. If the cathodic metal is more easily polarized, its potential shifts more towards the active anodic metal's potential and the corrosion rate/current density

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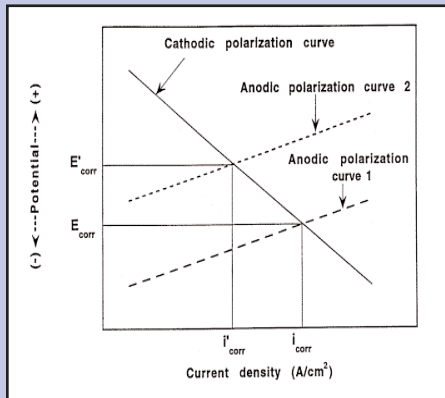


Figure 4. Polarization curves illustrate potential shift of anode in direction of cathode resulting in a reduction of the current density (corrosion rate) from i_{corr} to i'_{corr} .

is also reduced. On the other hand, when the anode potential shift is more easily polarized towards the cathode, with little potential shift or polarization of the cathode, there is an increase in current density and accelerated corrosion occurs.

Surface Area Effects

An important factor in galvanic corrosion is the area effect, or the ratio of the cathodic to anodic surface areas (see Figure 5). Corrosion of the anodic metal is both accelerated and more damaging as the voltage difference increases, and as the cathode area increases relative to the anode area. For any given current in a corrosion cell, the current density (amperes per unit area) is greater coming from a smaller area than a large one. The greater the current density leaving the anodic area, the greater the corrosion rate.

When the anodic current density (corrosion rate) on the active metal is small, the resulting

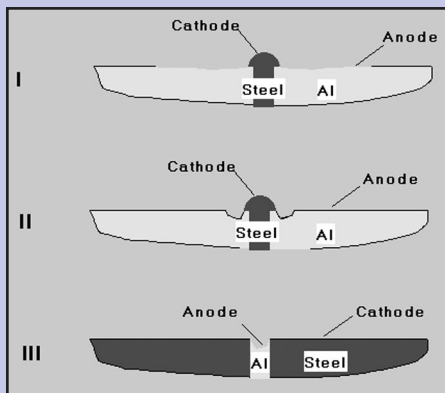


Figure 5. Galvanic Effects related to surface area ratio and electrolyte conductivity.

- I large anode-to-cathode ratio in high conductivity electrolyte.
- II large anode-to-cathode ratio in low conductivity electrolyte.
- III small anode-to-cathode ratio effect – rapid attack of the anode.

slow anodic polarization leads to less galvanic corrosion. A large anode surface will polarize slower than a small anode surface, producing much less galvanic corrosion due to the greatly reduced current density at the anode (See Figure 5 Condition I). The opposite area ratio effect (large cathode surface, small anode surface) produces more pronounced galvanic corrosion. A large cathode surface will polarize slower than a small cathode surface, causing more rapid corrosion of the anode due to an increased current density at the anode (See Figure 5 Condition III).

Unfavorable design ratios consist of small anode-to-large cathode surfaces. This area ratio is undesirable, because the galvanic current becomes highly concentrated onto the small anodic surface area, resulting in accelerated corrosion as illustrated in Figure 5 Condition III. Smaller anodic surfaces suffer deeper and more penetrating corrosion than larger ones. For this reason designs should always avoid creating small anodes connected to large cathodes. The desired arrangement when galvanic couples can not be avoided is the large anode-to-small cathode surface area ratio.

Therefore, barrier coatings applied only to anodic surfaces are undesirable, and present a serious corrosion risk because any coating breaks, defects, or imperfections can expose very small anode areas to much larger cathode areas. This often results in rapid corrosion (high current density) at the small anode sites. For this reason, the practice of applying barrier coatings to anode surfaces alone is not recommended. Galvanic sacrificial coatings (e.g. zinc coating) that provide cathodic protection are preferred.

Coating both anode and cathode surfaces, or only the cathode surface will reduce the rate of corrosion. Limiting the effective cathodic area by coating it reduces corrosion at the anode as well. Barrier coating the cathode alone is better than anode alone, as this reduces the cathodic surface area, and minimizes the corrosion rate controlling cathodic reactions. Increasing the anodic area by leaving it un-coated or by removing an existing barrier coating will also reduce corrosion rates by lowering the current density.

Moreover, in many environments, the oxygen-reduction reaction is of primary importance. In most cases the amount of dissolved oxygen available at the cathode, and the amount of surface area where oxygen-reduction can occur, controls the intensity and rate of corrosion.

The lack of dissolved oxygen in deaerated solutions limits the reduction reactions to metal ion reduction, or the formation of hydrogen gas, which tends to develop a barrier film on the cathode surface. This effectively reduces the cathode surface area and slows the corrosion rate.

Electrolyte Conductivity and Distance Effect

The conductivity of the environment or electrolytic nature is an important consideration. When large surface areas are in contact with high conductivity solutions, such as seawater; the attack on the anodic metal may be spread a great distance from its contact point with the cathodic metal, as shown in Figure 5 Condition I. This is less severe in low conductivity soft waters where the attack is usually restricted to the vicinity of contact, as shown in Figure 5 Condition II.

Galvanic couples of dissimilar metals that are in close physical proximity usually suffer greater galvanic corrosion than those further apart. The intensity of galvanic effects is usually greatest at the point where the anode and cathode are closest, and falls off as separation distance increases. (See Figure 5 Condition I and II). This effect is due to electrolyte resistance, which makes it more difficult for current to flow great distances. The distance effect is dependent upon the electrolyte conductivity and resistance, since current movement is of principal concern in corrosion.

Managing Galvanic Corrosion

Galvanic corrosion can be managed and made to work toward the durability of fluid handling equipment by understanding and utilizing the principles that govern it. Galvanic corrosion is perhaps the only form of corrosion that can be beneficial as well as detrimental. The materials engineer will regularly select galvanic corrosion – that is cathodic protection using galvanic sacrificial anodes, or coatings to reduce corrosion of equipment and structures.⁽⁸⁾ Noting the protective function, design engineers often use active materials as cathodically protective pigments (e.g., inorganic zinc primer and paint), that will sacrifice electrons to oxidation, thus protecting steel.

Galvanic corrosion concerns are important when designing products. Under some conditions the cathodic hydrogen-reduction is important as it may be adsorbed into cathode surfaces. When high-strength materials are used such as fasteners or shafting in assemblies, or cathodic protection systems are employed, the amount of hydrogen adsorbed can result in hydrogen embrittlement and cracking failures.

Material Matters

Selecting materials for fasteners, weld filler metals, and critical components such as pump and valve internals can take advantage of the galvanic effect, making these assemblies more durable. In fact pump and valve designs often incorporate dissimilar metals to provide a protective galvanic sacrificial anode effect to critical components such as internals and fasteners in assemblies. Large anodic metals are often furnished as thick-walled components to provide large sacrificial surface areas with low current densities. The general uniform corrosion attack of these surfaces is hardly noticeable, while critical components are significantly protected.

For example, large vertical turbine intake pumps of austenitic stainless steels (SS) perform well in chloride services as long as the pumps are operating and not left idle under stagnating conditions. However, spare pumps are usually made available for standby so they can be put into service promptly if one of those in operation shuts down. During standby periods in chloride media such as seawater, SS is subject to localized corrosion such as pitting, crevice corrosion and microbiological influenced corrosion (MIC). To prevent damage, large vertical pumps used in seawater are often constructed with type 316 SS internals, assembled to massive surface area thick-walled aluminum-bronze or austenitic cast iron (Ni-Resist) columns, casings and suction bells. The bronze and austenitic iron components are more anodic to SS and offer low uniform/general corrosion in seawater.

By design, the more noble austenitic SS internals are cathodically protected from localized corrosion by the galvanic effects provided from contact with more anodic active metals. Alternative designs incorporate attachment of galvanic sacrificial anodes (e.g. aluminum alloys) strategically placed within the pump equipment to provide cathodic protection.

A note of caution: If one reviews the Galvanic Series in Seawater, you will notice that graphite-carbon materials hold an electro-potential position that is as noble as platinum. Graphite-filled bushings, packing, gaskets and other carbon containing materials are very noble non-metallic conductors that can lead to severe galvanic corrosion in contact with metals and alloys of aluminum, copper, stainless steels, and other metals; due to significant potential differences when coupled together. These combinations are not recommended and are best avoided in designs if possible. Similarly, dual phase alloys such as duplex stainless steels, gray cast iron or high-zinc brass alloys, often have one phase that may be more

active than the other and preferentially corrode as the anode. The selective loss of the anodic phase is often referred to as selective leaching or de-alloying. In the case of high-zinc brass alloys, the zinc-rich phase would be more active than the copper-rich matrix phase, often leading to de-zincification in susceptible alloys.

Finally, ions of a more noble metal may sometimes be reduced on the surface of a more active metal (e.g., copper on aluminum or steel, silver or lead on copper, etc.). The resulting metallic deposit provides cathodic sites for galvanic corrosion and pitting of the more active base metal. This is often a concern in boilers and plumbing systems.

Protective Measures

If dissimilar metals are coupled without thought, consequences can be disastrous. As discussed above, galvanic corrosion can be used to our advantage as in cathodic protection by galvanic sacrificial anodes. Bolts, screws, and other fasteners used in assemblies should generally be made of more noble metals less likely to be oxidized, so those critical components are cathodically protected. Sacrificial anodes are commonly used with coatings to control corrosion in fluid handling equipment and on the underwater section of ships, piers, and other marine structures. The same principles can be used to protect steel if the anode metal is applied as a coating. Zinc (galvanizing) and aluminum (aluminizing) coatings are widely used to protect steel in corrosive environments: Examples are galvanized fasteners and automotive body panels, or aluminized automotive exhaust systems.

Under fully immersed conditions, a rough rule of thumb is that zinc coatings one mil (0.001 inch) thick will protect steel for about one year in marine environments.

There are three conditions that must exist for galvanic corrosion to occur. First there must be two electrochemically dissimilar metals or conductive non-metal present. Second, there must be an electrically conductive path between the two materials. And third, there must be an electrolyte providing a conductive path for the metal ions to move between the anode to cathode surfaces. If any one of these conditions does not exist, galvanic corrosion will not occur.

Galvanic Corrosion – Protection Methods

- **Materials selection** - Change materials to avoid dissimilar metal couples that are far apart. Select combinations of metals that will be in electrical contact from groups as close together as possible in the galvanic series to minimize electrical potential differences.

- **Modify the Environment** - Change the environment wherever practical. Add corrosion inhibitors and scavengers to control pH, remove aggressive ions and oxygen, or lower the conductivity of the environment.

- **Protective Coatings** - Barrier films/coatings (e.g. barrier, inhibitive, sacrificial) can be used to isolate the materials from the environment. Apply coatings with caution – Note that it is extremely dangerous to coat only the anodic member of a couple, since this may only reduce its area, resulting in an undesirable area ratio and concentrate accelerated attack at “holidays” or imperfections in the otherwise protective coating. If inert or organic barrier coatings are utilized, both the anode and cathode should be coated. Sacrificial coatings that provide cathodic protection are best if only the anodic metal will be coated.

- **Electrical Isolation** - Electrically insulate dissimilar metals wherever practical. If couples between dissimilar metals are unavoidable, the surfaces should be separated by inert spacers or thick barrier films of nonconductive coatings to break electrical continuity and provide electrical isolation. If complete insulation cannot be achieved, protective coatings at junctions (to increase resistance of the circuit and effect area ratios) will help.

- **Electrochemical Techniques** - Install cathodic protection systems to suppress galvanic corrosion by using galvanic sacrificial anodes or impressed current systems.

- **Design** – Avoid dissimilar metals in contact, unfavorable area ratios, and use more noble metals for critical components. Use designs that avoid crevices such as threaded connections, and provide for drainage. Avoid joining materials that are far apart on the galvanic series by threaded connections, as the threads will generally deteriorate rapidly. Seal and eliminate all crevices if possible, preferably by welding. ■■■

REFERENCES

(8) Gregory Kobrin, “Materials Selection.” ASM Metals Handbook, Ninth Edition, Volume 13, Corrosion, 1987, ASM International, p 324.