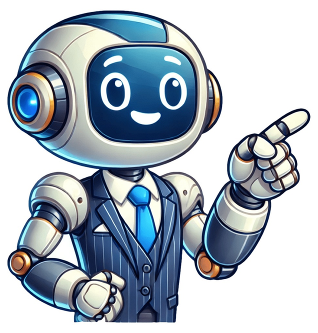

Impressed current cathodic protection (ICCP) is a corrosion mitigation strategy that uses the power of electricity to inhibit the electrochemical reactions responsible for metal corrosion.This approach is widely used in construction, marine, and oil and gas industries. The oil and gas sector relies on impressed current cathodic protection to shield buried pipelines carrying vital resources, as these are highly susceptible to external corrosion from perpetual soil and water contact. In previous articles, we provided an overview of cathodic protection and its importance in safeguarding metal from corrosion. Now we will take you on a deep dive into the world of Impressed Current Cathodic Protection.We will explain how ICCP works and explore the survey methods for monitoring its performance on buried pipelines. Corrosion is a natural process that affects metal. The degree of corrosion depends on the metal type and surrounding environment. Metal atoms have loosely attached electrons that they tend to lose.When a metal is placed in an electrolyte, such as seawater, this tendency leads to the formation of an electric potential difference between anodic and cathodic areas on the metal surface. Corrosion happens when the metal loses electrons from the areas that act like anodes. Impressed Current Cathodic Protection (ICCP) applies a low-voltage direct current to a metal structure, such as a buried pipeline or ship hull, to stop corrosion. This forces the entire metal surface to become a cathode, which stops the loss of electrons and prevents corrosion. An Impressed Current Cathodic Protection (ICCP) system is composed of: Rectifier – an electrical device that converts alternating current (AC) from the power grid into direct current (DC). Anode – an inert, conductive material (e.g., mixed metal oxide or graphite) buried in the soil at some distance from the pipeline. Reference Electrode – a specialized electrode buried near the pipeline that measures the electrical potential between the pipeline and the surrounding soil. The rectifier sends electrical current from the anode to the metal, making it the cathode in the electrochemical reaction. This way, the current is “impressed” onto the metal structure, hence the name “impressed current cathodic protection.”This impressed current creates a negative electrical potential on the metal, which counteracts the natural corrosion-causing potential difference between the metal structure and the surrounding environment.The reference electrode monitors the potential difference and provides feedback to the rectifier, allowing the system to automatically adjust the current to maintain the desired level of cathodic protection. Without any corrosion protection, a buried metal pipeline is susceptible to electrochemical corrosion due to the differences in electrical potential between the pipeline and the surrounding soil or seawater.This can lead to gradual deterioration and eventual pipeline failure over time. ICCP protects the pipeline from corrosion by applying a low-voltage direct current to the external surface of the buried pipeline, which becomes the cathode in an electrochemical reaction.This current creates a protective barrier around the pipeline, preventing the corrosion-causing chemical reactions from taking hold. Pipeline and Subsea Systems SoftwareLooking for a dedicated solution to centralize and analyze your pipeline ICCP survey data? Get started with IMS PLSS. Request a demo ICCP provides active, continuous protection against corrosion, unlike passive methods like sacrificial anodes. The system can be designed to provide adequate protection for the entire pipeline length, even in varying soil conditions. ICCP can be monitored and adjusted remotely, allowing for efficient maintenance and optimization of the system. ICCP is highly effective in preventing corrosion, which can significantly extend the lifespan of buried pipelines. By understanding the principles of impressed current cathodic protection (ICCP) and applying them to pipelines, the oil and gas industry can effectively prevent corrosion, maximize the lifespan of pipelines, and reduce the costs associated with maintenance and replacement. Any corrosion to the pipeline can lead to leaks, environmental contamination, and disruptions in delivering essential resources like oil, gas, and water. For that reason, maintaining the integrity of buried pipelines is critical, and impressed current cathodic protection (ICCP) systems play a pivotal role in this endeavor.However, simply installing an ICCP system is not enough – regular monitoring and maintenance are essential to ensure its long-term effectiveness in preventing corrosion. Industry best practices recommend that ICCP systems undergo comprehensive surveys at least once a year. These annual assessments provide a thorough evaluation of the system’s performance. They allow you to identify any areas where the protection may be inadequate or compromised.By conducting these surveys diligently, you can avoid potential issues and make informed decisions about necessary repairs or upgrades to the system. This survey measures the potential between the pipeline and surrounding soil/water to evaluate the CP system’s effectiveness. There are two key potential measurements: “On” potentials with CP current applied, indicating protection level. “Instant off” potentials with CP current interrupted, showing true polarized potential. Adequate protection is confirmed if either: “Instant off” potential is -850 mV or more negative vs copper/copper sulfate reference “Instant off” potential is at least 100 mV more negative than the native (unprotected) potential If potentials don’t meet these criteria for effective cathodic protection, adjustments need to be made to the CP system. The CP potential survey provides critical data on the CP system’s availability and effectiveness, allowing pipeline operators to verify adequate corrosion protection. This survey measures the electrical potential along the Onshore pipeline at close intervals, typically every 1-2 meters. It assesses the CP protection effectiveness along the entire pipeline and helps localize areas of insufficient protection. This survey measures the voltage gradient on the surface of the soil or water above the pipeline. It is a handy way to measure coating effectiveness and detect coating defects. Areas with high voltage gradients indicate potential coating damage, which can lead to corrosion if left unrepaired. The survey aims to identify moisture intrusion in the insulation of ICCP anodes or cables. It is conducted by applying a voltage between the anode or cable and the pipeline. If the current flows, the moisture is present in the insulation. This helps pinpoint areas where insulation has deteriorated or sustained damage, potentially compromising the ICCP system’s effectiveness or leading to system failure. The rectifier station survey evaluates the performance and condition of the rectifier, which powers the ICCP system. The survey measures the input and output voltages and currents, and the rectifier components’ condition. The goal is to ensure the rectifier is operating within its design parameters and providing the necessary current to the ICCP system. Any issues identified, such as high resistance connections or malfunctioning components, should be addressed promptly to maintain the system’s effectiveness. Discover IMS PLSSIMS PLSS is a Pipeline and Subsea Integrity cloud-based software. Gain control of your operations with features such as Anomaly Management, Scenario Assessment and our Traffic Light System. Learn More While the ICCP systems are crucial for preventing corrosion, the data gathered through the ICCP surveys are invaluable, as they can be used to make informed choices that preserve the integrity of buried pipelines. Cenosco’s IMS PLSS (Pipeline and Subsea Systems) provides pipeline operators with a comprehensive platform to manage all aspects of pipeline integrity, including ICCP survey planning and data analysis.One of the key features of IMS PLSS is its ability to generate schedules for ICCP surveys, ensuring that these critical inspections are conducted at appropriate intervals. Once the surveys are complete and data entered into the system, the repair schedules can also be triggered, based on the survey findings. The External Corrosion module within IMS PLSS serves as a centralized hub where operators can consolidate and examine ICCP survey data alongside other pipeline integrity information. It features a dedicated section for ICCP data, where you can easily input survey findings, detect issues, and track historical trends.This module allows you to calculate the external corrosion rate of your pipeline thus ensuring that ICCP data is seamlessly incorporated into the external corrosion calculation, promoting a holistic approach to pipeline integrity and external corrosion prevention. Want to learn more about IMS?Request a demo below to get a first-hand look at its capabilities! Impressed current cathodic protection (ICCP) is an electrochemical process used to prevent corrosion in metal structures by applying a controlled electrical current to the metal. This process involves the use of an external power source to apply an electrical current to the metal structure, which effectively creates a cathode and thus reduces the corrosion rate of the metal. ICCP is widely used in various industries, such as oil and gas, marine and construction, to protect metal structures from corrosion. For example, in the marine industry, ICCP is used to protect the hulls of ships, offshore platforms, and pipelines from the corrosive effects of seawater. In the oil and gas industry, ICCP is used to protect pipelines and storage tanks from the corrosive effects of the fluids being transported and stored. The effectiveness of ICCP is based on Faraday’s law of electrolysis, which relates the amount of corrosion protection provided by ICCP to the amount of current applied to the metal. The mathematical formula for Faraday’s law is as follows: $I = (W \times D) / (n \times F \times Z)$ Where: “I” is the current required for cathodic protection, in amperes. “W” is the weight loss due to corrosion, in grams per square meter per day (g/m2/day). “D” is the density of the metal, in grams per cubic centimeter (g/cm3). “n” is the valence of the metal ion being reduced. “F” is Faraday’s constant, which is equal to 96,485 coulombs per mole (C/mol). “Z” is the number of electrons involved in the reduction reaction. This formula is used to determine the amount of current required to provide adequate cathodic protection to the metal structure. Corrosion is a major problem for metal structures in various industries, including oil and gas, marine and infrastructure. Corrosion leads to the degradation of metal structures, which can cause safety hazards, environmental pollution, and economic losses. ICCP is a widely used method for preventing corrosion in these industries. The principle of ICCP is to create an electrical potential difference between the metal structure to be protected (the cathode) and an inert anode. The potential difference should be negative enough to prevent the electrochemical reaction that causes corrosion. The current that flows from the metal structure to the anode provides a protective layer of electrons that prevents the reaction from occurring. The effectiveness of the ICCP system depends on the current density, which is the amount of current per unit area of the metal surface. The injected current should be just enough to overcome the original corrosion current and result in an impressed protection current, which flows in the complete circuit. The correct value of protection current can be determined by reference electrodes. Reference electrodes are typically made of either zinc or silver and may be used as the signal source to automatically regulate the value of protection current. If the current injection is too high, hydroxyl ions will release at a rate causing the the anti-fouling paint to sponge and flake. The current density required for ICCP depends on several factors, including the type of metal, the environment and the level of corrosion. The required current density can be calculated using the following formula: $CD = (I / A) \times K$ Where: “CD” is the current density. “I” is the current output of the ICCP system. “A” is the surface area of the metal structure. “K” is a correction factor that accounts for the specific conditions of the environment. ICCP is a reliable and effective method for preventing corrosion in metal structures. However, it requires regular monitoring and maintenance to ensure its effectiveness. The reference electrode and anode need to be replaced periodically, and the ICCP system needs to be adjusted to account for changes in the environment. Corrosion is a naturally destructive phenomenon that occurs when some metals are exposed to the environment. The reaction between air, moisture and the metal substrate gives rise to specific chemical reactions that cause the metal to convert to its more chemically-stable oxide, hydroxide or sulfide form. In iron-based metals, such as steel, corrosion comes in the form of iron III oxides, also known as rust. For electrochemical corrosion to occur, three ingredients must be present: an anode, a cathode and an electrolyte. The anode and cathode are usually connected via a continuous electrical path while both are immersed in the same electrolyte. During this process, the anode experiences corrosion, while the cathode remains unaffected. Figure 1. A typical electrochemical cell showing electrons flowing from the anode to the cathode through an electrical connection. (Source: Alksub at the English Wikipedia / CC BY-SA) There are various methods to prevent and control corrosion. One of these is known as cathodic protection (CP). This technique works by connecting the metal to be protected to a more easily corroded "sacrificial metal." This sacrificial metal corrodes preferentially (acting as the anode) while the more valuable metal object under consideration (acting as the cathode) remains protected. In this article, we will explain how this sacrificial protection method works and describe its various applications. To understand how cathodic protection works, we must first appreciate the basics of bimetallic corrosion, also known as galvanic corrosion. Bimetallic corrosion, as its name implies, is a unique type of corrosion that occurs between the pairing of two metals. This corrosion is observed in several situations where dissimilar metals are in direct or indirect contact with each other. Bimetallic corrosion is usually characterized by accelerated corrosion in one metal while the other remains unaffected. In other words, one metal sacrifices itself while protecting the other. (This process is examined more fully in the article Why Do Two Dissimilar Metals Cause Corrosion?) Corrosion in an electrochemical cell is driven mainly by a property known as potential difference. This potential difference causes electrons to flow from one metal in the cell (the anode) to the other metal (the cathode) while generating a small amount of electricity in the process. As electrons flow out of the anode, oxidation occurs, causing the anodic metal to degrade or corrode. Meanwhile, as electrons flow to the cathode, reduction occurs, further protecting the cathodic metal. In bimetallic corrosion, this potential difference is a direct result of the difference in electrode potential between the two dissimilar metals. When a metal is immersed in an electrolyte, it adopts an electrode potential that represents the metal’s ability to be oxidized or reduced. The electrode potential of various metals is displayed on a list known as the galvanic series. (See An Introduction to the Galvanic Series: Galvanic Compatibility and Corrosion for more information.) The metals positioned higher on the table are considered to be anodic (more electronegative), while the metals placed lower on the table are more cathodic (more electropositive). The further apart the contacting metals are in the galvanic series, the greater the potential difference between the metals, thus the more severe the corrosion at the anode. Cathodic Protection (CP) and Its Method of Operation While the design of cathodic protection systems can be sophisticated, their operation is based on the concept of bimetallic or galvanic corrosion described earlier. By understanding the principles of this type of corrosion, we can purposely pair metals together to ensure that one cathodically protects the other. In other words, if we want to protect a particular metallic structure, we can create conditions where this metal becomes the cathode of an electrochemical cell. By electrically connecting the metal to be protected to a more anodic (electronegative) metal, we can ensure that the anode sacrifices itself by corroding preferentially over its cathodic counterpart. In some cases, external power sources can be used to supply additional electrons to the electrochemical process, which can increase the effectiveness of cathodic protection. Cathodic protection systems are employed in numerous industries to protect a broad range of structures in challenging or aggressive environments. The oil and gas industry, in particular, uses cathodic protection systems to prevent corrosion in fuel pipelines, steel storage tanks, offshore platforms, and oil well casings. In the marine industry, this protection method is also used on steel piles, piers, jetties and ship hulls. Another common type of cathodic protection, known as galvanizing, is commonly used to protect steel members and structures. (To learn more, read Galvanization and its Efficacy in Corrosion Prevention.) Types of Cathodic Protection (CP) As mentioned previously, cathodic protection works by intentionally forming a galvanic cell with another sacrificial metal. This can be achieved by employing two distinct types of cathodic protection: passive cathodic protection and impressed current cathodic protection. Passive cathodic protection In passive cathodic protection systems, the sacrificial anode is connected directly or indirectly to the metal to be protected. The potential difference between the two dissimilar metals generates adequate electricity to form an electrochemical cell and drive galvanic or bimetallic corrosion. This type of protection is commonly used in the oil and gas industry to protect the structural steel members of offshore rigs and platforms. Here, aluminum bars (or another suitable metal) are mounted directly on steel sections to assume the role of the sacrificial metal. Steel water heaters, tanks and piles are also cathodically protected using a similar method. Figure 2. Schematic of a pipeline being protected by a sacrificial anode using passive cathodic protection methods. Notice how there is no external power source involved. Another common example of passive cathodic protection is hot-dipped galvanized steel. During this process, steel members or structures are immersed in a molten zinc bath that coats the object. When the steel is removed from the molten zinc, it reacts with air and moisture to form a protective layer known as zinc carbonate, which creates a galvanic cell with the steel. When the steel member is scratched or damaged, such that the substrate is exposed, the surrounding zinc coating acts as the sacrificial anode and corrodes preferentially to protect the exposed steel. This type of protection continues until the nearby zinc is depleted. Impressed current cathodic protection (ICCP) In large structures, it may not be feasible to use passive cathodic protection methods. The number of sacrificial anodes required to deliver enough current to provide adequate protection can either be unrealistic or impractical. To address this, an external power source is used to assist in driving the electrochemical reactions. This technique is known as impressed current cathodic protection (ICCP). ICCP systems are ideal for protecting lengthy structures, such as underground pipelines. The flanges of connecting pipes are usually insulated using isolation kits to separate the pipes into smaller, more manageable sections for the purposes of ICCP protection. Figure 3. Schematic of an object being protected by an anode using impressed current cathodic protection (ICCP) methods. Notice how an external DC power source is involved. Limitations of Cathodic Protection In large pipeline networks, there may be many crossings, parallelism and approaches near the pipeline’s CP system. DC interference may occur between pipelines, which accelerates corrosion. In order to overcome this problem, pipelines can be electrically coupled, either directly or through resistance. For coated pipelines, cathodic disbondment may occur due to high CP levels where the applied coating quality is poor. Higher temperatures may also promote cathodic disbondment. High pH environments are also a concern in terms of stress-corrosion cracking. Conclusion Cathodic protection is a popular protection method for preventing corrosion in pipelines, offshore oil platforms and other steel structures. However, to be implemented effectively, it is crucial to understand the basic principles of bimetallic/galvanic corrosion. Choosing the right type of cathodic protection system depends on several factors, including cost-effectiveness and the size of the structure to be protected. Share This Article Impressed current cathodic protection (ICCP) is an electrochemical process used to prevent corrosion in metal structures by applying a controlled electrical current to the metal. This process involves the use of an external power source to apply an electrical current to the metal structure, which effectively creates a cathode and thus reduces the corrosion rate of the metal. ICCP is widely used in various industries, such as oil and gas, marine and construction, to protect metal structures from corrosion. For example, in the marine industry, ICCP is used to protect the hulls of ships, offshore platforms, and pipelines from the corrosive effects of seawater. In the oil and gas industry, ICCP is used to protect pipelines and storage tanks from the corrosive effects of the fluids being transported and stored. The effectiveness of ICCP is based on Faraday’s law of electrolysis, which relates the amount of corrosion protection provided by ICCP to the amount of current applied to the metal. The mathematical formula for Faraday’s law is as follows: $I = (W \times D) / (n \times F \times Z)$ Where: “I” is the current required for cathodic protection, in amperes. “W” is the weight loss due to corrosion, in grams per square meter per day (g/m2/day). “D” is the density of the metal, in grams per cubic centimeter (g/cm3). “n” is the valence of the metal ion being reduced. “F” is Faraday’s constant, which is equal to 96,485 coulombs per mole (C/mol). “Z” is the number of electrons involved in the reduction reaction. This formula is used to determine the amount of current required to provide adequate cathodic protection to the metal structure. Corrosion is a major problem for metal structures in various industries, including oil and gas, marine and infrastructure. Corrosion leads to the degradation of metal structures, which can cause safety hazards, environmental pollution, and economic losses. ICCP is a widely used method for preventing corrosion in these industries. The principle of ICCP is to create an electrical potential difference between the metal structure to be protected (the cathode) and an inert anode. The potential difference should be negative enough to prevent the electrochemical reaction that causes corrosion. The current that flows from the metal structure to the anode provides a protective layer of electrons that prevents the reaction from occurring. The effectiveness of the ICCP system depends on the current density, which is the amount of current per unit area of the metal surface. The injected current should be just enough to overcome the original corrosion current and result in an impressed protection current, which flows in the complete circuit. The correct value of protection current can be determined by reference electrodes. Reference electrodes are typically made of either zinc or silver and may be used as the signal source to automatically regulate the value of protection current. If the current injection is too high, hydroxyl ions will release at a rate causing the the anti-fouling paint to sponge and flake. The current density required for ICCP depends on several factors, including the type of metal, the environment and the level of corrosion. The required current density can be calculated using the following formula: $CD = (I / A) \times K$ Where: “CD” is the current density. “I” is the current output of the ICCP system. “A” is the surface area of the metal structure. “K” is a correction factor that accounts for the specific conditions of the environment. ICCP is a reliable and effective method for preventing corrosion in metal structures. However, it requires regular monitoring and maintenance to ensure its effectiveness. The reference electrode and anode need to be replaced periodically, and the ICCP system needs to be adjusted to account for changes in the environment. Share — copy and redistribute the material in any medium or format for any purpose, even commercially. Adapt — remix, transform, and build upon the material for any purpose, even commercially. The licensor cannot revoke these freedoms as long as you follow the license terms. Attribution — You must give appropriate credit , provide a link to the license, and indicate if changes were made . You may do so in any reasonable manner, but not in any way that suggests the licensor endorses you or your use. ShareAlike — If you remix, transform, or build upon the material, you must distribute your contributions under the same license as the original. No additional restrictions — You may not apply legal terms or technological measures that legally restrict others from doing anything the license permits. You do not have to comply with the license for elements of the material in the public domain or where your use is permitted by an applicable exception or limitation . No warranties are given. The license may not give you all of the permissions necessary for your intended use. For example, other rights such as publicity, privacy, or moral rights may limit how you use the material. In our last article, we examined electrochemical corrosion and introduced the major areas where cathodic protection is used to protect against corrosion in aggressive environments such as soils, waters, and chloride contaminated concrete. In this article, we take a deeper dive into how cathodic protection works. The two types of cathodic protection There are two types of cathodic protection: galvanic anode and impressed current cathodic protection. Both provide a cathodic protection current flow from cathodic protection anodes placed within the same electrolyte as the metal to be protected. The current flows from the anode into the electrolyte. It discharges onto the metal, controlling the corrosion. It must flow within the metallic circuit (the metal plus the cables) and back to the anode to complete the circuit. Galvanic anode cathodic protection (GACP) Galvanic anode cathodic protection works as summarised above. The anode materials are alloys of either zinc, aluminium, or magnesium – all more active metals than, for example, carbon steel. These more active metals corrode preferentially to the steel when they are metallically connected to the steel in an electrolyte. The corrosion current of the anode material is the cathodic protection current for the steel. The current flows through the electrolyte onto the steel, controlling its corrosion. The current returns to the anode in the metallic circuit. You may have heard the term ‘sacrificial anodes’. However, though this terminology describes the anode materials and how they act (the galvanic anode corrodes preferentially to the steel), it was changed in Europe in the 1980s to ‘galvanic anodes’. You may see galvanic anode cathodic protection identified by the acronym SACP or GACP. · How is galvanic anode cathodic protection used? Offshore, anodes are normally cast onto structural tubular cores which are welded to the offshore structure during construction onshore. Offshore oil and gas pipelines are protected with aluminium alloy or zinc bracelet anodes clamped over the protective coating and connected to the pipeline by short cables or welded connections. Such protection should last for 30 years or longer. Onshore, short pipelines are often protected using magnesium anodes. These are cast onto steel cores and connected to the pipeline with cables. In soils of low electrical resistivity, extruded or continuously cast and hot-rolled zinc ribbon is used. Zinc ribbon is widely used as an earthing electrode to mitigate induced alternating current (AC) on buried pipelines. Impressed current cathodic protection (ICCP) Impressed current cathodic protection is provided by connecting a DC power source between the metal being protected and the cathodic protection anodes. In contrast to GACP, the cathodic protection current is supplied by the DC power source and not by corrosion of the anode itself. The DC power supplies are typically transformer rectifiers (confusing acronyms include TR, TRU and T/R) which convert mains electricity to low voltage DC. In remote areas, solar panels and batteries are commonly used (and stolen); thermo-electric DC generators and both diesel and gas engines driving generators have also been used. The negative pole is connected to the protected metal (‘negative drain point’), and the positive pole is connected to the anode. As with GACP, the cathodic protection current flows from the anode, through the electrolyte and onto the metal being protected. The anodes can be scrap steel (a reasonably common practice in France, where old railway rails are often used in such applications), high silicon iron, or sophisticated ‘mixed metal oxides’ coated onto titanium. Other materials, including graphite, magnetite, lead, platinum-coated titanium and niobium, have also been used, though performance and cost have combined to reduce their use. · How is impressed current cathodic protection used? Offshore, anodes are typically mixed metal oxide coated titanium (MMO/Ti). These can be used in both seawater and saline mud, though in the latter their consumption rate is greater. For steel in concrete, most impressed current systems use MMO/Ti anodes either in mesh, strip, or tubular form. There is a tubular anode formed into a conductive ceramic of MMOs. In onshore applications, groups of anodes are normally used in ‘groundbeds’, which may take the form of a long horizontal trench in which multiple anodes are buried in a carbonaceous backfill. This increases the surface area, reduces the electrical resistance to ground, and extends the anode life. Similarly, anodes and ‘coke’ can be used in deep boreholes or multiple shorter boreholes. Anodes are typically high silicon cast iron or MMO/Ti. Most impressed current systems will require replacement after about 25 years. Which form of cathodic protection is best? If the cathodic protection system is well designed, installed, operated and maintained, both galvanic anode and impressed current cathodic protection can be equally effective. However, GACP is simpler and has proved to be more reliable offshore. Onshore, ICCP systems are easier to access for maintenance and, once installed, their components are not subject to the challenges of offshore environments. If properly designed, ICCP can protect many kilometres of well-coated pipelines. ICCP is also advantageous for bare or poorly coated steel as it can deliver hundreds of amps of low voltage direct current, while a typical galvanic anode will seldom deliver more than 5 amps. Cathodic protection – a specialist operation Cathodic protection is used extensively to protect critical infrastructure from corrosion. For example: It is legally mandated for gas and oil pipelines to ensure their safe operation Offshore gas and renewable energy structures are effectively mandated to receive effective cathodic protection by their certification bodies Ships benefit from extended dry-docking rules if they have effective cathodic protection The life of concrete bridges and structures affected by chlorides, from de-icing salts or marine exposure, is extended by cathodic protection Newly constructed, reinforced concrete structures in severe exposure conditions also have extended life when cathodic protection is used However, across all functions – from design through installation to testing and maintenance – cathodic protection is highly specialised. There are standards (BS ENs and BS EN ISOs) for cathodic protection applications for different structures in different environments. A key takeaway from the standards is that they make it clear that cathodic design must be undertaken by cathodic specialists with a documented, appropriate level of competence. How do you gain a cathodic protection specialisation? There are no degrees that can be gained in cathodic protection, and there are no postgraduate courses in cathodic protection engineering, either. Instead, you find that cathodic protection specialists may hold a science or engineering degree (or complete an apprenticeship) before undertaking specific training and gaining experience and expertise in cathodic protection. The Institute of Corrosion offers courses in cathodic protection, providing the training required for levels 1 to 3 for cathodic protection data collectors, technicians and senior technicians. These courses are produced, owned and administered by the Institute of Corrosion CP Governing Board (CPGB), part of the ICorr Professional Development and Training Committee (PDTC). These courses are designed for those seeking the certification of competence in accordance with standard BS EN ISO 15257. We also find that these courses add value to managers and others who want to know what their cathodic protection staff and/or contractors must be doing and the limits of what they should do. Independent of the cathodic protection courses and the PDTC and CPGB, the Institute of Corrosion also offers an independent assessment of competence through its Professional Assessment Committee (PAC). This is recognised internationally as confirmation of experience, knowledge and task skills as defined in standard BS EN ISO 15257; it is valid internationally. For cathodic protection companies and for independent cathodic protection specialists, attainment of cathodic protection training and certification will ensure demonstration of competence, experience and expertise. This translates into more effective work, improving reputational excellence, and more employment opportunities. To learn more about our range of cathodic protection training courses and the experience and qualifications needed for certification, please visit our pages detailing the Cathodic Protection, Training, Assessment and Certification Scheme. In our next article, we explode 7 cathodic protection myths. Cathodic protection systems prevent corrosion of pipelines, above ground storage tank bottoms, plant piping, and many other buried or submerged steel metallic structures. Major concerns for asset operators are extending their service life and protecting workers and the public. Since corrosion is a leading cause of premature and sometimes catastrophic failure, installing and regularly testing the systems is a proven solution to ensure long-term protection. A wide range of civil and industrial applications use CP systems to effectively prevent corrosion. Installation typically occurs during original construction, major expansions, or upgrades. This article covers the basics of cathodic protection and answers common questions through our FAQs. Additionally, we invite you to ask questions for personalized guidance. Cathodic protection (CP) is an electro-chemical process that prevents corrosion currents by applying direct current (DC) to a metal structure. When applied properly, CP stops the corrosion reaction, ensuring the long-term integrity of steel or other metallic structures. Curious about how CP can protect your critical infrastructure? Contact us today for more information. Ted Huck is “YouTube Famous” for his explanation of cathodic protection in this video with nearly 300,000 views! CP systems come in two primary forms. A galvanic system uses anodes (often made of magnesium, zinc, or aluminum) connected to the protected structure to create a circuit. The potential difference between the anode and the structure drives current to the structure, preventing corrosion. Galvanic anodes (sacrificial anodes) are low maintenance and don’t require an external power source. ✓ Low maintenance✓ No external power source is required✓ Requires structure to be electrically isolated✓ Generally used for small segments of well-coated steel Ready to benefit from low-maintenance CP solutions? Explore our galvanic anodes. Want to learn more before committing? Dive deeper into galvanic anodes and galvanic corrosion prevention. When galvanic CP isn’t sufficient, an external power source (a rectifier) is used to provide a more robust solution. ICCP systems are known for their higher current capacity, longer-lasting anodes, and ease of monitoring and control. ✓ Higher current capacity—Suitable for protecting large infrastructure such as pipelines, storage tanks, and marine structures. ✓ Greater system control—The adjustable power supply allows for precise current output based on environmental conditions. ✓ Longer-life anodes—ICCP systems utilize mixed metal oxide (MMO) and other durable anode materials to reduce maintenance frequency. ✓ Ease of monitoring—ICCP systems enable real-time performance tracking through rectifier readings and remote monitoring tools. FeatureGalvanic CPImpressed Current CPCurrent OutputFixed, lowerAdjustable, higherMaintenanceLowPeriodic checks requiredPower SourceNone (self-powered)External rectifierAnode LifespanShorterLonger-lastingApplicationSmall structuresLarge infrastructure For those requiring a more controlled and long-lasting CP system, ICCP systems offer significant advantages in demanding environments. Ready to learn how ICCP systems can safeguard your assets? Check out our complete range of solutions. Want to learn more before committing? Dive deeper into the benefits of impressed current CP systems. Cathodic protection works by creating a complete circuit between the anode and the metal being protected. The current flows through the electrolyte, and corrosion is redirected from the structure to the anode. This process prevents further corrosion of the structure. Without cathodic protection, natural variations in potential lead to corrosion along a pipeline. By applying cathodic protection, current discharges from the anode to the pipeline, preventing further corrosion. Explore our comprehensive pipeline corrosion protection solutions for more details on how CP protects pipelines. Properly designed CP systems provide decades of corrosion protection for steel structures. Effective design requires engineers who are experts in both the structures being protected and the environmental factors affecting corrosion. With over 50 years of experience, MATCOR’s design engineers ensure CP systems are tailored to specific environmental conditions and structure requirements. Learn more about our successful projects. Applications: Underground and above-ground storage tanks Oil and gas pipelines Plant piping Well casings Marine structures (docks and piers) Sheet pile walls Water storage tanks (internal wetted surfaces) Condenser (water boxes) Wastewater systems systems (flocculators, clarifiers, lift stations, etc.) Other metallic structures Effective CP systems rely on additional components for successful operation, including rectifiers, reference electrodes, and test stations. These components work together to provide comprehensive corrosion protection and allow for easy monitoring and maintenance. Explore MATCOR’s comprehensive range of cathodic protection solutions, including products, materials, and services. Get beyond the basics with the answers to the most common questions we hear. Have a question not answered here? Ask our experts! Protect your assets for the long-term. Contact MATCOR today for a custom CP solution tailored to your project needs! What is an Anode? An anode is a primary component in cathodic protection systems. It functions as the source of electrons and discharges DC current. The anodes is more negative relative to the protected structure. What is a Cathode? The cathodically protected structure is the cathode in a CP system. It is where current flows after it discharges from the anode. The cathode is more positive relative to the protected structure. As electrons flow to the cathode, it polarizes, or becomes more electrically negative. What is an Electrolyte? An electrolyte, for cathodic protection purposes, is an environment around the cathode (protected structure) that is electrically conductive enough to allow current to flow from the anode to the cathode. In addition, the anode and cathode must both be in this environment enabling cathodic protection current to flow from the anode to the cathode. In some cases, there might be multiple electrolyte layers or types through which the current might flow. What structures typically require cathodic protection? Buried or submerged structures require or can benefit from the proper application of cathodic protection. Assets commonly protected utilizing CP, for example, include oil and gas steel pipelines, steel and ductile iron water piping systems, tank bottoms on large diameter above ground storage tanks, ductile iron fire hydrant risers, and HVAC transmission tower guide wire anchors. Marine near-shore structures, such as steel pilings and sheet pile walls, ships and other large vessels, are some additional examples of cathodically protected assets. These are some common CP applications, but there are numerous others. What is Polarization? When cathodic protection current flows from the anode to the protected structure (the cathode in the circuit), the structure’s electrical potential will shift more electrically negative. This is typically measured in mV. We call this shift in potential polarization. Polarization is a measure of cathodic protection current effectiveness. Once the polarization is sufficient, we deem the structure cathodically protected. Important to realize, is that the time it takes to fully polarize a structure can vary. It depends on the structure and its environment. In some cases a structure can take weeks to fully polarize. What is Depolarization? When cathodic protection current stops flowing from the anode to the protected structure, the structure begins to depolarize. The rate of depolarization can vary depending on the structure and its environment. When is my structure cathodically protected? What is the criteria for Cathodic Protection? There are two basic criteria per NACE International standards you can use to confirm that a structure is cathodically protected. 100mV of polarization is the first criteria. This simple criteria entails the following: first, you measure the potential of the structure without any CP applied (native potential). Then, after you apply cathodic protection long enough to achieve polarization, measure the potential again. If the potential difference is greater than 100 mV, the structure is protected. This is commonly known as the 100 mV shift criteria. The other criteria is the 850 mV Off potential criteria. In this case, a native potential baseline is not necessary. This criteria simply requires that the potential of the structure be more negative than -850 mV after accounting for all current sources (by turning them off for an instant). What is “Instant off”? Instant off is the process of taking measurements the instant you turn off power to an impressed current CP system. When you have multiple current sources, you must turn them off simultaneously using synchronized interrupters. The purpose of turning all the current sources off is to eliminate the IR drops in the circuit. As current (I) flows through cabling there is a resistance (R) that the current must overcome – this is known as voltage drop because $V = I \times R$. When attempting to measure the level of polarization, it is important to eliminate the IR drops in the circuit that are the result of current flow creating these IR drops. By instantaneously turning the current off, the IR drop readings immediately reduce to zero because the current (I) is now zero. This means that the polarization you measure immediately after turning off the current is the true polarization current. Timing is critical because with the current turned off the structure will immediately depolarize. The polarization potential will begin to decay. The goal of instant off polarization readings is to catch the polarization level as you turn power off and before the depolarization process begins. What are the different types of anodes? Anodes can be broken down into two basic anode types – galvanic anodes (frequently referred to as sacrificial anodes) and impressed current anodes. Galvanic anodes use the natural voltage differential between the anode and the structure to drive current off the anode and to the structure. On the other hand, impressed current anodes use an external power supply to drive current off the anode and to the structure. What is a galvanic or sacrificial anode? Galvanic anodes are basically metal castings that do not utilize an external power supply to drive current. They rely on the natural potential differences between the two metals to drive the cathodic protection current. There are three primary types of galvanic anodes. Magnesium is the most active type of galvanic anode and is used primarily in soil applications. Comparatively, Zinc galvanic anodes are less active and commonly used in low resistivity soils and brackish water. Zinc is also the primary metal in galvanized applications. Finally, seawater applications typically use the third type of galvanic anodes, aluminum. NOTE: People often refer to galvanic anodes as sacrificial anodes because the CP reaction consumes them. This is also true for many impressed current anodes. The term sacrificial implies that a power supply does not exist, and that the anodes utilized are more active than the protected structure. What are the advantages of a galvanic anode system? There are two major advantages of galvanic anode systems. Firstly, they do not require a power supply. In addition, in many applications the cost of providing power and installing a power supply can be quite significant. Second, since there is no power supply, they require virtually no regular maintenance. As a result, in the right applications, these two benefits make galvanic anode systems cost effective. What are the disadvantages of galvanic anode systems? Galvanic cathodic protection systems come with three considerable limitations. Firstly, they have Limited power. The driving force between the anode and the structure is limited to around 1V maximum, and frequently much less than 1V driving force. Therefore, larger structures often require more current than what can economically be provided by galvanic anodes. Secondly, they have limited life. Galvanic anodes consume at relatively large rates in terms of several kg/amp year. As a result, this significantly limits the anode life in some applications. Thirdly, the offer limited control. Galvanic anodes have no power supply, so we cannot adjust the output by varying the power applied to the anode. Galvanic anode systems operate solely based on the system resistance, relying on the voltage differential between the anode and structure. What is an impressed current anode? Impressed current anodes discharge current when powered by an external DC power source. Typically, this external source is a transformer/rectifier that converts AC power to DC power. With enough external power supply units, impressed current anode systems can discharge enough current to protect virtually any structure. This is regardless of size or coating status. We do not need to choose these anodes based on their activity level. We can instead choose them based on their current discharge characteristics – how much current can they handle. The three most common impressed current anodes are graphite, high silicon cast iron, and electro catalytic type anodes. What is the expected life of an anode? There are two basic classes of anodes. Anodes that electro-chemically react to generate the electrical current flow includes magnesium, zinc and aluminum as well as graphite and high silicon cast iron impressed current anodes. These anodes consume at a defined rate based on the generated current. We can define their consumption rate in terms of kgs of mass consumed for every so many amp-years of operation. There is always a consideration for utilization of the anode. You can never fully consume 100% of the anode mass. At some point, the anode degradation impacts the anode’s ability to perform. So, it is quite possible for these electro-chemically reactive anodes to calculate the expected anode life.The second class of anodes are electro-catalytic. They are not a reactant but promote electro-chemical reactions. These catalytic type anodes are either platinum based or MMO type. MMO is short for mixed metal oxide. MMO is a coating that consists of an iridium (or ruthenium) metal oxides and other components. Because these anodes are catalytic, they do not consume in the same manner as the electro-chemically reactive anodes. There is no measurable loss of mass with MMO anodes. This is because they are not directly reacting with the electrolyte. However, these catalytic anodes do have their own definable anode life also based on amp-years of operation. What is a Mixed Metal Oxide (MMO) anode? MMO is a coating consisting of a mix of rare earth metal oxides with either iridium or ruthenium as the active catalyst. Iridium is suitable for all CP environments while ruthenium-based anodes are suitable only for seawater applications. The exact coating mixture can vary from manufacturer to manufacturer. The key is that the manufacturer has a proven recipe and that we can predictably calculate its performance characteristics. This includes anode life based on accelerated life testing programs. Manufacturers apply these MMO anode coatings to a Grade I or Grade II commercially pure titanium substrate. Some of the common MMO anode shapes include wire, rods, tubes, strips, ribbon mesh strips and sheets, plates and discs. What is a Rectifier? A rectifier is simply a power supply that converts AC power to DC power. For most impressed current cathodic protection systems, a rectifier is an integral component in the system design. Rectifiers are available in a wide range of enclosure types depending on the environment and hazardous area classification of the location. The rectifier size is based on a maximum DC Power Rating. For example, 50V x 50 Amps would imply that the rectifier is capable of 2500 Watts of power. What is the proper DC wiring for a cathodic protection rectifier? It is critically important to properly install the DC rectifier output polarity before energizing the rectifier or power supply. The DC positive must always connect to the anode system. And the DC negative must always connect to the structure lead(s) connected to the structure. To repeat, the anode must always connect to the positive. The structure to the negative. If the anode and structure leads are tied to the opposite polarity, current will be driven off the structure and towards the anode system. This could be catastrophic, causing accelerated corrosion of the structure. For steel this would be in the rate of 20 lbs/amp year. What is a Cathodic Protection Test Station? Test stations are another key component in cathodic protection system design. We typically install test stations at strategic locations to enable access for testing. Test station is a generic name. They can range from a simple lead from the pipe or buried structure, to a test station that allows for easy electrical connection. Very complex test stations may include corrosion rate probes, AC and DC coupons and remote data collection and monitoring equipment. What is HMWPE Cable? What is HMWPE/Kynar or HMWPE/Halar Cable? In the cathodic protection industry, buried anodes and harsh service environments are typical. To protect the integrity of the anode cabling system, the industry uses a “direct burial” cabling system. The most common in the US is a high molecular weight polyethylene cable or HMWPE. This cable insulation is generally 110 mils or more thick and is extremely robust and difficult to damage with even the harshest of handling. For some highly chlorinated environments, it is common to use a dual insulation with an inner sheath of a fluoropolymer. The common types used are PVDF (Kynar) and ECTFE (Halar). These have very similar chemical resistance characteristics. Where do CP systems use dual insulated HMWPE/Kynar or HMWPE/Halar cable? Dual insulated direct burial cable has an inner layer of chemically resistant fluoropolymer (Kynar or Halar). This provides additional chemical resistance in highly chlorinated environments. If salts are present, these salts can result in the formation of chlorine gas which reacts with water to create hydrochloric acid. This can be very damaging to standard cabling. We highly recommend the added chemical protection of dual insulated cables in areas where high current densities occur in a chloride rich environment with minimal gas or electrolyte mobility. Deep anode ground beds, salt laden soils, and marshy areas can all create problems for standard cable. These applications call for a more chemically inert cable insulation. What is the concern with cable to anode connections in cathodic protection? For impressed current cathodic protection systems, it is critically important that there are no nicks, cuts or cracks in the cabling or any cable connections/joints. This is especially critical for the anode cabling tied to the positive side of the power supply. If any part of the anode cabling system is compromised, and the copper conductor has an electrical path back to the environment, then the copper becomes an unintended anode. It will begin to very quickly consume, leading to an open circuit and an inoperable CP system. Thus, it is very critical on the anode side that every splice or connection is completely water tight and that all of the cable insulation is in good condition. What is an RMU? How do Cathodic Protection Systems Use RMUs? RMU is short for Remote Monitoring Unit. In cathodic protection remote monitoring, RMUs are used to monitor, and in most cases control the performance of rectifiers in impressed current cathodic protection systems. We also apply RMUs to test stations, critical bonds and other monitoring applications. A variety of technologies are available including broadband, cellular, and satellite communications to enable system monitoring and control. What is a CIS (or CIPS) Survey? CIS or close interval survey, internationally more commonly referred to as CIPS (close interval potential survey), is a common means of validating the proper performance of a cathodic protection system along long length pipelines or within stations/plant piping networks. The survey consists of taking potential readings as the crew walks over the center of the buried pipeline. We usually take these readings while cycling on and off all influencing current sources at a regular intervals. Thus, readings capture the potential between the pipe and a reference electrode. We capture both the current on and current off cycle readings. This process repeats over the entire length of the pipeline. We then analyze the on/off data to confirm the CP system is working properly and achieving the required system polarization. What is an “Interrupter”? An interrupter is a sophisticated switch we can use to interrupt the operation of a rectifier. The interrupters used today automatically synchronize from a satellite signal allowing for numerous interrupters to synchronize to the same timing so that the OFF data collected is accurate. Many new pipeline rectifiers feature built in interrupters that we can energize remotely for surveys and for CP system testing. What is a deep anode system? Sometimes referred to as a deep anode well or deep anode ground bed, a deep anode system is often an effective means of injecting a large amount of current into the earth from a single location with a very small surface footprint. We use conventional drilling equipment to drill a hole approximately 200-400 feet deep. Then, we lower one or more anodes into the hole before backfilling the hole. We locate the anodes sufficiently far enough from the surface to be able to consider them electrically remote from the structure. As a result we are able to project current into a congested underground environment or distribute current for miles in each direction for isolated pipelines. What is gas blocking of an anode? The cathodic protection electrochemical reaction generates gas as part of the reaction process. This also liberates electrons to allow current to distribute through the electrolyte. In most environments that gas is able to diffuse or discharge somewhere. However, in those rare cases where the generated gas cannot migrate away from the anode surface, the gas can actually block the flow of electrons and choke the cathodic protection reaction. This is more common within deep anode systems where a hole is bored from the surface down into the earth, and the surrounding environment around the bore hole may not be very permeable thus trapping gases. Most deep anode systems use a vent pipe to allow gases to vent away to prevent gas blockage. What is a vent pipe? Vent pipes are small diameter piping with drilled holes or cut slots that allow gases to vent away from the anode during the cathodic protection process. This reduces the buildup of gasses around the anode or the concentration of low pH hydrochloric acid that can form when excess chlorine gas is available and not vented away. This low pH environment can attack HMWPE cable insulation and result in premature failure of the cabling. What is the role of a coke backfill material? Almost all buried anodes have some form of backfill material. It is either built into the anode packaging or supplied externally for installation. Impressed current anodes generally use a coke backfill. The primary role of the coke backfill is to provide a uniform low resistance environment into which the anode can easily discharge current. This helps to reduce any issues with poor earth contact of the buried anode. In addition, it increases the anode’s effective size reducing the anode backfill to earth resistance. Does the coke backfill also consume and if so, how much? Carbon itself can act as an impressed current anode. When another impressed current anode is installed in a coke backfill, some of the coke backfill will act as an extension of the impressed current anode. To the extent that carbon is consumed, the impressed current anode consumption is likely reduced. How fast the coke backfill consumes and how much of a positive impact that has on the actual anode life is very much site specific. Variables include coke column quality, coke particle compaction, moisture level, and particle shape.There are two conduction modes for electrons. With electronic conduction, the electrons flow from the anode through the coke. As an extension of the actual anode, the electrochemical reaction occurs from the carbon to the environment. As a result, the carbon is a reactant. Ionic transfer takes place where the current is generated at the anode and then flows along a moisture path on the outside of the coke particles. This does not involve the carbon as a primary reactant and thus no consumption occurs. The bottom line is this: it is difficult to know how an individual installation will operate or at what rate the backfill will consume. Where can I learn more about cathodic protection? You can always contact MATCOR of course, however ScienceDirect topics include many books and peer reviewed journals on the subject of CP. We will reply to your question via email and post it here. To get in touch with our team of cathodic protection experts for more information, to ask a question or get a quote, please click below. We will respond by phone or email within 24 hours. For immediate assistance, please call +1-215-348-2974. Contact a Corrosion Expert