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## Decibel

This article is about the unit of level. For other uses, see 1 Decibel (disambiguation).

the ratio between two values of a physical quantity, of- originally measured in units of Miles of Standard Cable ten power or intensity. One of these quantities is often a (MSC), where 1 MSC corresponded to the loss of power reference value, and in this case the decibel can be used over a 1 mile (approximately 1.6 km) length of standard to express the absolute level of the physical quantity, as telephone cable at a frequency of 5000 radians per second in the case of sound pressure. The number of decibels (795.8 Hz), and roughly matched the smallest attenuation is ten times the logarithm to base 10 of the ratio of two detectable to the average listener. Standard telephone capower quantities,[1] or of the ratio of the squares of two field amplitude quantities. One decibel is one tenth of one bel, named in honor of Alexander Graham Bell. The bel tributed shunt capacitance of .054 microfarad per mile" is seldom used without the deci- prefix.

The definition of the decibel is based on the measurethe Bell System in the United States. Today, the unit is attenuation of signals, and signal-to-noise ratios are often advantages, such as the ability to conveniently represent very large or small numbers, and the ability to carry out multiplication of ratios by simple addition and subtrac-

A change in power by a factor of 10 corresponds to a 10 dB change in level. A change in power by a factor of two approximately corresponds to a 3 dB change. A change scribed in the NBS Standard's Yearbook of 1931.[191] in voltage by a factor of 10 results in a change in power by a factor of 100 and corresponds to a 20 dB change. A change in voltage ratio by a factor of two approximately corresponds to a 6 dB change.

The decibel symbol is often qualified with a suffix that indicates which reference quantity has been used or some other property of the quantity being measured. For example, dBm indicates a reference level of one milliwatt, while dBu is referenced to approximately 0.775 volts

In the International System of Quantities, the decibel is defined as a unit of level or of level difference, equal to one-tenth of a bel. The bel is then defined in terms of the neper, an alternative unit of level of root-power quantities, applicable when the natural logarithm (base  $\epsilon$ ) is used to define the level.[3]

The decibel originates from methods used to quantify The decibel (dB) is a logarithmic unit used to express signal losses in telephone circuits. These losses were ble was defined as "a cable having uniformly distributed resistance of 88 ohms per loop mile and uniformly dis-(approximately 19 gauge).[4]

The transmission unit (TU) was devised by engineers of ment practices in telephony of the early 20th century in the Bell Telephone Laboratories in the 1920s to replace the MSC. 1 TU was defined as ten times the base-10 logaused for a wide variety of measurements in science and rithm of the ratio of measured power to a reference power engineering, most prominently in acoustics, electronics, level.[5] The definitions were conveniently chosen such and control theory. In electronics, the gains of amplifiers, that 1 TU approximately equaled 1 MSC (specifically, 1.056 TU = 1 MSC). The threshold of hearing is 25 dB<sup>[6]</sup> expressed in decibels. The decibel confers a number of In 1928, the Bell system renamed the TU the decibel,[7] being one tenth of a newly defined unit for the base-10 logarithm of the power ratio. It was named the bel, in honor of their founder and telecommunications pioneer Alexander Graham Bell.[8] The bel is seldom used, as the decibel was the proposed working unit. [9]

The naming and early definition of the decibel is de-

Since the earliest days of the telephone, the need for a unit in which to measure the transmission efficiency of telephone facilities has been recognized. The introduction of cable in 1896 afforded a stable basis for a convenient unit and the "mile of standard" cable came into general use shortly thereafter. This unit was employed up to 1923 when a new unit was adopted as being more suitable for modern telephone work. The new transmission unit is widely used among the foreign telephone organizations and recently it was termed the "decibel" at the suggestion of the International Advisory Committee on Long Distance Telephony.

The decibel may be defined by the statement that two amounts of power differ by 1 decibel when they are in the ratio of 1003 and any two amounts of power differ by N decibels when they are in the ratio of  $10^{N(0.1)}$ . The





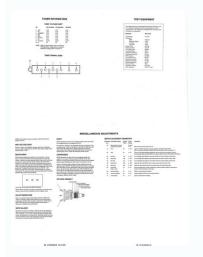


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may prevent adequate current from reaching a corroding surface. Protecting a bare structure requires sufficient current to protect all the metal exposed to the electrolyte. 21 Analog Meters.......



## Nace cathodic protection. Nace cathodic protection certification.

. Stray current discharge and a positive potential shift on the foreign structure occurs at

g. A properly isolated casing is shown in Chapter 9. Focus (at the very least) on understanding Ohm's

(fill in your entire name) SUBJECT:

. This is equal to the total voltage less the voltage drop across R4 or 20 V - (10 A x 0.95  $\Omega$ ) = 10.5 V. A medium is

END SEAL VENT PIPE CASING PIPE LYING ON CASING DUE TO LACK OF INSULATING SPACERS Figure 3.8 Cathodic Shielding Due to a Shorted Casing © NACE International, 2006 1/2008 Underground Corrosion Control 3:25 Dielectric If a sheet of plastic or other insulator is placed close to the surface of a cathodically protected structure, it

position D. ALUMINUM Aluminum alloy anodes are used primarily in seawater applications and are produced in a variety of alloys, of which the mercury and indium alloys are the most common. To avoid this © NACE International, 2006 7/2007 Safety situation, an electrical bond must be temporarily installed around the location where a pipe section is to be cut or a flange is to be disconnected. After you measure the millivolt drop across the shunt, multiply the millivolt drop by the amps/millivolt dro VOLTSDC] Measure the IR drop across each resistor and add them up and measure the source voltage. The following list of observations can lead to early detection of a potential problem. 4 Inhibitors . Cautionary Note: It is possible to overprotect some materials such as prestressing wire, lead, and aluminum. Aluminum anodes are also used because the corrosion products of the anode are colorless and non-toxic. 4 Technical.. Applications of Impressed Current Cathodic Protection Typical uses of impressed current are: • for large current requirements, particularly for bare or poorly coated structures • in all electrolyte resistivities • as an economical way of protection of large heat exchanger water boxes, oil heater-treaters, and other vessels • for interiors of water storage tanks • for exterior bottoms (both primary and secondary) of above ground storage tanks • for underwater components of off shore structures • for foundation piles and sheet piling, both underground and in the water. Set the meter to the V DC scale as shown on the next page. 19 If the voltage drop reading is positive, then the direction of current flow is from the positive to the negative terminal of the voltmeter. © NACE International, 2006 1/2008 Installing CP Components 8:13 Handle Graphite Mold Starting Powder Weld Metal Metal Disk the environment becomes ten times more acid or alkaline. Although there are exceptions, alternating currents do not cause significant corrosion of common structural materials. 2 10 10 ÷ = 1 3 30 50 7. The preventative measures are then incorporated into the job work procedure. Unmatched Usability: CP-Compass was designed with the user in mind. The practical examination is closed book. © NACE International, 2006 1/2008 Underground Corrosion Control 3:17 Silicon-chromium-iron anodes are brittle in comparison to graphite, but the hardness of the alloy makes the anode less susceptible to damage from abrasion or erosion. cm lb / ft kg / m 0.154 0.237 0.280 0.322 0.365 0.375 0.375  $0.375\ 0.375\$ 176.65 188.41 200.31 212.22 μohms/ft 76.2 26.8 15.2 10.1 7.13 5.82 5.29 4.61 4.09 3.68 3.34 3.06 2.82 2.62 2.44 2.28 2.15 2.03 \*Conversions: 1 in. © NACE International, 2006 1/2008 Field Measurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasured Rshunt VOLTS + RB Current Shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasured Rshunt VOLTS + RB Current Shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasured Rshunt VoltTS + RB Current Shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasurements 5:12 E + RA Icalculated = IRC Voltmeter is connected in parallel across the current shunt Vmeasurement shunt Vmeasure with known resistance value is in series with the circuit Figure 5.10 Shunt Measurement Current shunt may be given in ohms or amps/millivolts. Recertification requires a minimum of 2 years work experience in cathodic protection and 8 hours per year (24 hrs total) of professional development hours. (See % The Appalachian Underground Corrosion Short Course (AUCSC) is a week-long annual event that provides seminars and other topical presentations on cathodic protection. No metal loss occurs at the cathode is protected). Please call or write to us with questions: NACE First Services Division Phone +1 281 228 6223 Fax +1 281 228 6329 Email: [email protected] www.nace.org See you in class! JULY 2007 ELECTRICAL FUNDAMENTALS - Ohm's Law By Buddy Hutson, Enron Corp. The anodes were developed primarily for use in seawater and other chloride environments since both substrates form protective, dielectric, oxide layers when made anodic in the presence of chlorides. They are found most commonly on long pipelines in higher latitudes, but have also been seen in lower latitudes, but have also been seen in lower latitudes. (8 x 8 x 8) = 83 2. Also, in the United States pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of Transportation (DOT) to enact "Operator Pipeline industry, efforts are being made by the U.S. Department of U.S. Department of U.S. Department o qualifications of personnel who are monitoring cathodic protection. Some, such as those used in potable water systems, lay down a protective film over the entire metal surface. It is important to that you can tell which side of the joint is being tested. The ratio of the secondary voltage to the primary voltage is directly proportional to the ratio of the secondary turns. If the reading is negative, then the direction of current flow is from the negative to the positive terminal. The chemical composition of the backfill is such that the anode functions more efficiently because the backfill ... On a coated structure, it is necessary to protect only the metal exposed at breaks, or holidays, in the coating. There must be a voltage difference between the anode and cathode of a corrosion cell for current to flow. Pertinent terms and descriptions are given in this chapter. I understand that the names of the categories within the NACE International Cathodic Protection Tester CP 2 CP2-Cathodic Protection Technician CP 3 CP3-Cathodic Protection Technologist CP 4 CP4-Cathodic Protection Specialist 4. Cathodic protection is often used in conjunction with other corrosion control methods including protective coatings and electrical isolation. Figure 5.12 shows the set-up. The anodes are close together and the corrosion is characterized as general metal loss. Heat exchanger water boxes and tube sheets are often protected by anodes in the water box. A molecule is the smallest unit of a substance. E = I x R = 5 A x 0.01 Ω = 0.05 V = 50 mV © NACE International, 2006 1/2008 Field Measurements 5:13 An easier method for calculating current is to determine the amps/millivolt rating of the shunt. Pressure D. We also see the Greek letter Omega (Ω) used as well. It is necessary to know the power required by a cathodic protection rectifier, for example, in order to size the alternating current supply circuit. If not, why? This will lead to increased anode-to-earth resistance and decreased anode life Gummow, (CorrEng Consulting Service Inc., Downsview, Ontario), James R. The separation distance between the anode groundbed and the structure is automatically optimized based on the user specified acceptable voltage drop (see plot under Section 6). © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:3 Oxygen Atom Hydrogen Atoms Figure 2.2 Water Molecule Acidity and Alkalinity (pH) When discussing an aqueous medium (including soil), the question often arises as to how acid or alkaline the solution is. Chemical Activity It is the chemical activity of the electrolyte that provides the Redox (Oxidation-Reduction) reactions necessary to drive a corrosion cell The more important concepts are discussed in this chapter. © NACE International, 2006 1/2008 Field Measurements 5:9 Measuring Current measurement. Insert steel and copper sheet in side of tray and 1-1/2 inches of fresh tap water. Since most instruments used today are digital with automatic polarity display, a surveyor may not be as concerned with the sign of the reading when connecting the voltmeter for the measurement. Place reference electrode in the water at the copper/water interface. Ohmmeters find limited use in corrosion work. Ship hulls are a good example of this phenomenon. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:5 CORROSION RATE 1 4 8 12 pH and Lead Aluminum ALUMINUM LEAD Figure & 2-7B Figure 2.4 Effect of pH on the Rate of Corrosion An understanding of the effect of pH is also important in the application of cathodic protection. Reverse 4. If a combustible atmosphere is present, an explosion can occur. The voltmeter used for measuring current outputs. Your company probably has specific criteria for various situations. Got the answer? Alternating current regularly reverses direction of flow, commonly 100 or 120 times per second. Step 4. This is primarily a laboratory electrode. Maintenance of Environmental Control Inhibitors and other environmental control must be applied at the proper dosage and must be applied at the proper dosage at the proper dosage at the proper dosage at the proper dosage at the proper dosa ... Place the reference electrode near the steel and record the steel's potential. Upon completion of the survey, the data are downloaded into a computer and often printed in graph form. Using an ohmmeter to check effectiveness of an isolation joint in service is not reliable because of the parallel resistance paths through the soil as illustrated in Figure 5.13. When referring to these recommended practices, be certain to obtain the latest revision follows the RP number). Galvanic anodes may be used to overcome cathodic interference problems. High risk of causing stray current interference. If you do test the output this way, be certain the rectifier is turned off when the circuit is opened and when it is closed again. Conductors have many free electrons and therefore, current flows quite easily. • On offshore structures, large galvanic anodes may be used to protect the underwater components. When checking rectifier outputs on a routine basis, there are four basic cases of symptoms requiring investigation: zero current and voltage, or significant current outputs on a routine basis, there are four basic cases of symptoms requiring investigation: zero current and voltage, significant current outputs, zero c 2006 1/2008 Installing CP Components 8:19 Figure 8.17 Aluminum Alloy Anodes for Offshore Structures Hanging anodes, usually of aluminum alloy, may be used to protect piping on a wharf or similar structure. Care should be taken to prevent damage to the coating when installing bracelet anodes. The signal creates an electromagnetic field around the pipe. Isolating Joint All local and national codes should be followed in installing electrical isolators. All the voltage drops in the measuring circuit are controllable except for the one through the electrolyte. The anodes used in an impressed current system are usually constructed of a relatively inert material. Corrosion prevention can be better understood after acquiring a good understanding of corrosion itself. This can be achieved by electrically isolating the water box from the shell. Instead, other combinations of metal electrolyte in Corrosion Cells. Chapter 6-Stray Current Interference Definitions. Calculate total current? Galvanic anodes attached to a structure represent a parallel circuit. A safety person is to be on the surface while the worker is in the excavation and must remain there until the worker comes out. Higher voltage settings will be necessary to produce the desired current. This is a flow of current in the direction of the positive ion transfer (so called positive current). Graphite Electrode Graphite is a pseudo-reference electrode that is sometimes used in reinforced concrete structures. 0.7 megOhms = 700,000 Ohms 9. The difference in potential between the steel and the copper is the same as measured in Step A. Zinc is actually a pseudo-reference electrode since the potential of zinc can change as the environment changes. Examples include cathodic protection interference electrode since the potential of zinc can change as the environment changes. Examples include cathodic protection interference electrode since the potential of zinc can change as the environment changes. are within dikes around tanks containing combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, natural gas or combustible materials, facilities housing or encompassing propane, and the propagation of the propagation Measurements are made using Ohm's Law and sometimes by using an ohmmeter. Adding chromium ties up free graphite as carbides and strengthens the alloy. Backfill The chemical backfill used for galvanic anodes consists of 75% gypsum (CaSO4), 20% bentonite clay, and 5% sodium sulfate. Input voltage may vary from 480 volts to 115 volts. Another situation where a high-energy spark may be generated is when a cathodically protected structure is inadvertently or purposefully electrically connected to another metallic structure. First, © NACE International, 2006 7/2007 Troubleshooting 9:6 when two structures are electrically isolated from each other by a fitting or a casing spacer, there is still a parallel resistance through the electrolyte. Underground anodes should still be installed in the special anode backfill that comes with prepackaged anodes. PLATINUM The two most common platinized anodes incorporate titanium and niobium substrates. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:7 Reduction Reduction is the term applied to the gain of one or more electrons to an atom or molecule, which then forms a negatively charged ion or neutral element. .320 + Soil Parallel resistance & indicate shorted insulator Figure 5.13 Isolation Joint Test Using an Ohmmeter If an isolator is not in service and a parallel path does not exist, then an ohmmeter can be used for testing the fitting. The equations for power and the symbols used are: P = EI P = I2R where: P = Power in watts R = Resistance in Ohms E = Voltage in volts I = Current in amperes © NACE International, 2006 1/2008 Basic Electricity 1:10 Kirchhoff's Laws Voltage Law This law states that the sum of the source voltages around any closed loop of a circuit is equal to the sum of the voltage drops across the resistances in that loop. For shorted diodes, the meter will display some low voltage value in both forward and reverse bias configuration. An ammeter can also be inserted into the rectifier circuit. However, the open circuit may be due to a tripped circuit breaker at the rectifier input. The difference is that in an impressed current system, the current is supplied by an external source rather than by the galvanic action between the anode and the structure. This -0.800 criterion includes the voltage drop in the water. Many of these problems can be solved by some basic troubleshooting techniques when structure-to-electrolyte potential measurements indicate inadequate protection or when some other malfunction occurs. • A negative potential of a least 850 millivolts relative to a saturated copper-copper sulfate reference electrode. Offshore Platforms in Salt Water SP0176 Corrosion Control of Steel Fixed Offshore Platforms Associated with Petroleum A negative (cathodic) voltage of at least -0.800 volts measured between the platform surface and a silver-silver chloride (Ag-AgCl) electrode contacting the water. 2 2 4 × = 5 5 25 e. Measured Total Resistance RT = R14 + R12 + R13 = Ω STEP 5. Do not use steel wool or other metallic abrasive since particles of metal may become embedded in the antimony and affect the reading. Figure 5.18 illustrates the principle of the conductive locator. Repeat Step 2. • reduces the consumption of the anode since the backfill is conductive and when properly tamped becomes part of the anode and is consumed in addition to the anode. This AC can then be passed through a transformer to give an output of several hundred volts, peak. If cathodic protection current is interrupted, then current is zero. The AC field surrounding the structure can then be detected in a manner similar to that described for the conductive locator. 9 Section 5 Chapter 5-Field Measurements Other Portable Reference Electrodes ..... . The direction of current is determined by the polarity of the voltage. Limitations of Galvanic Anodes • • • • Low driving voltage/current output. There are welders for making connections to both horizontal and vertical surfaces. The two components are sprayed in the correct proportion onto the pipe, usually in one or two coats to achieve a final thickness of 12 to 16 mils (0.304 mm to 0.406 mm). Ions are relatively heavy and slow moving. EXPERIMENT 3.1 © NACE International, 2006 1/2008 Underground Corrosion Control 3:10 Applications of Galvanic Anode Systems The following are among the conditions where galvanic anodes are used: • When a relatively small amount of current is required to work in unsafe conditions. Connect the meter's negative lead to the reference electrode. 24 Criteria for Cathodic Protection.. field coating selected must be compatible with the adjacent coating and as durable as that on the structure itself. For example, consider the following circuit: I E I1 R1 I2 R2 I Figure 1.7 Parallel Circuit © NACE International, 2006 1/2008 I3 R3 Basic Electricity 1:14 IT = I1 + I2 + I3 ET = I1R1 = I2R2 = I3R3 RT = I1 = 1 1 1 1 1 + R1 R2 R3 ET R1 I2 + + + + R1 R2 R3  $5\Omega$   $4\Omega$   $2\Omega$  RT = 1 1 = 1 . For In-House courses, this information may not be posted until payment has been received from the hosting company. This usually occurs when two or more facilities are being protected by a single rectifier. Foreign Line Crossing Underground structures such as pipelines or cables frequently cross each other or are in proximity to other facilities. It is very important that you have a thorough understanding of this, since if IR drop is not considered, your data may indicate that the structure is protected when © NACE International, 2006 1/2008 Underground Corrosion Control 3:26 indeed it is not. Computer Records and Spreadsheets Nearly all corrosion records today are kept on computer databases. Water is to be kept from entering the excavation. A pipeline paralleling an HVAC transmission line can reach dangerous AC voltages when it is welded together on skids, but not backfilled. An external disconnect switch on AC wiring should be provided. Very complex circuits can be reduced to a circuit consisting of series-parallel elements. Cathodic protection current may not penetrate into the point of contact. Effects Direct stray currents, as opposed to alternational, 2006 1/2008 Installing CP Components 8:28 Well Cap Shunt Box Vent Casing To Rectifier Gravel NOTE: Sealing may be required by state or local codes Anode Backfill Active Anode Area Figure 8.24 Deep Anode Installation Negative or return circuit The negative or return circuit is the cabling from the structure to the rectifier. For example, a high-energy spark can occur on a cathodically protected pipeline carrying current back to the rectifier if the pipeline is cut or separated at a fitting. Galvanic anodes should be backfilled with compacted native soil, not sand, pea gravel, or other high resistance material. Build up of electrons B. Consequently, electrolytes have much higher resistivities than metals. These two methods are discussed below. Although there are many remote monitoring systems in use today, it is still necessary to take field data to ensure that cathodic protection systems are operating properly and are providing adequate protection to the structure. You must know how instruments work and what errors are possible. In © NACE International, 2006 1/2008 Field Measurements 5:4 moving water, the electrode may swing about, so some structures are equipped with guide wires or perforated plastic ducts to restrict the movement of a portable electrode. After a specific hazard exposure. • Galvanic anodes are typically used and are placed in the area of current discharge. Polarization is the deviation from the passage of current discharge is due to the cathodic protection current provided to the structure and part is caused by local corrosion cells on it surface. This course was developed for cathodic protection field technicians, although this knowledge is also needed by corrosion engineering personnel. 11 Parallel Circuit Current output of galvanic anodes. A score of 70% or greater on both the written and practical examination(s) is required for successful completion of the course and to obtain certification. For example, magnesium, aluminum, zinc, iron, and lead are all more active than hydrogen. © NACE International, 2006 1/2008 5:33 Field Measurements 5:34 Conductive The conductive The conductive locator uses either a radio or audio frequency AC signal that is connected to the structure by a direct wire. © NACE International, 2006 1/2008 Underground Corrosion Control 3:35 3. 2 Girth Weld and Other Field Coatings Graphite also exhibits excellent performance in chloride environments such as seawater. RT = R N where: RT = Total resistance R = Resistance of each resistor N = Number of resistors Turn now to Group Exercise 1.3 for further practice with parallel circuits. © NACE International, 2006 7/2007 4:6 Safety • Avoid measurements during thunderstorms since hazardous voltages may occur on structures as a result of even remote lightning strikes. Current Flow on a Pipeline or Cable A length of pipeline, cable, or similar long, thin metal structure can serve as a shunt. Datalogger Figure 5.6 Data Logger X-Y Plotters These instruments have two pens that record data on the X (horizontal) axis and the Y (vertical) axis. This is the smallest full-scale voltage range possible with the meter. Although your company may take every precaution to keep you safe, your observations and actions on location will be the final determination as to whether you or someone else may be injured or killed. For low-voltage ranges, the circuit resistance becomes more sensitive and external resistance such as those associated with test leads and reference electrode-to-electrolyte contact may cause an error in the reading. There are several forms of corrosion, such as erosion, fretting, nuclear, high temperature, and electrochemical. This also increases current shunts are usually installed in the permanent circuit of a galvanic anode system (not in anodes connected directly to the structure, however). If all the current passes from the shorting structure by the short, no cathodic protected structure by the short, no cathodic protected structure by the short, no cathodic protected structure and Layer Resistivity This measurement is done by taking a series of measurements at everwidening pin spacings. The unit of measurement is the Siemen-cm (mho-cm). Restriction of gas flow C. Never press a probe end and a terminal or wire between your fingers to make a contact. The same is true of many large industrial plants, refineries, college campuses, and similar facilities. Disbonded coatings may have the same result. These calculations are beyond the scope of this course but are covered in advanced cathodic protection courses. Example: If a person's resistance is 1000 \Omega and contact is made with 120 VAC then, using Ohm's Law (I=E/R), the current through the body is 120 mA, likely enough to be fatal. Other metals, such as copper, are less active (or more noble) than hydrogen. Inhibitors Inhibitors are added to liquids to change the characteristics of the liquid or to form protective films on the surface of the metal. Remember it is the current through your body that kills. The electrode is composed of a copper rod, immersed in a saturated solution of copper sulfate, held in a © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:16 non-conducting cylinder with a porous plug at the bottom, as shown in Figure 8.10. This information will also help prepare you for the CP 1-Cathodic Protection Tester course. Power is measured in watts. In this case, current pick-up or resistance testing (as described above under "Casing Shorts") will indicate the effectiveness of the joint. Here again, constant current rectifiers may be needed. This is important in the design of cathodic protection. Impressed current anodes may be installed in either surface groundbed configurations or a deep anode configuration. Above about 15%, there is little change in resistivity. A break can occur in the negative cable, too. This could lead to failures, leakage, fires, explosions, and other hazardous situations. Using the voltage of the battery. Impedance also depends on the frequency and wave shape of the current. 29 Soil Box Cathodic protection is used to prevent corrosion of the steel substrate at the holidays in the coating. Ribbon or Strip Anodes Ribbon or area it must be turned off, locked out and tagged out to avoid the exposure of an arc that may be encountered are oxygen, chlorine, carbon monoxide, and hydrogen. Project Job Safety Analysis Hazard Identification and Assessments (see list of hazards) Not Acceptable Risk Assessment Acceptable Not Acceptable Preventative Measures Acceptable Start Project © NACE International, 2006 7/2007 Safety Some hazards that need to be considered include: • Travel – Automobile or truck (highway or secondary roads) - All terrain vehicles (ATV) - Airplane - Helicopter - Boat • Electrical - Rectifiers - Hazardous AC voltage on structures • Environment - Atmospheric such as acid gases, H2S - Soil and water pollutants • Hazardous Materials - MSDS • Trenches - Sloped or shored • Reptiles, animals or insects • Working at heights - Over land - Over water • Working underwater • Specific hazard(s) related to a project. No one else can then inadvertently turn the AC on before it is safe. If essentially the same structure-to-electrolyte potential is read from each contact, continuity is indicated. water tank interiors ship hulls ballast tanks docks sheet piling foundation piles on land and in the water bridge decks and substructures hot water storage tank interiors heat exchanger water boxes and tube sheets internal surfaces of oil heater treaters reinforcing steel in concrete lead or steel sheathed telephone and electrical cables. The flow of current in this circuit is adjusted to assure that the polarized potential is at least as active as the most active anode site on the structure. (C) 11/01/04 OHM'S LAW Now that we have defined the elements of "Ohm's Law" let's look at the discoveries that George made back in 1828. Japan Several documents list cathodic protection criteria, including: • The Overseas Coastal Area Development Institute of Japan, "Corrosion Protection and Repair Manual for Port and Harbor Steel Structures." • Japanese Port Authority Association, WSP-050, "Cathodic Protection Manual for Coated Steel Water Pipe." Australia Australia Australia Australia Australia Australia Australia Australia Protection. The criteria are the same as in SP0169. This force is measured in volts, millivolts, and microvolts. Wire the 1000 Ω (R14), 100 Ω (R12), and 10 Ω (R13) resistors below the battery in series and measure the total resistance (RT) with the ohmmeter. If you have measured the voltage and current in a cathodic protection circuit, for example, you can easily calculate the circuit resistance. Native soil is usually used to finish backfilling the trench. There should be difference of at least 100 mV or more between the pipe-tosoil potentials of the casing and the pipeline. To determine if the short circuit is external to the rectifier, disconnect one of the DC output connection leads and reset the breaker. SOLAR PANELS Solar panels generate DC by a photovoltaic action with sunlight. + Reading Reference Electrode + Voltmeter with + Reading Reference Electrode Current Flow Figure 5.5 Potential Measurement Between Two Reference Electrode Voltage (IR) Drop in Potential Data Accuracy of data is one of your most important responsibilities. Students will perform tests and collect data. The sequence of short circuit location is shown in Figure 9.9. AC Input Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage level Yes Yes Disconnect Output Lead & Reset Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier on the input side Does Breaker Trip No Temporary short-restore output Voltage No Problem external to rectifier output Short-restore output No Problem external to rectifier output Short-restore output No Problem external to rectifier output No Problem external drop. These are called switchmode rectifiers. Polarization coupons are made of the same material as the structure. • Remember to turn OFF, lock out and tag the AC disconnect when working on or removing rectifier components. Gas flows through a pipeline as a result of the pressure on the system. 9 Reaction Products These fittings can also be tested with radio frequency insulation checkers. There is also concern over public safety and environmental damage. Limitations of Impressed Current Systems • • • • • Higher inspection and maintenance cost than with galvanic anodes. This example illustrates how this information can be used by a NACE CP 1-Cathodic Protection Tester. Current is leaving the positive terminal of the battery and proceeding counter-clockwise around the circuit. This comes from the term Intensity since current is a measure of how intense or concentrated the electron flow is. Opening this connection takes time, and after testing, the connection must be made again. Electropotential force C, 10 10 ÷ 30 50 = Solve for "x" in the following equations. Polarity Sign Most digital meters will display a negative reading and no sign for a positive reading. Location of reference electrode To minimize the IR drop in the electrolyte, the reference electrode should be positioned as near to the structure as possible. A shorted pipeline casing is an excellent example of metal shielding. © NACE International, 2006 7/2006 3 Cathodic Protection CP 1 - Cathodic Protection Tester (Must be submitted to NACE Headquarters for certification to be complete) ... Yes ... No NACE Member: Member: Member # Applicant's Name: Company Address: Zip/Postal Code: Country: Phone: Home Business Fax E-mail: SIGNATURE: DATE: PRINTED NAME: REQUIREMENTS NECESSARY TO ACHIEVE CERTIFICATION: To achieve this certification, qualified individuals have two options: CLASSROOM

TRAINING - CP1 - Cathodic Protection Tester course or EXAM ONLY OPTION - CP 1-Cathodic Protection Tester Exam Only APPLICATION PROCEDURE It is strongly recommended that Exam Only candidates submit a completed application for certification at least 60 days in advance so that work experience requirements and education prerequisites

Law, Series and Parallel Circuits, and Meter Operations. Hourly Rate: \$0 - \$0(33)Pay ranges for people with a NACE Cathodic Protection (CP) Tester Certification by employer. This course has both written and practical (hands-on) final examinations and the final examinations will be given on Friday. Care should be exercised to ensure

said to be alkaline when an excess OH- (hydroxyl) ions are present. The two connections to the casing and carrier pipe are necessary to make casing-to-pipe resistance tests. (4) Recognize and acknowledge that only through continual association and cooperation with others in this field can the safest and most economical solutions be found to the many cathodic protection problems. Test stations include those installed in association with: • cased road crossings • anodes • stationary reference electrodes • coupons • dielectric isolation • crossings with foreign structures • measurement of current flow on a pipe or a cable system. Chloride contamination changes the chemical reactions and the reference potential becomes a lower composite with the error being -20 mV at concentrations of 5 ppt and -95 mV at concentrations of 10 ppt. Remember that polarization will dissipate when current is interrupted, and polarization is the measurement of interest. If the cable comes loose from the structure, but remains close to it, the rectifier output current may drop, but not to zero. This ratio can be expressed as follows: PRIMARY VOLTAGE NUMBER OF PRIMARY TURNS This exact relationship holds true under no load conditions. IMPORTANT NOTICE: Neither the NACE International, its officers, directors, nor members thereof

Impressed Current Systems - Ground Current from High Voltage DC - (HVDC) transmission line earth electrodes. • If there is no cathodic protection current to interrupt or if it is difficult to do so, a temporary current drain could be established and "on" and "off" readings recorded as described above. (I) Current (Ammeter) A (E) Voltage (Battery) (R) Resistance Figure 1. © NACE International, 2006 1/2008 Basic Electricity 1:12 For example, consider the following circuit, where: ET = Total Voltage Across the Circuit IT = Total Current in the Circuit IT = Total Current in the Circuit IT = Total Current in the Circuit IT = Total Voltage Across the Circuit IT = Total Current in the Circuit IT = Total Voltage Across the Circuit IT = Total Current in the Circuit IT = Total Voltage Across the Circuit IT = Total Current in the Circuit IT = Total Voltage Across th

Protection Training and Certification program, please email [email protected] or visit the Education/Certification section of the NACE International, 2006 1/2008 Underground Corrosion Control 3:11 oil heater-treater vessels, depending on the quality of the interior lining and the fluid chemistry and temperature. Mitigation Bonds Mitigation bonds, also called drain bonds or cables, provide a metallic path between the affected structure and the source of stray current. Therefore, in areas with stray current, a digital meter may not be as useful as an analog meter. Electrical Isolation Electrical isolation devices may be used to separate different metals or other anodic and cathodic components of a corrosion cell. Backfill and materials must be kept back a meter or more from the edge of the excavation if not secured. The measured value is displayed as discrete digits; the digits do not require operator interpretation as the analog display does. Consequently, a shunt in the circuit is the preferred method of current measurement. Therefore, the measurements 5:15 Table 5.2 Shunt Types and Values Shunt Resistance Shunt S

2. 9 of 23 CP 1-Cathodic Protection Tester Course Manual - Chapter 6 ©NACE International, 2004 April 2006 3 Steady State or Static Stray Currents • Constant magnitude and direction • Typical sources include: - Cathodic Protection

(date you are taking exam) 3. Electrochemistry is a branch of chemistry dealing with chemical changes that accompany the passage of an electric current, or a process in which a chemical reaction that produces an electric current. If you have a question about the NACE Cathodic

can be verified. (7) Agree to inform clients or employers of any business affiliations, interests, and/or connections which might influence my judgment. Using a clamp-on ammeter, service lines in the affected area can be tested. 4 1 × 8 2 =

on-line LAST NAME: Your last name (surname) FIRST NAME: Your first name (or name by which you are taking SUBJ SCORE: This is the version of the exam you are taking NAME:

that the explosion-proof design of the equipment meets the classification of the area and that the design is not defeated by improper installation. 28 Diode Bias...

accept any responsibility for the use of the methods and materials discussed herein. (8 x 8 x 8) =

type of exam you are taking, e.g., CIP Level 1) DATE:

Clamp-On Ammeter Clamp-on DC ammeters are available for pipes using species Change with Unchanged Voltage If the DC current output significantly changes	Corrosion technicians must understand the effects of s	ome of the more important factors. The final wr Resistivity of an electrolyte is an important factor trician, electronics technician or work in corros it resistance has changed. As mentioned earlier ed voltage? Corrosion control personnel must having a Short Circuit in a Rectifier Circuit © NAC	ritten examination is open book and students or in evaluating the corrosivity of an environation control, you will need to have a good wo er, even the low resistance of the ammeter callave a good basic understanding of corrosion CE International, 2006 7/2007 Short is in out	may bring reference materials and notes into the exament and designing cathodic protection systems. © Norking knowledge of basic electrical fundamentals. We note that cause the instrument to read a current lower than to mechanisms. The transmitter is a source of radio frequent circuit Troubleshooting 9:12 Zero Current Output	ACE International, 2006 1/2008 Field Measurements 5:11 Figure 5.9 believe everything in the internet must be free. Significant Current he actual anode output. Solve the following. In fresh water, zinc and quency AC that is used to impress a signal on the structure. Does Breaker
subscribe to the NACE Corrosion Network, you will be part of an E-maildriven of the course manual. Conductivity is equal to the reciprocal of resistivity. Prep saturated copper-copper sulfate reference electrode. If the rectifier stacks are of the business affairs and/or technical process of clients, employers, or custom Structure examination by excavation or divers • Close interval potential survey to above ground structures, too. 0 volt $E=0.9$ Kirchhoff's Laws	open discussion forum on topics A-Z in the corrosion in ackaged anodes should be kept dry during storage; also found to be operating properly, the transformer should ters when their interests so require. 1 15 50 + =2 2 10 s © NACE International, 2006 7/2006 7:3 Monitoring to the who the owner is and whether the structures have if "a" is in feet and "R" is in ohms, the formula become ated in a bond to control the amount of stray current is node of the cell. The unit of measure of voltage is the er, the connection is made with a split bolt connector so tential of -1.55 V referenced to a copper-copper sulfar atting effect on zinc. If a soil box is used for measuring	dustry. Write your answer in the space provide o, they should not be prewetted or soaked prior be investigated for possible winding-to-winding 50 b. Other procedures for monitoring the effectiveness and Recordke These elements are the building blocks of the property of	ed. You should become thoroughly familiar war to installation. First, it enlarges the size of g shorts. Cathodic protection current lost to ectiveness of cathodic protection, which may be eping Recordkeeping Importance of Good R ohysical world and are composed of atoms. 34 E International, 2006 1/2008 Field Measuren lect data so that the resistivities of various land be determined by inserting an ammeter into senergized, appropriate measurements should ystems Anodes MAGNESIUM Magnesium and labit. 0.1 = 10 a. Some inhibitors © NACE In mped in the box to simulate natural compactions.	the anode, thus reducing the anode-to-ground resistant other structures through this short will return to the reducing the conducted at specified intervals or as appropriate, be conducted at specified intervals or as appropriate, ecord Keeping Documentation is the only way to follow a Experiment 3.2 Demonstrate Change in Polarized Polarity of Scillary the Wenner method, the soil resistivity yers of soil can be calculated. Schramm William H. The othe circuit or by the use of a shunt. It is especially unled be made to verify that the connections are correct. Odes are available in two alloys: a high-potential alloy ternational, 2006 1/2008 Underground Corrosion Comon and be flush with the top of the box. Figure 9.5 illustrations.	main on the service line. (6) Agree to treat as confidential my knowledge include: • Coupon test stations • Electric resistance probe test stations • with the history of a system. Thermite welding may be used for connections obtential with Time
shown in Figures 8.13 and 8.14. Backfill For underground applications, impressinstead. If you find a structure that is not up to its protection criterion, a short have clear economic and operating advantages over other impressed current persurrounding soil and thus reducing the resistance of the anode to earth. 7 Power above for vertical anodes. In practice, even the low internal resistance of an amazime members of the coating in the best possible condition. The meter in structure with the coating in the best possible condition. 2 2 × 5 5 = listed. Potential refers to the possibility of doing work. Examples of structures that drives the corrosion process. In cathodic protection rectifiers, taps are local installation. If the cathodic protection current can be interrupted "on" and "or groundbed resistance to earth. This was explained in Chapter 1, but is repeated NACE International, 2006 1/2008 Installing CP Components 8:8 ISOLATING UNSLEEVE NUT INSULATING WASHERS STEEL WASHER INSULATING GASKET	circuit may be the cause. Various power sources have ower sources. Current flow back to the main will be for	been used with impressed current systems included on the shorted service line. Each branch manned to the sem. SCRAP METAL Although not commonly used ing the meter on the positive terminal. The best across the structure-toelectrolyte boundary (interpretate of the positive terminal of the meter, the justments are possible. However, nonmetallic most the isolation fitting with the reference cell in ing, or the casing vent may serve as one of the END SEPARATOR Figure 8.6 Isolating Coupling	uding: • • • • • Rectifiers Solar (photovoltaic ay have a different resistance; thus, the value know the various conditions under which corred as an anode material because of its high cost method of proceeding is to reduce the volt	cells Engine generators Wind-powered generators Te of the current in each branch may be different. Also, rosion can occur on underground facilities. They are is consumption rate, scrap iron or steel can be employed age output tap to a low level and reset the circuit breample. It is important that you help ensure proper isola ential and the cathodic polarization. Asphyxiation can rete cylinder pipelines underground tanks and piping the difference in available oxygen between sand and cleaxcept for their use in electrical isolating devices. Be a arriving to class. Vertical Anode Installation Auger to the property of t	Thermoelectric cells Where AC power is economically accessible, rectifiers the backfill swells upon getting wet, providing a tight fit with the installed, using coke breeze backfill, in a manner similar to that explained a Basic Electrochemistry aker. These will be found in various standard practices (SP) or ation. Coating inspection is important because it is desirable to install the occur due to the displacement of oxygen by some of the other gases exterior bottoms (both primary and secondary) of above grade storage ay areas in contact with a structure that produces the electrical energy certain to follow the design specifications and drawings during to the depth indicated on the plans. This will cause an increase in the sa of the metal in the higher concentration of salt is usually the anode. © al, 2006 1/2008 Installing CP Components 8:9 STEEL STUD INSULATING
corrosion. This is of special concern in deep anode beds. Remember, if the data CURRENT ANODE Figure 3.3 Typical Galvanic Anode Cathodic Protection Another Current and Copper Steel Another Steel Steel Copper Steel S	des There are several metals commonly used as galvannsitive meter must be used. The slug is connected to a sed corrosion on amphoteric metals such as aluminum and Measured Voltage Drop(mV) Meter Positive Meter Newstare more electrochemically active than hydrogen. (D. Mace International, 2006 1/2008 Basic Electricity 1 stion of 0.5 mV/°F or 0.9 mV/°C must be either added once the early 1900's, but are being used less and less and 4 For CP beginners, I recommend Peabody's Pipeline tanks, data are frequently taken around the periphery metal surface to zero. For example, when a neutral irosee- ee- ee Figure 2.5 Anodic Process (half reaction) The	ic anodes: • aluminum • magnesium • zinc. Sucterminal on the top of the tube. As the resistant and lead. Figure 1.11 shows a typical alternating gative Direction of Lead Lead Conventional Curonot write on the back of this form). Forms much miscovered some facts involving voltage, curonot Tries and the source of the total versubtracted when reference temperature is about because of toxicity and environmental concorrosion and Cathodic Protection. Electrical Coff the tank. © NACE International, 2003 Page 2 atom (Fe) oxidizes, it may lose two or three electrode or metallic site where oxidation occur	ch practices may be encountered on bare medice increases, the current output for a given by growing current. Electrochemical force D. © NACE rrent in External Circuit Copper Steel to Step 1st be printed legibly in black ink or typed. The process of the collage, ET = 20 V Total current flow IT = ET process of the process of the collage, ET = 20 V Total current flow IT = ET process of the collage, ET = 20 V Total current flow IT = ET process of the collage of the colla	etal or very poorly coated systems where complete cat voltage drops. This not only saves time, but also yields International, 2006 7/2007 Basic Chemistry and Basic el Copper to Zinc Steel to Steel Zinc to Copper Zinc to his information is intended to assist students of the NA is a difference in elevation between the starting and $\Gamma/RT = 20 \text{ V}/2.003 \Omega = 9.98 \text{ A Next}$ , calculate the voltagely. An advantage of using cathodic protection is that Basic Chemistry and Basic Corrosion Theory 2:31 Resign become complacent with electricity as in many cast SWER KEY 1. Please provide all information requested in the starting and information requested in the starting and starting and sample of the starting and the starting and Basic Corrosion Theory 2:31 Resign become complacent with electricity as in many cast SWER KEY 1. Please provide all information requested in the starting and t	hodic protection may not be feasible because of cost. If readings below is a more accurate reading than that obtained with an ammeter. Highly it is a corrosion Theory 2:33 Results Meter Positive Lead Meter Negative of Zinc Copper to © NACE International, 2006 7/2007 Which metal is the ACE Cathodic Protection Training and Certification Program prior to class ending flow points. This instrument is not suitable for electrochemical age across the parallel part of the circuit. 10 January 2008 VI Section 10 it it avoids the use of bonds and the installation and maintenance cults Metal Sample Copper Potential Steel Conclusion 1. 2 Dynamic Stray es the voltage being measured is very low with a low source of energy. Each As explained earlier in this chapter, cathodic protection involves $e+++2e-Fe \rightarrow Fe++++3e-ELECTROLYTE\ e-Fe++Fe++e-++$ rade insulation checker but is designed to be used only with test wires to
Confirm that the AC power is off by testing as breaker contacts can fuse togeth pure water, H2O. Cathodic protection is achieved by making the structure the cathodic Process (half reaction) © NACE International, 2006 7/2007 Basic Chefewer test stations. If a poor coating is found, it may be necessary to excavate and many other data. Keep one fresh electrode in the office or shop to be used insignificant. It is the resistance of a conductor when a voltage of one volt prod Standards Organization (ISO), Det Norske Veritas (DNV), etc. 0.03 Volts = 30 r of a galvanic anode system rectifier voltage output structure-to-electrolyte pote or overlooking problems with the system. These types of anodes are usually pla safety hazards are those specifically related to cathodic protection and are not have been created somewhere on your structures. Sample Phone: 409/111-432 2006 1/2008 Underground Corrosion Control 3:36 Corrosion Current 14 mA -0. fluctuating measurements, you may suspect that you are working in a stray cur	er thus making contact in the tripped position. Calibral cathode of a direct current circuit. Repeat steps D1 to be ceiver is near the structure, the AC field around the structure and Basic Corrosion Theory 2:8 Electrochemical nore of the pipe to see how far the deterioration exists to calibrate your field electrodes. Wt = KIT = kg K = House a current flow of one ampere along the conductor illivolts c. Connect the meter to the metal samples as ential voltage drop across a pipe span voltage across a ced parallel to the section of pipeline to be protected. always in a standard safety program. This serves as a 1 Company: ZZZ Coating Inspection Inc. 6 Electrochem 29 V -0.31 V + + Same Meter + Conventional Current rent area. It contains a step-down transformer, a mean	te the span by passing a known amount of batted of the other metal configurations shown in fructure induces a voltage in the pickup coil. The l Circuits The basic electrochemical corrosion of Facility Maps and Work Documentation Compared Table 2.1, the loss rate is 9.1 kg/A-yr I = 8° C. © NACE International, 2006 7/2006 Monitoring indicated below. © NACE International, 2006 7 current shunt A voltage measurement, like any RECERTIFICATION REQUIREMENTS Every the check of the accuracy of the rectifier meter. Pownical Circuits	ery current between the outside leads and me the table below. © NACE International, 2000 be process appears in Figure 2.6. e- He- H2 2 cell is illustrated in Figure 2.7. The various pranies that operate underground plants, such that operate underground plants,	easuring the change in voltage drop across the span (6 1/2008 Basic Electricity 1:18 Direct Current (DC) Discard CATHODE eee eee- e H0 e -H 0 H0 + -e H H+ H+ H arts of the basic cell are discussed following the figure as pipelines or cables, maintain atlas maps showing therefore be: 9.1kg/A-yr x 0.875A x 4 years=31.9kg=7 cordkeeping Monitoring Requirements Although regulation Theory 2:13 There are several voltage measurements expated value in mind including the magnitude, sign, a with sun spot activity and the earth's magnetic field). On the device. • Stray Current - current in a structure that the find extensive use in protecting the interior surface of Eliternational, 2006 7/2006 Stray Current Interference imponents depending on its usage. If the structure is a	AE) using the inside leads. This concept is better understood if we look at frect current flows in only one direction. 5 Computer Records and H+ H+ e- H+ e - e -H 0 H+ ee- e H+ H0 H+ ELECTROLYTE Figure 2.6 e. It is preferable to err on the side of more test stations rather than the location of structures, test points, cathodic protection installations, 0.3 lb If the loss is occurring over the entire bulkhead, it will probably be latory agencies have adopted standards set forth by NACE, International commonly made in cathodic protection surveys: • • • • • driving voltage and units to prevent mistakes in meter connections, misreading the meter, 0.8 Ohms © NACE International, 2003 Page 2 of 3 10. The following is not part of the intended circuit. If so, an interference problem may of heat exchanger water boxes and other vessels. © NACE International, ence 6:4 Proximity of Possible Sources Even before you encounter adequately protected, the corrosion rate will be zero. Technical Accurate
Figure 2.17. (2) Recognize and acknowledge that the control of cathodic protect knowledge of the dimensions of the pipe. • The total (equivalent) resistance is a dock will usually make electrical contact through metallic hawsers or other conshould be inspected to ensure that backfill material surrounds the anode. The 1 problem in deep groundbeds and in tightly packed soils. If a voltmeter is connected.	it is a 24-volt battery. WEB INSTRUCTIONS FOR ACC as in the Wenner method. When a low resistance medipositive than steel, zinc, or magnesium. Step 1. High version MA) N/A CP Calculated Voltage Icp Drop (Vr) Resistor working on the equipment. Step 5. Recording voltmet ority of facilities containing hazardous materials are results that are caused by disturbances in the earth's mask (Molecules)	ESSING STUDENT GRADES It is NACE policy to must as salt water, brine, or some other very oltage DC (HVDC) transmission systems (mainly N/A N/A N/A N/A 1,000 ohms 100 ohms 10 ohms 10 ohms and display data on charts or may record designated by agencies enforcing the Code of Fedgratic field by sun spot activity. The pressure community is important to note that of enter. These include flanges, couplings, and userial resources, to reduce economic losses, and of Cathodic Protection Surveys	to not disclose student grades via the telephory low resistivity material gets into the annularly in monopolar operation). © NACE Internations CONCLUSIONS 1. The short circuit must be atta for later computer printout. Repeat steps level Regulations (CFR). Measure corrosion of auses the gas to flow in the pipe just as voltated there must be a substantial potential differunions. 35 Use of Current Interrupters	one, e-mail, or fax. Impedance is measured in Ohms, a ar space between the casing and the carrier pipe the rational, 2006 1/2008 Underground Corrosion Control 3 be the last component connected when the circuit bre B1, B2 and B4. The antimony electrode consists of a surrent (Icorr). Typical sources: DC rail transinge caused electrons to flow in an electrical circuit. Morence, or driving voltage, between a galvanic anode and the process, the metal absorbs energy during the transinger example when a ship or barge containing a combustivarrent control. NACE International, 2006 1/2008 International, 2006 1/2	manifestation in pipe-to-soil potential in the area of the casing is similar to :37 RESULTS Circuit Conditions Esteel Native (OC) (open circuit) aker trips. Lock Out / Tag Out A lock out / tag out (LOTO) is intended to slug of © NACE International, 2006 1/2008 Field Measurements t systems and mine railroads Welding operations Telluric currents HVAC easure the voltage drop in millivolts across the measuring span (without and the structure to be protected. $0.4 = 6.20$ Surface Groundbed A classic example of a galvanic cell is the flashlight battery, shown in formation. The accuracy of this test method depends greatly on accurate the material docks at a cathodically protected dock, the barge and the stalling CP Components 8:15 Prepackaged Anodes Prepackaged anodes conform to specifications. Gas Venting Problems This is a common the event of the stable of th
NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory maintained, the cable will fail from electrolytic corrosion. You can determine the designs have more than one negative circuit. 0.5 Amperes = milliam precaution is to turn off the cathodic protection rectifier(s) until the vessel is seen and perhaps a wooden plank about a foot over the cable. Consequently, you are Surface Storage Tank Figure 8.22 Surface Distributed Anode Groundbed Configuration Deep anode installations are those where the anodes are installed potential drops (becomes more positive) at least 100 mV, the criterion has been Sheets	onnection for Test Lead Copper Rod Clear Window Por 2:17 Use and Care of Copper Sulfate Reference Electre e rectifier current output by measuring the voltage dreps e. Figure 3 shows the relationship. © NACE Internated International English of the dock. Illegible information can dean important part of the record keeping operation. The guration Berths { { { { { { { { { { { { { { { { { the solute open to the english open to the electron, producing a neutral hydrogen atom (H). Open to application is seawater. When acids dissociated to solve. Look for vent obstructions. 0.4 = by occur. They are also used on ship hulls and in ballast	ous Plug Saturated Copper Sulfate Solution Coppedes • • • • • • • • • Keep clean. © NACE International Sulfate Solution Coppedes the shunt. The receiver picks up the stional, 2006 1/2008 Underground Corrosion Coppedes the application process. With a shunt in placere are isolator checkers that are based on a himage of the solution of the shunt in placere are isolator checkers that are based on a himage of the solution of the shunt in placere are isolator checkers that are based on a himage of the solution of the shunt in placere are isolator checkers that are based on a himage of the solution of the shunt in placere are isolator checkers that are based on a himage of the solution of the shunt in placere are isolator checkers that are based on a himage of the solution of the shunt in placere are isolator checkers that are based on a himage of the solution of the shunt in placere are isolator checkers that are based on a himage of the solution of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a himage of the shunt in placere are isolator checkers that are based on a him	pper Sulfate Crystals Figure 2.14 Copper-Co ational, 2006 1/2008 Installing CP Componersignal on the structure and provides it to the entrol Experiment 3.2 3:38 Demonstrate Charace, the measurement can be made without high radio frequency and are more reliable for a few figures of the figure of	this 8:22 If insulation integrity on the buried or submetuser as an amplifier sound. Therefore, electrolytes witning in Polarized Potential with Time NOTE: Instructor having to open the circuit. If there is a concern over derisolators in service. © NACE International, 2006 1/2 is Ramp { Piles Shore Line Figure 8.23 Distributed Anne surface is being prepared and the coating is being found, adequate slack in the conductors should be prose, either measure a case-to-ground voltage or use an inductivity or its reciprocal (resistivity) is an important 1/2008 Installing CP Components 8:7 Test Box 1 Term both the pipeline and the casing. The transformer relationary reference electrode built into them and some	th Figure 2.15 Portable Copper-Copper Sulfate Reference Electrodes © rged header cable (positive lead wire), including splices, is not th higher ionization have greater conductivity. Some cathodic protection r will demonstrate this experiment. It serves two purposes. Another amage to the cable from future excavations, lay a plastic warning tape 008 Installing CP Components 8:26 Power Source Pipeline _ + Anode ode Groundbed Protecting Wharf Piling Deep Anode Groundbed applied in an atmosphere conducive to proper coating performance. If the wided within the test station to facilitate test connections. 4 Data instrument that detects AC voltage by a light that comes on when placed to parameter in the study of corrosion and its prevention. Spreadsheets minal Board 4 2 5 3 Figure 8.5 Foreign Line Crossing Test Station A reduces incoming AC voltage down to the operating voltage of the cathodic chave a nonmetallic tube from grade to the coupon which a reference
electrode can be lowered into. How does it compare with your calculated value is the true criterion for eliminating corrosion. © NACE International, 2006 1/20 disbonding, damage, checking, cracking, chalking, and other deterioration. Fol corrosion control program will not know how well the structures are protected. usually 0.250 volt to 1.000 volt or more. The chemical backfill surrounding magunderstanding of corrosion and cathodic protection. These requirements can be the probe's electrical resistance. © NACE International, 2006 1/2008 5:28 Field ISO 15589-1 Petroleum and Natural Gas Industries-Cathodic Protection of Pipe Anaerobic soils or sulfate-reducing bacteria (SRB) more negative than -950 mV mixed metals or SCC conditions more positive than -850 mVCSE. Care must be connecting and disconnecting this type of locators as high voltages may be involved to establish continuity. Wherever possible locate isolating devices in an Corrosion Cell The concept of cathodic protection involves reducing the potentiest stations are used to measure the magnitude and direction of current flow corrosion cell. 18 Meter Operation	low the following diagram. Note that in this discussion 17 Offshore Anodes	isolating joints should be installed above grade we are utilizing the concept of conventional cumulations. 2 Recordkee that that reduces self-consumption of the anode. It done in accordance with the manufacturer's synwhere Four-Pin Method Most soil resistivity Metal-to-electrolyte potential chosen for a constant 1,000 $\Omega$ -m f -650 mVCSE for $\rho$ > 1,000 $\Omega$ -m • is (positive lead wire) to avoid damaging insulational current in the electrolytic circuit is from the manufacturer in the electrolytic circuit is from the manufacturent in the electrolytic circuit is from the manufacturer in the electrolytic ci	e. Figure 5.4 illustrates © NACE International arrent flow (see Chapter 2). The test current reping	al, 2006 1/2008 Field Measurements 5:5 a pipe-to-soil is set up between the pipe wires and those on the casi	potential profile. This can be done visually, looking for signs of ting. Without accurate data, those responsible for your company's fective, the pipe-to-soil potential on either side of it should differ by so of electricity, chemistry, and electrochemistry form the basis for an oplied. The probe is wired in such a way that the instrument can measure
oxide anodes (also referred to as DSA for dimensionally stable anode) consist of determines the value of the shunt resistance. The water box is connected to the occurs at the anode. Consequently, electrical instruments are used in some commeasured at a given spacing, then the spacing can be changed and resistance maintenance after electrode has been used in a situation where contamination lead you to suspect a shorted casing. 23 Naturally Occurring Corrosion	e exchanger shell through hinges and bolts. Negative of rosion testing and we need to understand various electrosion testing and we need to understand various electrosion testing and we need to understand various electrosion testing and the new spacing. Cable Breaks Cable breaks could have occurred (e.g., salt water). Figure 8.11 shows the state of the sample of t	ircuit The return or negative circuit is the cablicatical terms, laws, and circuits when working wilks may be caused by third party damage from every a coupon station. An interrupter is a switch the necessary to copy the data onto fresh sheets to be necessary to copy the data will be used to every the same size. NACE International Recomme reight loss. WARNING - DO NOT TOUCH THE Party, databanks, data collectors, and organizers. The voltage drop across a 200-ft span of 30-in. 4 Do not highly stressed area is usually the more activature © NACE International, 2006 7/2007 Basic manner. 3. Many rectifier	ing from the structure to the rectifier. Running ith cathodic protection. Hence the name, galexcavation or from discharge of current from that is alternately turned on and off on a regregative returning from the field. CONDUCTIVE evaluate the effectiveness of cathodic protect ended Criteria General There are several critemated Criteria General There are several critemater and Felluric currents are naturally-occurring dyn Date, Time, and Weather	ng a detailed survey or, on a pipeline, a pipe-to-soil porvanic anode. For seawater application aluminum anotopositive cables. Measure the forward and reverse volular timed cycle by some mechanical or electronic meter POLYMER This is a flexible wire-like anode that is used ion, interference bonds, stray current control devices are recommended by NACE. A damp, well-aerated metataking VOLTAGE READINGS. Voltage Voltage (joul amic stray currents that are caused by disturbances in the instance of the control of the	ottential profile may help in identifying the problem. Metal loss (corrosion) des are often sized to fit the size of the structure. After resistance is stage and record if it is good, open circuit or shorted. Perform eans. Discovery of such a shift in the usual pipe-to-soil potential should used underground and also to protect reinforcing steel in concrete. This and the like. This is shown in Figure 2.4, which is typical of the behavior retal surface may undergo more rapid general corrosion than a surface de/coulomb), or potential, is an electromotive force or a difference in the earth's magnetic field by sun spot activity. Step D Current Direction Coatings may be hot or cold applied. Perhaps there is something wrong allation of a casing. The anode and the cathode can be on different metals parts of an electrochemical circuit in which charge movement is andling the current. For underground use, the anode can be obtained in a
voltage by using Ohm's Law. If the solution becomes cloudy, clean it out and redifficult to read a specific value from the fluctuating members. Use a Number 2	place with fresh copper sulfate solution. Explosions or pencil. 200 millivolts =	Ignitions In addition to hazardous areas, many ally have a shunt in them to permit measurement tion system is 1 volt and the protective current sulated test leads and clips. 1,000 Amperes = 1 mg Cathodic Interference Location of Foreign Strials Does the voltage drown beneath the anode should be free of holidays. OPY OF THIS DOCUMENT FOR YOUR RECORD Prectifier. Two reference electrodes, mounted a sually have a centering device on them to keep to be to resistance in a direct current circuit. At tends an important role here, too. See the figure on the only need to know the amount of current flowing the string in the sum of t	structures containing potentially explosive on the magnitude and direction of current is 100 mA. Printouts are then generated at a kiloampere d. Chapter 2 covers basic corrost tructures and Rectifiers Here again, you may be sum = total power voltage? $10x = 130 x = 100 $	for combustible substances are cathodically protected. flow. If an AC voltage in excess of 15 V is measured, to the appropriate times for technicians to take into the sion chemistry and basic corrosion theory. Leave over by be able to spot possible interference problems just for 13 8. Loading PreviewSorry, preview is currently unaround Corrosion Control 3:16 Advantages of Impressed acknowledge that the proper control of cathodic problems in the hand. These currents can be manmade or natural in it in a constant in the number of anode groundbeds required (see plots the current output may be reduced. Still, precautions are (RT) of R12, R13 and R14. Surface Groundbed Confidetermine the direction of flow. When you are talking	If a voltage is changing, the numbers are also changing, and it may be he structure is considered hazardous; and steps must be undertaken to field for the next scheduled tests. • Use caution when working near night. © NACE International, 2006 7/2006 Stray Current Interference 6:5 rom looking around. Be aware that a person need not be completely vailable Calculate current? High conductivity of Current Systems • Flexible with capability to handle a wide range of cotection can be critical to the safety and welfare of the general public in origin. If a service line is shorted, the signal will travel up the line and Group Exercise 1.2 for further practice with series circuits. Impressed under Section 3 above). A cable is then run from the positive bus bar to need to be taken in handling the negative cable. Casings become an igurations General Surface groundbeds are those where the anodes are with colleagues from your own company and from other companies, you
used for cleaning metals • Caustics used in polarization cells • Chemicals used math. 9 Output Problems	in reference electrodes. For energy pipelines, regular	monitoring is required by code. Easy to add and melts, and drops down, welding the wire to the are 5.12 if 10 A of battery current passes from to mV. © NACE International, 2006 1/2008 Underly 2:4 above 7. Magnitude and direction of current drive about your territory, be alert for cathodic enegative than the statistical standard deviation of the material can be tolerated. If we had a custof the material can be tolerated. If we had a custof the material can be considered and in the surface pacemaker? Because corrosion cells are usually tivity. It is important that the pins are placed in the table of the surface is been backfilled properly, the backfill will not formally and the surface is been backfilled properly, the backfill will not formally make the surface is the surface of the surface o	odes in most cases. Relationship between Custructure. Be careful not to make direct phy the east to the west outside leads, resulting iterground Corrosion Control 3:20 ENGINE-GET rent through mitigation bonds. Surface Prepic protection rectifiers. The meter determines on of the native potentials. These cells result furrent of 2 Amps and a resistance of 10 Ohm International, 2006 7/2007 4:8 Safety Mater y microscopic and the measured potentials at a straight line and that they are equally spand of a pipeline. Steel is more electronegative to fully serve its purpose and deterioration of the	rrent and Voltage $11/01/04$ He established the fact the sical contact with the measurement circuit. • The voltage drop change ( $\Delta E$ ) of : On = 5.08 mV Off = 0 ENERATOR UNITS Engine-generator units may be use a ration Proper surface preparation is essential if the case resistance by providing a small current or voltage across from voltage differences caused by such factors as surface years as a voltage equal to 20 Validades and Safety Data Sheets (MSDS) Material safety data share mixed corrosion potentials, the initial measurement ced. Depolarizers include: • Dissolved oxygen • Microsthe rectified DC still has some ripple in it, however, so than copper 2. If, however, the fluid contains sulfides the anode itself will be accelerated. When testing multi	at these relationships never change, so now they can be expressed by age drops may all be different depending on the value of each resistance, .17 mV $\Delta E = 4.91$ mV Then the calibration factor will be: $K = 10$ A 10 A or ed as a power source for impressed current systems. Acid solutions have a coating is to bond properly to the metal. 22 Soil cross an internal resistor and comparing its value to the external resistor. rface irregularities, mill scale, oxygen concentrations, differences in the Volts. They can be useful for checking circuit continuity and for other neets (MSDS) are available for every chemical and many pieces of ts are most likely to be an average of corrosion potentials for several biological activity • Water flow © NACE International, 2006 7/2007 Basic of it is not the pure DC that comes from a battery. Low maintenance or hydrogen sulfide, a minimum potential of -950 mV (-900 vs Ag-AgCl) ple pipelines that are bonded together, the survey data may represent an
average of all the pipelines. This configuration is typically used on transmission Ohm's Law is a relationship between the ratio of voltage and current to the resultance flakes at the grain boundaries. Since voltage (or IR drop) is a product of current operate the meter comes from the circuit itself. Opposite B. (Note: the ions do pins. This is because the corrosion current is concentrated in a small area (larg "hazardous" and electrical equipment must be contained in a sealed hazardous General	istance of a circuit. IR DROP Since cathodic protection t and resistance, voltage decreases when either current of plate out on the cathode.) On the other hand, negate current density). The sound of the signal, such as the junction box. If the resistance unit is ohms, use Ohm's Water flow through a heat exchanger water box and to metals exposed to an electrolyte such as soil, we her persons. With current interrupted, watch the decay tray Current	it or resistance decreases. Remember that you is a polarized post or resistance decreases. Remember that you is requested ions (anions) move toward the anion of the pulse, can be controoned to be frequency and rate of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to be a post of the pulse, can be controoned to	may be assigned to do an annual inspection may be assigned to do an annual inspection node and away from the cathode. The averagolled by the transmitter. Electrical Hazardous ion that may be necessary to maintain the uneasuring Structure Continuity	etermine the level of protection. HIGH SILICON IRON on an unfamiliar structure using only the data sheets be soil resistivity is a function of the voltage drop betworks. Areas Where there is a possibility of an explosive minists of the law (amps and volts or milliamps and millive minists of the law (amps and volts or milliamps and millive minists	N Regular silicon iron consists of a very hard matrix, which has graphite of the person who was there before you. Note that the energy needed to een the center pair of pins with current flowing between the two outside xture of a hydrocarbon, the affected area will be designated as olts). 29  national, 2006 1/2008 Underground Corrosion Control 3:6 Cathodic Protection Technicians, NACE CP 3-Cathodic Protection Technologists, 2 Conventional Current Flow Figure 2.10 shows the actual What is the current flow? Type in your 4-digit Password (Normally the Digits)  *Note that the Student ID number for NACE arface are thoroughly dry. This can be accomplished by causing a current have been used as impressed current anodes. The most important truations in structure-toelectrolyte potentials and, on pipelines, by the pipe, and then through the meter, back to the anode. 19 Faraday's
Attachment	he current is the same everywhere. © NACE Internation In SELF ASSESSMENT The CP 1-Cathodic Protection To Trends can be analyzed over extended time and plans RDS S A M P L E Form 1: Summary of Cathodic Protection. Various bacteria enter into redox type reactions. In the symbol used for resistivity is ρ (Greek letter and only half the current (1 Amp), now the voltage would chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and Basic Corrosion Theory 2:6 Oxidation a tional, 2006 1/2008 Underground Corrosion Control 3: Chemistry and 2:00 1/2008 Underground Corrosi	d the zinc's potential. An electrical log is frequential, 2006 1/2008 1:30 Basic Electricity 1:31 Reserver and CP 2-Cathodic Protection Technician can be made for maintenance and repair. 11 Andrion Related Work Experience Instructions: Makin addition to attempting to make the IR drop northo). To determine what effects are occurring a maximum	ently made of the hole to determine areas of ecord the data collected on the Exercise 1.4 courses involve the use of basic mathematic lodes	lowest resistivity. x + 3 = 5 x = 2 b. In many distribution and the provided and sheet provided. Aluminum anodes are commonly as skills including addition, subtraction, division, fraction	ons systems, however, it is difficult to use post-mounted test stations vused in process vessels containing brine. This matter is discussed in the ons, algebra, balancing equations, conversions of units, percentages, and need Name: Date: THIS DOCUMENT MUST BE SIGNED AND RETURNED
electrochemistry. © NACE International, 2006 1/2008 Installing CP Component Series Circuit	ts 8:3 Types of Test Stations Potential Measurement P Insulated Wire Connection to Structure Protected parallel to the moving coil to shunt a significant potentional, 2006 1/2008 1 kilovolt 1000 millivolts 100 me concerned with voltage when making various measurement. IR drop will affect the accuracy of the data collection 8. Before the power source is energized, it must be bound test stations are preferred. Students who do not aim the meter on the positive terminal. Divide the currile, this can be done only once as the calibration factor ious parts of the structure. (D), 2. © NACE Internations should be provided with suitable test stations to per Piping Systems. If the short circuit is internal to the rethe electrode bulb. Again, be certain to follow the desired.	otential measurement test stations are used to red Structure Special Galvanic Anode Backfill Station of the total current around the moving coil illivolts 10 millivolts 1 millivolt 1 microvolt Basis rements in cathodic protection work. The following cathodic protection testing. • There is the verified that the negative conductor is connected the manual before the class may find the class flow in amperes (I) by the change in voltage may be recorded for subsequent tests at the sail al, 2006 1/2008 Basic Electricity Exercise 1.4: In the measurements of effectiveness of isolation a certifier, the circuit breaker will again trip. Base and drawings and specifications during the instations.	monitor the effectiveness of cathodic protect trip Anode Earth Backfill Figure 8.15 Ribbon I. Often this is a mixture of sand and bentonic Electricity 1:2 Common symbols for voltage wing are instructions for this process: To accis no testing that is required behind the paneted to the structure to be protected and the lass much more difficult than they would other drop in millivolts to express the calibration me location. RATED BATTERY VOLTAGE (ETRESISTOR and Instrument Lab Simple measure and to permit installation of control resistors. Hourly Rate (USD)Certifications in the same fallation. Avoid open flames. RESISTANCE Measurements.	ion, check for stray current effects, and, on unprotect or Strip Anodes Bracelet Anodes Bracelet anodes are te. Be certain that this connection is made to the prope are: emf E or e V or v electromotive force - any voltages grades on the NACE Web site go to: www.nace.or el with the rectifier energized with the exception of magnetic positive conductor is connected to the anodes. These erwise. 2H2O + O2 + 4e- → 4OH- Hydrogen Ion Red factor (K) in "amperes per millivolt." The calibration for the conductor is ammeter and voltmeter functions of Canada Canadian Standards Association Standard, Ze industry as NACE Cathodic Protection (CP) Tester Cathodic Protection (CP)	ed or partially protected pipelines, to locate areas of active corrosion. 10 used on offshore piping, river crossings, and other underwater per terminal. The following shows their relationship: 1,000 Volts 1.000 age unit voltage across a source of electrical energy (e.g. battery, pipe-tog Choose: Education Students Only Grades Access Scores Online Find easuring the input AC supply voltage. The corrosion rate of aluminum terms are determined by how many free electrons are available to allow action—more common in acidic environments $H++e-\rightarrow Ho$ Corrosion factor is calculated as follows: $K=I/\Delta E=I/E$ with current applied $-E$ Volt(s) STEP 2. In this test, one reference electrode is placed at a fixed a digital multimeter can be used to determine the characteristics and 662, Oil and Gas Pipeline Systems references CGA Recommended
insulation on the wire. Some structures with overall impressed current cathodic Animals, reptiles and insects • Vehicles: Drive defensively and be aware of haze seawater. Of particular interest is the pH, which expresses the hydrogen ion contection, therefore, with less current during dry periods than otherwise. ER The most common method of attaching wires and cables to a structure is by exametals such as aluminum and lead. There are times when it may not be desirable.	c protection systems may have isolated points where a red situations that could occur © NACE International, neentration in the electrolyte. Also, if the structure-to-elected in the important thing to note about Ohm's Law: in othermic welding, also known as thermite welding. In alle or even practical to isolate protected from unprotected even even test station can be used to determine the line current test station can be used to determine the line current through the electrolyte What can be reduced to zero by interrupting the current flow the flow of current. If the casing has only one wire, the However, in most cases, within 7 to 10 business days	dditional current in relatively small amounts is a 2006 7/2007 4:10 CHAPTER 5 Field Measureme electrolyte potential happens to be the same on a order to find an unknown value, you must know act, current shunts are favored over using an act ed structures. Also, on bare or ineffectively consistivity in microhm-cm = Resistance of 1 ft of ent even if the dimensions of the pipeline are used to the voltage drop across R1? They must be ship of NACE International, 2006 1/2008 Field Measurement is used as the other one. These instrument following receipt of exams at NACE Headquarters.	needed. 16 Component Parts of Impressed Cents Other Portable Reference Electrodes Sine either side of an isolating joint and no AC is the two other values. Depending on the attempted in most cases. High cathodic protect ated pipelines, the measurement of a net proweight per foot pipe, microhms © NACE Into Nach Nach Nach Nach Nach Nach Nach Nach	urrent Systems	LEAD-SILVER This material is used only in chloride environments. • chloride (Ag-AgCl) reference electrodes are used for measurements in e double insulated or single insulated. You may be able to maintain uctor, semi-conductor or an insulator. Thermite (Exothermic) Welding ghly stressed steel and may actually increase corrosion of amphoteric redetermined current discharge points) may be sufficient. 8 Rectifiers 33.14 23.39 16.09 17.36 15.12 13.42 12.07 10.96 10.04 6.25 8.60 8.01 oper. Thank you. This helps to reduce protective current requirements. Derly tensioned. The IR drop through the electrolyte can be reduced to all esource, galvanic anodes or impressed current, must have electrical evaluated. The log helps to determine the desired locations for the cathodic protection current to a structure: • galvanic anode system •

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pH is used to create a water that will not be aggressive to the metal piping and vessels it contacts. One branch deals with solid state reactions that take place in semiconductors such as transistors and diodes. The currents entering Points A, B, and C equal those leaving these points. Care should be exercised so that lead wires and connections are not
 damaged during backfill operations. 053 \Omega 0.2 + 0.25 + 0.5 0.95 RT = IT = 20 V = 19 A 1 . Here again, if an ammeter is used, it must have sufficient capacity to handle the test current. The exterior of the pipe is wrapped with kraft paper for protection during shipping and handling. © NACE International, 2006 1/2008 Field Measurements 5:2
Comparison of Potential Values of Typical Reference Electrodes vs. Look for significant output changes. Remember also that the positive lead from the meter is connected in parallel with the shunt and the negative lead to the right terminal. Connect
 anode to copper sheet as shown and measure initial cathodic protection current and polarized potential of the structure. When a structure common in neutral environments. Another component required for a soil application anode is a chemical
backfill. While low soil resistivity tends to increase electrochemical corrosion, it enhances cathodic protection by lowering the anode-to-earth resistance, thus allowing higher current output for a given voltage. The meter will now read to the right, but the position of the switch will indicate that it is a negative reading. Fill the soil box with water and
any available soil samples, © NACE International, 2006 7/2006 1 of 23 Chapter 6 Stray Current - Types of stray current - 
Manual - Chapter 6 © NACE International, 2004 April 2006 1 Definitions • Interference - any electrical disturbance on a metallic structure caused by a stray current. Therefore, current flow is: I = K x mV drop = 2.04 A x .17 mV = 0.347 A = 347 mA mV Referring again to Figure 5.12, note that the positive lead of the digital meter is attached to the
east inner lead. Given an electrical circuit with a driving voltage of 12 Volts and a resistance of 10 Ohms, how much current does the circuit produce? MAGNETITE Magnetite is a form of iron oxide. This may lead to cyclic wetting and drying of the soil, thus changing its resistivity. 0 volt E = R 1000 Ohms = 0. Attachment to Structures Galvanic
anodes must be directly attached to the structure through a metallic conductor. Much of the material in the courses is based on existing NACE cathodic protection training material which was developed and refined over several years by members including Robert A. Anode efficiency is the ratio of metal consumed producing useful cathodic protection
current to the total metal consumed. If you suspect this is the case, other testing, beyond the scope of this course, will be required. Standard rectifiers and many types of lightning arresters are potential ignition sources. © NACE International, 2006 1/2008 Field Measurements 5:6 Reading + Voltmeter Cu/Cu SO 4 Ref. What is the resistance of this
circuit? May cause overprotection resulting in: - coating damage - hydrogen embrittlement Component Parts of Impressed Current Systems Anodes GRAPHITE (CARBON) Graphite anodes installed underground with carbonaceous backfill function well. The survey is made over the line, so other personnel are assigned to locate and stake the line and
provide other assistance. Current Flow of electrons Unit of measure Ampere Symbol I (This symbol will be used in the Ohms Law Formula) Compares to The flow of gas or liquid in a piping system RESISTANCE Resistance can be defined as the opposition to current flow. Data must be entered accurately and neatly. The internal resistance of an
 ammeter should be low to prevent adding resistance to the external circuit, thus reducing the current of the external circuit. • Coating breakdown in a localized area near a foreign anode bed or other source of stray current. Current Interrupt Switch Shunt Reference Cell Reference Tube Pipe Lead Pipeline Coupon Element Figure 8.11 Typical
Coupon Test Station © NACE International, 2006 1/2008 Installing CP Components 8:12 Electric resistance probes are also used in oil heater-treater and other vessels, water storage tanks, and on marine structures. This will ensure that the cathodic protection system performs as designed. • Bubble only one answer per question and do not fill in
more answers than the exam contains. Significant Changes in Both Voltage and Current Outputs Sometimes both the voltage and current outputs will decrease significantly. 9 Cathode Reactions
                                                                                                                                                                                                                                                                                                                                                                     . Repeat Steps B1 and B2 for the steel. Follow wiring diagrams carefully to ensure the
negative circuits are connected to the correct terminals in the junction box. DIODE CHECK Check the diode with the diode checking circuit. Turn now to Group Exercise 1.1 at the end of this chapter and work through the calculations in the exercise 1.2. The potentials shown are approximate since they vary somewhat
depending on the environment. Given: A 30 A/50 mV shunt has a voltage drop of 10 mV. © NACE International, 2006 1/2008 Installing CP Components 8:6 Test Box Casing Figure 8.4 Casing Test Station Note that different color wires are used on the pipe and the casing. 13 Series-Parallel Circuit
                                                                                                                                                                                                              .... It is important that electrical continuity between the water box and the shell be maintained in order to protect the tube sheet. Additional testing is required to determine the extent of the fluctuations
and the source of the stray current. The wire is attached to a test station and the operator walks over the pipeline, making contact between the electrodes and the earth at closely spaced intervals. A current pick-up test is run by applying a cathodic protection current to the pipeline and measuring the resultant shift in pipe-to-soil potential. Caution
because of this low internal resistance, it is important not to set your multimeter on the ammeter when attempting to measure voltage, 36 20 8 - = 78 78 39 © NACE International, 2003 Page 1 of 3 d. Severe conditions of low pH and high sulfate concentration can increase the consumption rate. Protective Coatings Underground or Submerged
Structures General Coatings are the first line of defense in many corrosion control programs. Thomason Florida Gas Transmission Company; Maitland, Florida Southern California Exxon Co. USA, Houston, Texas CC
Technologies, Dublin, Ohio CorrEng Consulting Service Inc., Downsview, Ontario Kinder Morgan Energy Partners L.P., Tucson, Arizona LORESCO, Inc., Houston, Texas CC Technologies, Houston, Texas ENEngineering, Woodridge, IL Conoco, Inc. In cases like
this, the pipelines can be connected together and protected by a series of rectifiers, with each company assuming responsibility for a portion of the system. 20 + Voltage measurement is positive MV Curr en t Figure 2.12 Current Direction When measuring the voltage difference of dissimilar metals, the sign is positive when the positive terminal of
the voltmeter is connected to the more noble metal as shown in Figure 2.13. The safety precautions may include temporary electrically isolating physical contact with the pipe and other grounding of the pipe, avoiding physical contact with the pipe and other grounded structures and avoiding physical contact with the pipe and other grounding of the pipe, avoiding physical contact with the pipe and other grounding physical contact with the pipe and other grounding
current must enter the meter on the positive terminal. © NACE CP 1-Cathodic Protection Tester course, please read the entire manual. © NACE International, 2006 7/2007 Troubleshooting 9:8 Groundbed Malfunctions Galvanic and Impressed Current Groundbeds Anode Deterioration Anode deterioration leads to reduced anode
size. This device clamps around the metallic path through which the current is flowing and measures the magnetic field created by the current. © NACE International, 2006 7/2007 4:4 Safety 4:5 Figure 5.1 Group Scissor Lock Out / Tag Out (LOTO) All cathodic protection personnel should carry a LOTO kit with them when in the field if they plan to
                                                                                                                                                                                                                                                                               . See Figure 8.15. Major crossings between underground structures will generally warrant installation of a test station. 1 Current
                                                                                                            . As an inspector, however, you will want to be sure the unit is connected to the specified input voltage. The "Tools" menu in CP-Compass allows users to perform design calculations for any CP system for any structure. Rectifiers Routine Maintenance Many problems with
rectifiers can be prevented by regular maintenance. The sound of the signal can be received through earphones or a speaker. So this tool was designed for free download documents from the internet. For the following discussions, only standard single-phase, manual adjustment type rectifiers are considered. Some gases are toxic when inhaled. For
liquids, pH (litmus) paper or a pH meter may be used. Again, the AC wiring needs to be in the hands of a qualified electrician. When a voltmeter is connected across a metallic element, such as a wire or pipeline with external current flow as
 illustrated in Figure 2.12. Clean field electrodes if they are more than 5 mV different from your calibrating electrode. Be very careful not to damage the anode lead wire insulation. This is one reason why meters having input resistances of millions of ohms are used in taking potential measurements. • Can be man-made or natural in origin. A full cycle
is completed in a 50th or 60th of a second. Cables requiring a larger charge size can be divided into a "crow-foot" with each end attached to the pipe with a 15-gram charge. • If AC may be present, measure AC voltage first. A medium is said to be acidic when there is an excess of H+ ions. The coatings have high impact resistance and resist the
development of holidays over time. Periodically clean the porous plug to prevent clogging the pores. 21 Causes of Corrosion...
                                                                                                                                                                                                                                                                      . On an analog meter, the needle will swing to the right when current enters the positive terminal. These anodes are used in seawater, brackish water, fresh
water, and high-resistivity soil. How much, if any, corrosion is caused by telluric currents is still questioned, but they do create large variations in pipe-to-soil potential and current flow measurements. 4 3 × 7 4 =
                                                                                                                                                                                                                                                                                                                  f. Provide uniform distribution of current. Different alloy charges are used for steel and cast/ductile iron structures. 6
                                                                                                                      . Note the sign of the voltage drop to determine the direction of current flow. If not kept in good working order, the affected structure may undergo serious corrosion. Electric transmission lines (danger of induced AC). All active CP card holders are permitted to use
the term "NACE CP 1-Cathodic Protection Technologist," or "NACE CP 2-Cathodic Protection Technologist," or "NACE CP 3-Cathodic Protecti
2006 1/2008 1:24 Basic Electricity the smaller the shunt resistor must be to allow greater portions of the current to bypass the coil. It is essentially impossible, however, to determine the shunt resistor must be to allow greater portions and provide more
                                                                                                                                                                      .. Non-communicating, battery-operated, silent, non-printing calculators, including calculators with alphanumeric keypads, are permitted for use during the examination. Do not contact a measurement circuit until the potential is
 determined to be safe. (5) Recognize and acknowledge that the quality of my work reflects on the entire profession of corrosion control. © NACE International, 2006 7/2006 Stray Current Interference 6:2 Typical sources of stray currents are: 1. No installation files to download, no browser plug-ins required, no USB dongles to carry around, and no
license keys to transfer from one PC to another. Naturally occurring corrosion takes place because of local action cells on the structure. Lewis Ed Ondak Larry Rankin John Schmidt David A. Reference Books The primary reference for this course is Peabody's Control of Pipeline Corrosion by A.
the voltage drops? Build up of pressure B. These concepts will be thoroughly reviewed at the beginning of class; however, students may have difficulty understanding cathodic protection practices that are demonstrated in class if they are not familiar with these fundamentals. Series-parallel Circuit A series-parallel circuit (Figure 1.8) combines the
elements of both a series circuit and a parallel circuit. Coupon test stations are used mainly on pipelines. Insertion of dielectric material interrupts the electronic portion of the corrosion cell, thereby isolating the anode from the cathode. The metal oxide coating is highly conductive and demonstrates an extremely © NACE International, 2006 1/2008
Underground Corrosion Control 3:18 low weight loss. Maintenance Inspections While detailed inspection personnel may be called upon to make an inspection of exposed coating. 22 Digital Meters
of conductivity) and oxygen content, may provide the driving force for corrosion. Division of electrons D. In this case, oxygen reduction is the primary cathode reaction and corrosion of steel is the anode reaction and corrosion of steel is the anode reaction. Whether an analog meter is used to measure woltage, current, or resistance, each of these measurements depend on the measurement of
current flow. From time to time you will encounter problems with the cathodic protection you are monitoring. Flow of electrons C. Usually the shunt rating data are stamped on the shunt. To find more books about nace cathodic protection exam questions, Nace Cathodic
Protection Training, Nace Cathodic Protection Tester Study Material, Nace Cp2 Exam Questions, Nace Cp3 Exam Questions, Na
currently unavailable. The voltage is relatively high for such metals as magnesium, aluminum, and iron, and relatively low for such metals as copper and silver. An oxidation reaction occurs any time electrons are given up by an atom or molecule. The corrosion-cell potential can be estimated using the following expression: cell potential =
potentialcathode - potentialanode Step B-Potential Measurement + V - - V + Copper Sheet Tap water in tray Steel Sheet 1. Also, when using a digital meter, the reference electrode is connected to the negative terminal to obtain the proper polarity reading. Applicant Information: Name: Phone: Fax: Company: Address: City: State/Province: Zip/Postal
 Code: Country: Please summarize below the information on each copy of Form 2, Individual Job Documentation. 6 Cathodic Protection Levels
                                                                                   kiloampere d. There are several potential benchmarks in common use, but all of them are related to a basic standard. When hanging anodes are used, it is necessary to connect a lead wire between the anode eyebolt core and the structure. As another example, when galvanic anodes are used
to protect well-coated piping or tanks, loss of current to other structures often means that the piping or tanks do not receive adequate current for protected with 10 amps and after the survey the structure became electrically shorted to some large bare
structure, would measuring 10 amps at the rectifier still represent adequate protection on the structure of interest? There are some common rules that apply: • The person that installs the LOTO must be the one to take it off • If there is more than one person working on the equipment, then a group scissor-type lock is to be installed with each
person's lock on it (Figure 5.1). We will also cover measuring structure continuity and diode bias. If the display shows a negative sign, current is flowing into the negative terminal. This greatly reduces the size and cost of cathodic protection systems. Coating also plays an important part in cathodic protection engineering. The anodes are cast on a
steel pipe core, which in turn is welded to the platform or other structure to be protected. As the anode size diminishes, the resistance of the anode to the electrolyte increases. Above Ground Storage Tanks RP0193 External Cathodic Protection of On-Grade Metallic Storage Tank Bottoms • A negative (cathodic) potential of at least 850 mV with the
cathodic protection applied. Environmental Factors There are many situations where it would not be physically possible to make meaningful tests unless a suitable test station is installed at the time of construction-piping systems installed under concrete flooring, for example. As noted earlier, there is no single, universal criterion for cathodic
extensive amount of cable in the ground. 8. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:32 Results Metal Sample Copper Potential Steel Conclusions 1. Electrolyte resistivities vary greatly. Losses in the core and laminations reduce the output voltage when under load. Both single phase and three phase power is
used, depending on rectifier requirements and available power. List your experience beginning with the most recent, followed by less recent experience. Lead wires should have sufficient slack in them to avoid strain. Bowles, Jr. Raul Castillo David Edwards Gerry Garleiser Kevin Garrity Robert Gummow Brad J. Record the temperature when taking
readings in the event temperature correction is needed. The transmitter converts DC from dry cell batteries to AC by means of a vibrator circuit. Shield the electrode from direct sunlight during measurements (e.g., place dark tape over clear strip on side of electrode). Current Range The most common DC current scales on meters are as follows: • •
• • 200 microamps 2 milliamps 20 milliamps 2
symbol will be used in the Ohms Law Formula) Pressure in a gas or liquid system CURRENT Current can be defined as the flow of electrons. There are other criteria and reference electrodes covered in this standard along with a lengthy discussion of testing techniques. • If changing an answer on the ParSCORETM sheet, be sure to erase completely.
It is important that galvanic anodes be installed according to construction specifications. Friction of the inside pipe wall 6. Connect the meter as indicated across a 10-Ω resistor between the two metals. Figure 5.11 shows the test setup. 4 Adjustment of pH...
large currents flow through it; therefore, resistors are placed either in series or parallel to the meter movement to control the maximum current flow through the meter coil. W. 28 Measuring Electrolyte Resistivity.
and the anodes is a remote distance. 1. The atoms of a molecule are held together by a force referred to as chemical bonding. (3) Recognize and experience of many diverse disciplines and levels of technical competence which
must often be consulted. All questions are from the concepts discussed in this training manual. 1,000 ampere 0.000 ampere 0.000 ampere 0.000 ampere 1 milliamperes 1 milliamperes 1 milliamperes 1 milliamperes 1 milliamperes 1.000 ampere 0.000 ampere 0.000 ampere 0.000 milliamperes 1.000 ampere 0.000 ampere 0.000 ampere 0.000 milliamperes 1.000 ampere 0.000 milliamperes 1.000 milliamperes 1.000 milliamperes 1.000 milliamperes 1.000 ampere 0.000 milliamperes 1.000 mi
unit of current such as:amperage unit Amperes or Amps milliamperes or microamperes or microamp
produces an inherent weakness in the alloy. The information is advisory only and the use of the materials and methods is solely at the risk of the user. Oxygen Content As oxygen levels increase, polarization tends to decrease. Current Requirement Tests You may be asked to assist in making current requirement tests. Figure 5.1 shows a stationary
CSE unit. The same applies to a LOTO where if it becomes a habit to follow this procedure, you will feel uneasy if it is not in place making you more aware of the hazard. Figure 3.5 shows a rectifier schematic. 5A × 12 mV = 1.2 A 50 mV b. A corrosion circuit produces 2 Amperes of current at a driving voltage of 1.6 Volts, what is the resistance of this
circuit? Also, the large cathode may not polarize easily, thus maintaining a high rate of corrosion. 3 = 0.3 10 c. To accomplish this, a current interrupter is inserted in amperes. As with other test stations containing wires of different colors, it is
important that the wires are placed as shown on the design drawings. A completely dry environment will not support this form of corrosion. Since the direction of the current before connecting the meter into the circuit. Voltage drops are
negligible in the measuring circuit under the following conditions: • metallic paths — when lengths are short and/or area cross-sectional to current flow is large. Current pick-up or resistance tests between the casing and the pipeline may be required. 35 21 + =
is to be of any value. © NACE International, 2006 7/2006 7:4 Monitoring Cathodic Protection Effectiveness and Recordkeeping Sketches • Show layout of structure(s). Where flush mounted test stations are used; it is good practice to cast a concrete collar around the top of the station to minimize loss of the test point.
voltage drop across R2? Begin by momentarily interrupting the current flow to determine the "instant off" (polarized) potential. 1 IEEE Std. Test lead wire connections to a structure must be installed to remain mechanically secure and electrically conductive. Damage to insulation should be avoided, and repairs should be made if damage occurs. 5
                                                                                                                                                                                                        A fused switch box should be installed ahead of the rectifier so power to the entire unit can be turned off before any work is done on the rectifier. Corrosion is the result of the oxidation reaction in a
corrosion cell. A pipe and cable locator can be a great time saver for making such determinations. 2 Monitoring Cathodic Protection
                                                                                                                                                                                                                                                                    Be certain to coat the negative connection in the same manner as test wires and other connections are coated. If no test wires are in place, testing can be
conducted if contact can be made to the pipe on either side of the joint. © NACE International, 2006 1/2008 Field Measurements 5:17 Rectifier Current Output Most rectifiers have a shunt on the panel. If the short circuit is external to the rectifier, the circuit breaker will not trip. Zinc Reference Electrode Zinc is sometimes used as a reference
electrode since the potential of zinc is relatively stable. If the various pressure drops are added up, they will equal the total pressure drop across that length of pipeline. 9 Component Parts of Galvanic Systems.
                                                                                                                                                                                                                                                                                                                                                              . Reduce the fraction to the lowest terms. The voltage (I x R or IR) drop across each resistor is 8
Practice DAY FOUR Outdoor Field Program (weather permitting) DAY FIVE Chapter 8 Installing CP Components Chapter 8 Installing CP Chapter 8 Installing CP Cha
                                                                                                              . Ions allow for transfer of electrical charge in liquids. When the difference of potential between two charges forces a third charge to move, the charge in motion is an electrical current. 5 Maintenance of Environmental
                                                                             In corrosion work all three units are used. NACE CORROSION NETWORK (NCN) NACE has established the NACE Corrosion Network, an electronic list serve that is free to the public. Electrical Isolation General A single metallic contact (called a "short circuit" or "short") can destroy the
                                                                                                                                                                                                                                                                                                                                From the data, the amount of current required for protection can be determined. Cathodic protection systems on
                                                                                                                                                                                                                        To provide a low resistance path up to a reference electrode that may be inserted in the tube, a low resistivity backfill is used within the tube. Occasionally it is desirable to provide joint cathodic
 considered for valid interpretation of the data. SP0169 "Control of External Corrosion on Underground or Submerged Metallic Piping Systems" RP0285 "Corrosion Control of Submerged Areas of Permanently Installed Steel Offshore Structures Associated with
 Petroleum Production" RP0388 "Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks" RP0177 "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems" SP0575 "Internal Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels" RP0193 "External Cathodic Protection (CP) Systems in Oil-Treating Vessels "External Cat
              Protection of On-Grade Metallic Storage Tank Bottoms" RP0196 "Galvanic Anode Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks" SP0290 "Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks" SP0290 "Steel Cased Pipeline Practices" TM0497
 "Measurement Techniques Related to Criteria for Cathodic Protection on Underground or Submerged Metallic Storage Tanks" Section 11 Worksheets CP Tester Practical Exam Reference Sheet January 2008 VII
 Instructions for Completing the ParSCORETM Student Enrollment Sheet/Score Sheet 1. The more ions, the greater the conductivity; the greater the conductivity; the more current for a given cell voltage; and the greater the conductivity; the more current for a given cell voltage; and the greater the conductivity; the more ions, the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the conductivity; the more ions, the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the current for a given cell voltage; and the greater the great
 and protect yourself from this hazard. Opposition C. If you break the shrink wrap on this manual, but do not attend the class, there will not be a registration refund. There are regulations on the back sloping requirements for different soil conditions in every jurisdiction otherwise shoring is required. 4 1 1 × = 8 2 4 g. A. The values of current vary
between the person and the length of exposure. 30 Section 9 Chapter 9-Troubleshooting Introduction.
                                                                                                                                                                                                                                                     Copper-Copper Sulfate Electrode Copper sulfate reference electrodes (CSE) are the most commonly used reference electrode for measuring potentials of underground
structures and also for those exposed to fresh water. Regardless of the source, currents flowing in an electrolyte — when resistivity and/or cathodic protection current flow is
used. What is often referred to as a structure-to-electrolyte potential is actually the potential measured between the structure and a reference electrode. Various materials are used for this procedure including heat shrink sleeves, hot- and cold-applied tapes, two-component liquid resins, coal tar mastics and fusion bonded epoxy. • Know the
handling/storage procedures for chemicals or other hazardous materials or equipment. Unparalleled Functionality: CP-Compass is not just for CP design and verification of CP design and verification of CP design calculations by 3rd party contractors, it also gives you tools to predict the corrosion rate of the structure WHEN CP IS ON! Refer to the screen shot below for details
maintenance program is the prevention of failures and prompt repair when failures do occur. 22 =
                                                                                                                                                      c. Results Meter Positive Lead Copper Meter Negative Lead Steel Steel © NACE International, 2006 7/2007 Copper Approximate Potential mV +400 -400 Actual Potential Basic Chemistry and Basic Corrosion Theory 2:30 Conclusions 1
Some operators install galvanic anodes at each location where a leak is repaired rather than installing a complete cathodic protection system. When mechanical considerations allow, always select materials that will exhibit little or no voltage differences when in contact with each other and a common electrolyte. The splice is the most critical part of
rectifier by beginning at the input terminals and adding one component at a time to the circuit breaker trips. There has been limited. If you want voltage, placing the thumb over the E shows you that E = I x R. Research indicates the maximum
and two pins in the center for voltage measurement as illustrated in Figure 5.16. I understand that my failure to comply with these requirements could result in disciplinary action. The reading on the scale represents the current flow through the coil from the external circuit. Galvanic anodes can be ordered bare or prepackaged with these requirements as illustrated in Figure 5.16. I understand that my failure to comply with these requirements could result in disciplinary action.
backfill. Aluminum is preferred for seawater applications because it has a much lower consumption rate than magnesium or zinc. For soils, a pH meter may be used, or a filtrate may be used.
status and insert readings in the appropriate line. There are two reasons for this. Metallic Path e A + ions - ions C Electrolytic Path Conventional Current Flow Figure 2.7 Basic Corrosion Cell - An Electrochemical Circuit Electrolyte is an ionized solution capable of conducting electricity. 16 Measuring Resistance
flowing to each structure, negative cables may be run to a junction box in which resistors can be placed. Some locators contain both types in one unit: • Conductive • Inductive. This quick test cannot be relied on for a final determination of the effectiveness of an isolating fitting. Spacing between the anode and structure is operator controlled. Any
                                                                                                                                        millivolts c. © NACE International, 2006 1/2008 Installing CP Components 8:25 Surface Remote Groundbed, the anodes are placed in one location and the current flows from them to the protected structure. The AC
voltage-to-ground of a structure should always be measured first if there is a possibility of hazardous potentials. It also allows the designer to set the CP criteria (e.g., 100 mV or 150 mV) to meet the corrosion rate target when CP is on. Do not handle these materials unless you have the proper training or certification. 8 Galvanic and Impressed
                                                                                     . These anodes are equipped with an insulated wire for the electrical connection. Find: What is the amount of current in this section we will explore two techniques for determining current flow along such a structure: • 2
wire test points • 4-wire test points connections to the structure should be made by permanent test wires; probe rods are sometimes used on bare or poorly coated piping. b. Prerequisites It is recommended that attendees have had at least six months of cathodic protection work experience and a High School diploma or GED. Underground
                                                                                                                                                                                                                                      ... Field Training On Wednesday, students will participate in a field training activity at a training site, weather permitting. Oxygen acts as a depolarizer, thus increasing current
Constant current — the current output remains constant over a wide range of circuit resistances up to the maximum rated output voltage. 1 Electrons
 Figure 8.19. Does it equal the printed battery voltage? For these reasons I: (1) Agree to give first consideration in my cathodic protection work to public safety and welfare and to protection of the environment. This high current could have been a temporary problem, perhaps due to a lightning surge, or a permanent short circuit. The formation or
decay of polarization can be measured to satisfy this criterion. May be ineffective in high-resistivity environments. Wire should be installed with slack. 0 Neutral pH = 7 Acid Alkaline pH < 7 pH > 7 Neutral Acid 14 Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure 2.3 Illustration of Acid and Alkaline ph = -log [H+] Figure
protection work. Reasons for Monitoring The most obvious reason to monitor cathodic protection is to make sure corrosion is under control. These sheets provide information about the hazards associated with chemicals, dust, corrosion products, etc., and provides valuable information for first aid or medical personnel. Insulators have very few free
current flows in an individual, consecutive, and continuous path from the source of voltage through the various loads and back to the source. The law is expressed in the following formula: Wt = KIT = kg where Wt K I T = = = weight loss, kg electrochemical equivalent, kg/A-yr Amps years The value of 'K' (in kg/A-yr and lb/A-yr) for some common
metals is shown in Table 2.1. Table 2.1. Table 2.1. Table 2.1. Table 2.1. Consumption Rate (K) for Various Metals(1) Metal Kg/A-yr Lb/A-yr Carbon Aluminum Magnesium Iron/Steel High Silicon/Chromium Iron Nickel Copper (Monovalent) Zinc Tin Lead (1) 1.3 3.0 4.0 9.1 0.5 9.6 20.8 10.7 19.4 33.9 2.86 6.5 8.8 20.1 1.0 21.2 45.8 23.6 42.8 74.7 Based on Table 2, Chapter 2, Basic
Course Manual, Appalachian Underground Corrosion Short Course. Installed underground with carbonaceous backfill, the anode performs similarly to graphite. The positive terminal is connected to the west end of the span. Resistivity Test Instrument C1 P1 C2 P2 Soil Box Current Plate Voltage Pins Figure 5.16 Resistivity Soil Box If a soil box and
resistivity meter are available, take time now to work with them; connect the instruments as shown in Figure 5.16. Zero Current and Voltage Outputs: For the case of zero output for both current shunt is installed in series with the circuit
the same as the ammeter. This is illustrated in Figure 9.1. © NACE International, 2006 7/2007 Troubleshooting 9:2 Protected Structure Metallic Short Foreign Structur
                                                                                          (Remember, a 15 gram charge is the largest that can be used on a steel pressure pipeline.) The strands of the cable may be crow-footed and welded using the correct size charge. Also, it is important to determine points of electrical continuity and discontinuity. The symbol for the Ohm
is the letter R from the word resistance. You need only to multiply the rating by the millivolt drop to obtain the current. See Figure 1.10. Resistivity in ohm-cm R = Resistance in Ohms A = Cross-sectional area in cm2 L = Length in cm If the resistivity of
               is known (see Table 1.1), the resistance of a conductor such as a cable or pipeline of known length and crosssectional area can be calculated from: R = © NACE International, 2006 1/2008 \rho \times L A Basic Electricity 1:4 L L \rho R A Figure 1.1a \rho R A Figure 1.1b Crossectional Area A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) w = width (cm) A(cm2) = h x w where: h = height (cm) A(cm2) = h x w where: h = height (cm) A(cm2) = h x w where: h = height (cm) A(cm2) = h x w where: h = height (cm) A(cm2) = h x w where: h = height (cm) A(cm2) = h x w where: h = height (cm) A(cm2) = h x w where: h = height (cm) A(cm2) = h x w where: h = height (cm) A(cm2) = h x w where: h = hei
mr2 where: r = radius (cm) The terms are the same as in the above equation. The anode installation depends on the spacing of the anodes. In this course we will cover testing resistance across an isolating fitting and between a casing and a pipe. Current from the external circuit flows through the coil and creates a magnetic field. The installation
should be made in such a way that the anode is centered in the special backfill; the special backfill should be compacted prior to backfilling with native soil. Re-measure the polarized potential of the structure at intervals until relatively stable.
temperature caused by the compressed gas. Any questions, please contact Carol Steele at [email protected] or at 281-228-6244. a. © NACE International, 2006 1/2008 Installing CP Components 8:21 Figure 8.18 Prepackaged Impressed Current Anode The conductor (negative lead wire) to the structure should be correctly connected. © NACE
International, 2006 1/2008 Installing CP Components 8:16 Anode Lead Wire Coated Powder Weld Connections Hole Depth Based on Soil Resistivity Header Cable Structure Anode Spacing Figure 8.14 Multiple Prepackaged
 Vertical Anodes © NACE International, 2006 1/2008 Installing CP Components 8:17 Non Packaged Anodes Non packaged anodes are used in water environments and occasionally in soil. The test box may contain a resistor for control of current flow or a shunt to measure current output. The standard hydrogen electrode half-cell is awkward to use in
 most circumstances in which potential measurements are to be made. • The total resistance (RT) of a series circuit equals the sum of the individual resistances. If, on the other hand, the bulkhead is coated and loss is taking place only at holidays, then several penetrations might occur in the short time of four years. Some of the chemical species
present in an electrolyte may assist in retarding or slowing chemical action by aiding the production of protective films. In accordance with Faraday's law, the weight of metal corroded is proportional to the amount of current being discharged from it into the electrolyte. Mechanical Mechanical connections are used typically in places where flammable
survey • Changes in current flow on a pipeline. If it is arbitrarily agreed that the potentials of all the other metals in their appropriate solutions can be described in terms of this reference. Using this technique, if a spark occurs
it occurs at the location where the bond is attached and prior to release of any potentially explosive vapors. Nonmetallic materials also play an important role in corrosion control. Tape Coatings Most tape systems are cold applied. 23 Using Ohm's Law.
measure potentials along a structure, we must discuss reference cells. The receiver controls the volume of the electrolyte or by shutting off the current. These test stations consist typically of two No. 12 AWG insulated wires, thermite-welded to the pipe. Figure
measures for each step of the project. An ohmmeter measures the current flow caused by a known voltage source and indicates resistance on the scale or readout. This is done with a series of tests between the suspected source and indicates resistance on the scale or readout. This is done with a series of tests between the suspected source and indicates resistance on the scale or readout.
Transformer AC Breaker Switch Adjusting Taps on Secondary Winding Housing - Rectifying Stacks + Current Shunt A Output Voltmeter V - To Structure Output Ammeter Grounding + To Anodes Figure 1.13 Typical Transformer Wiring in a Rectifier An alternating magnetic field is established in the core from the voltage applied to the primary
 winding. An example of this is the splash zone on submerged steel piling. Result D. These can be placed underground, inside water storage tanks or other vessels, or on marine structures. Low pH (acid) environments can exist around anodes in deep groundbeds. The testing and design of such systems are, however, beyond the scope of this course. 26
presence by measurements, it is necessary to determine precisely what the source is. Criteria for Cathodic Protection Tester Course Manual What to do with this manual NOW 1. 2 Resistance and Resistivity.
panels are combined with storage batteries to provide power during hours of darkness and on cloudy days. The galvanic anode is connected to the structure it is protecting, either directly or through a test station so it can be monitored. Whenever a current-carrying conductor is separated, depending upon the characteristics of the circuit, a spark may
 be generated. Do not touch the rectifier case while testing or in the first test do not extend your arms to bridge between the case and the ground probe. Calculate current using Ohm's Law I = .05 \text{ V} / .01 \Omega = 5 A If in the above example we wished to estimate the voltage drop for a known current, we would again apply Ohm's Law. 9 Routine
                                                                                                            Faraday's Law is also very useful for determining the expected life of cathodic protection anodes. Definition Cathodic protection is the cathodic protection is the cathodic protection areas (cathodes) to the most active potential on the metal surface. Corrosion current decreases
                                                                                                                                                                                                                                                                                                                                                               . 9 Section 7 Chapter 7-Monitoring Cathodic Protection Effectiveness and Recordkeeping
                                                                                                                           Address: 987 Gage Avenue City: Millspec Fax: 409/111-1234 State/Province: TX Zip/Postal Code: 77987 Country: USA Please summarize below the information on each copy of Form 2, Individual Job Documentation. Remember, you cannot use an ohmmeter to
material and expected output of an anode, you can calculate the life expectancy. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Rate Faraday's Law The weight of any material deposited on the cathode (or liberated from the anode) is directly proportional to the quantity of electric charge passing
through the circuit. Corrosion control requirements can be found in these parts of the code: • • • Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 193, Subpart I Liquefied Natural Gas Pipelines - 49 CFR, Part 
cathodic protection system is operating properly and protecting a structure from corrosion, the following data are recorded on a routine basis: • • • • • Structure-to-electrolyte potential. In a distribution system, where metallic service lines are electrically continuous with the mains, a failed isolating fitting at the meter will cause a short circuit. If
         CATHODE + eeee- - e e + + ANODE Figure 2.10 Electron and Ion Flow Charge Transfer in the Electrolyte Movement of charged ions is the mechanism for charged ions is the mechanism for charge transfer through an electrolyte as opposed to the flow of electrons in a solid metal conductor. There are two major types of polarization. Flow of product C. Inspection Procedures Initial
Inspection Surface preparation must be inspected to ensure adherence with the specifications. (A second meter from another kit can be used to obtain the information as shown.) 14 mA + Corrosion Current flow (amperes) or a single meter can be relocated to obtain the information as shown.)
lower circuit resistance is indicated. A difference in voltage may arise due to differences in the natural energy levels of different metals or composition variations formed during alloying. Some of the more important factors follow. Full scale deflections as low as 2 mV is sometimes necessary. These can be taken into the field for trouble shooting. A
well-coated structure may well have less than 1% of its surface exposed at holidays. There is a scale on the side of the antimony electrode that is calibrated in millivolts and pH. 14 of 23 Pipe-to-Soil Data Plot Indicating Interference POTENTIAL (VOLTS) -1.5 -1.0 -0.5 POINT OF SUSPECTED INTERFERENCE 0.0 DISTANCE 15 of 23 CP 1-Cathodic
Protection Tester Course Manual - Chapter 6 © NACE International, 2004 April 2006 5 Stray Current. Keep a few spares on hand. Most locators include a metallic path between the affected structure and the source of stray current. Keep a few spares on hand. Most locators include a
transmitter and receiver. Connect the steel to the copper through the 10-\Omega resistor. 1 Types of Mill Applied Underground Coatings.
                                                                                                                                                                                                                                            . The cable running out to the groundbed represents a series circuit, the groundbed itself a parallel circuit. If the data are not accurate and correct, the evaluation will be faulty and
those responsible for the corrosion control program will be misled into thinking that systems are working properly when they may not be. 10 of 23 11 of 23 Dynamic Stray Current Indications • Structure to electrolyte potential fluctuations • Variations in line current flow 12 of 23 CP 1-Cathodic Protection Tester Course Manual - Chapter 6 © NAČE
International, 2004 April 2006 4 Typical Potential Recording in Stray Current Area POTENTIAL TIME 13 of 23 Steady Stray Current Indications • Test point structure-to-electrolyte potential changes. This AC voltage measurement is only to be completed by persons properly trained and is only to be measured if the terminals are readily accessible at
the side of the rectifier. The word hertz (hz) is used to represent a cycle, so AC is known as 50 hz or 60 hz current. VOLTAGE Voltage can be defined as a difference of potential. 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 Outside Diameter in. Smell for unusual odors (examples: rotten egg-selenium failure, ozone -insulation failure, burning-
insulation failure). Electric powered mass transit systems (often called stray traction current). Note the meter is showing a positive indication. Keep free of contamination. Therefore, several surrogate criteria have been developed to assist meeting the true criterion. • May be difficult or expensive to replace spent anodes. Figure 6.4 illustrates a
similar bond for mitigating cathodic interference. This method is used to determine the resistivity of soil within an area. Where do we find voltage, current and resistance? 73 = 343 4. Note that the units used must be consistent: amperes, volts and Ohms. 1 Environmental Factors ...
corrosion is not controlled, it can lead to large costs in repairs or facility replacement. (B), 3. Discussion of these two latter criteria is beyond the scope of this course. Figure 5.1 Stationary Reference electrodes containing both zinc and Aq-AqCl units are used
on offshore structures. See Figure 2.16. On a bare structure, if the potential is measured at the structure-toelectrolyte boundary, then the electrolyte is no longer in the measuring circuit and its resistance is nearly zero. Sources Stray currents can be produced by any system conducting an electric current that has two or more points of contact with
an electrolyte. Temperature Differences in the Metal If parts of a structure are at different temperatures, the higher temperature area is usually the more active area and becomes the anode of the corrosion cell. Among the most common methods are the installation of mitigation bonds and the use of cathodic protection. Typical applications include:
Poorly or incompletely coated buried valve installations • Shorted casings that cannot be cleared • Isolated sections where the coating has been badly damaged • Areas where electrical shielding impairs effective current distribution from remotely located impressed current systems • In cases of cathodic interference, if the conditions are suitable,
galvanic anodes can be used at the discharge point on the foreign line to return interfering current. The consumption of any metal is directly proportional to the amount of current discharged from its surface. Electrical Shielding Metal Metal components connected to a protected structure may prevent cathodic protection current from reaching a
corroding surface. Change oil if rectifier components cannot be seen beneath the oil. If you are making a routine survey, you should suspect the possibility of steady state stray current. This is important since accumulation of gas can increase the resistance of
the anodes to ground. © NACE International, 2006 1/2008 Underground Corrosion Control 3:8 Structures That Can be Cathodically protected. The backfill also absorbs corrosion products from the anode; this prevents the products from sticking to
the anode and increasing its resistance to ground. Oil Heater-Treaters SP0575 Internal Cathodic Protection Systems in Oil Treating Vessels A minimum of -850 mV vs CSE (-800 mV vs a silver-silver chloride electrode (Ag-AgCl)). The fluctuations are easily discernible on the chart. Magic Circle Memory Aid E E I R I OR 11/01/04 R Ohm's Law
Formulas FINDING VOLTAGE Using the Magic Circle Ohm's Law Formula for finding Voltage = R (I) (R) Current x Resistance In other words, to find Voltage Multiply the Current times the Resistance. 1 Underground or Submerged Structures
                                                                  Note that rectifiers may be serviced with 240 VAC, 480 VAC or up to 600 VoltsAC thus the body current would increase proportionally. For all coatings, the surface must be clean and dry. REVIEW THE OHM'S LAW TUTORIAL AND THE BASIC MATH SELF ASSESSMENT. Rate of corrosion is measured
with the same instrument as discussed above. Refer to the section on "Wire Attachment" for procedures and precautions, Improper Backfill is in good contact with the anode, For oil heater-treaters, heat exchanger water boxes, and other vessels, reference
electrodes can be installed through the vessel wall at strategic locations. Among products for which safety information is available are: • Copper sulfate • Impressed current and galvanic anodes • Metallurgical and petroleum carbon backfill. Current usually refers to the applied cathodic protection current; the measurement current (current required
to operate the meter) or stray © NACE International, 2006 1/2008 Underground Corrosion Control 3:27 currents can be significant, however. A current interrupter is shown in Figure 5.21. If less than 100mV, further testing may be necessary. 32 y 33 = 3. 23 Experiment 2.1-Metal Electrode Potentials in Tap Water ...
left hand zero instrument, you can still connect the reference electrode to the negative terminal, but it is © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:15 necessary to throw the reversing polarity switch. These anodes are also called sacrificial because they may be thought of as sacrificing themselves to protect
the structure. Thus, in oxygenated environments, high current requirements are to be expected. RESULTS Time Ecopper Cathodic Protection (mV) Current (mA) Instant of connection
                                                                                                                                                                                                                                                                                                                                                                                                                                            CONCLUSIONS 1. I understand that I
am solely responsible for making sure that all necessary work experience documentation is complete and submitted in good order to NACE International, 2006 1/2008 Field Measurements 5:14 Note also the battery and the direction of current flow around the circuit. © NACE
International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:14 Figure 2.13 Voltage Measurement of a Noble Metal Immersed in an Electrolyte Sign Conventional current must flow into the positive (+)
terminal. © NACE International, 2006 1/2008 Field Measurements 5:22 3. Record the voltage drop across the resistor and note polarity. Continuity of pipelines, cables, and similar structures can also be tested by using a pipe or cable locator. To correctly verify diode operation, at least one lead must be disconnected from the circuit. In some
situations, structural members are isolated from supports using sheet type dielectric material and insulating sleeves and washers. They are often used to make correlation curves between rail-to-pipe voltage and pipe-to-soil potentials in mass transit stray current work. © NACE International, 2006 1/2008 Underground Corrosion Control 3:28 To
understand the applicable criteria for the structures with which you are working, you need to read thoroughly the criteria section of each of the following referenced documents. Lay the header cable in the trench, again being very careful not to damage the cable insulation. The electrolyte itself has no potential value against which the potential of a
structure can be measured independently of the potential of the reference electrode used. Minimum right-of-way/easement costs. • Satisfy high current requirements with a single installation. Magnesium is normally used in soils and fresh water. Data Sheets are extremely important. Solve the following questions. Consequently, the
current is flowing from left to right through the shunt. Where the predominant anodic reaction is the evolution of oxygen, higher driving voltages are needed. No authorization is implied concerning the use of patented or copyrighted material. 1 Typical Applications..
zone around the weld can be hardened and may serve as a site for failure initiation. Current will flow from the active to the noble metal through the electrolyte and from the noble to the active metal through the electrolyte and from the noble to the active metal through the metallic path. Typical thickness is 12 to 15 mils (0.304 mm to 0.381 mm). This is done by measuring the voltage drop across the span,
determining the resistance of the span from a pipe table, and using Ohm's Law as you would with a shunt. © NACE International, 2006 7/2006 Stray Current Required to Operate Train + Bond Cable Tracks Negative Return Bond across High Resistance Joints Figure 6.3
Mitigation Bond Used to Control Stray Current Flowing Through the Earth to Return to Protected Line Foreign or Affected Line Foreign or Affected Line Figure 6.4 Mitigation Bond
Used to Solve a Cathodic Interference Problem © NACE International, 2006 7/2006 Stray Current Interference 6:8 Mitigation with Cathodic Protection can sometimes be used to overcome stray current problems. The severity of the problem on the position and surface area of the shorting structure. For example: Given
Shunt = 0.01 Ω Voltage across shunt = 50 mV Calculate Current: 1. • Lock out and tag the rectifier breaker or AC disconnect after turning OFF when installing an interrupter, changing taps, replacing components, or installing and removing the rectifier. A functioning diode will typically display a meter value from 0.3 V to 0.9 V in the forward bias;
positive lead to anode, negative lead to anode, negative lead to cathode. Aluminum is an amphoteric metal and can be damaged by excessive cathodic protection. As mentioned in the discussion of galvanic anode materials, elevated temperatures can affect the performance of aluminum and zinc anodes. Other species thrive under aerated conditions and form acids. Backfill
around the pipe carefully and compact the backfill thoroughly. 9 Clamp-on DC ammeters are available for pipes using special sensing hoops................................. If, for example, a production well casing is being protected, and it is electrically connected to unprotected structures such as gathering or other pipe, building grounds, or other underground structures,
some of the protective current will be lost to those structures. Electrical isolation is also an important part in cathodic protection work and will be discussed in some detail in subsequent chapters. Because natural compaction and natural moisture content are not always accurately simulated, the test results may vary from in situ soil resistivity
measurements. Power of the external circuit © NACE International, 2006 1/2008 Field Measurements 5:10 should be de-energized before breaking the circuit and inserting an ammeter. After a © NACE International, 2006 7/2006 7:2 Monitoring Cathodic Protection Effectiveness and Recordkeeping potential survey has been conducted, however,
                                                                                                                                                                                                                                                                                                                                                                                               .. The copper sheet potential is more electronegative than in Part B. Once
other indirect measurements can be used to monitor a system before the next potential survey. (B), 4. They are located near the structure and connected to it through the test station head. 1 Protective Coatings ...
the potential is obtained, the pH can be determined from the scale. ALUMINUM Aluminum anodes are used primarily in unheated water storage tanks. Using Ohm's Law Using Ohm's Law is one of the best ways to determine resistance between structures buried or immersed in an electrolyte. Figure 5.8 depicts direction of current flow in an ammeter
measurement. Use of Pipe Locating Devices During corrosion testing, it is often necessary to accurately determine the location of such buried items as a pipeline, conduit, or storage tank. In this type of test station, the pipeline acts as a resistor; the magnitude of the current is determined by measuring the voltage (IR) drop across the span of the test
                                                                                                                                                                                                                                                                                                                                                                                                                 in a gas system. Microbiological Influences
wires. • internal circuit of the meter — when a high-input resistance meter (10 megohms, for example) is used. The test voltage of the meter is DC voltage and is suitable for metallic elements. The white, powdery backfill within the package serves two purposes. Voltage compares to
Microbiologically induced corrosion (MIC) is common. Connect the meter to the zinc and to the reference electrode as indicated in the figure. It doesn't matter which cell is connected to which terminal of the meter since it is the potential between the two electrodes that is of interest. Electrochemical corrosion involves the transfer of electrons across ac
metal/electrolyte interfaces. 32 Chapter 1 Appendices Appendix 1-Meter Fuses - Instructions for Replacement Appendix 2-Color Code for Resistors Section 2 Chapter 2-Basic Chemistry & Basic Corrosion Theory Basic Chemistry ...
                                                                                                                                                                                                                                                                                                                                                                                                                            . These chemical reactions are electrochemical
reactions. These should not be made of nonmetallic material. When you attend the NACE Cathodic Protection Tester course, one of the first things you will be taught is basic electricity. A pen or stylus records voltage as the chart moves. You're done! You'll get an e-mail back telling you how to participate, but it's so easy that you'll figure it out without
any help. Constant voltage — the DC voltage at the terminals remains constant for all current outputs up to the rated maximum rectifier current. Calculated Current (IT) = ET /RT = :
                                                                                                                                                                                                                                                                                   A STEP 6. That's all! Then: 1. With closer spacing, it is usually more economical to dig one long trench for both the header cable and the anodes. 13
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Keep in mind that these terms will be expounded upon during the actual course. The atom or molecule decreases in negative charge. Keep the plastic/rubber cap on the porous plug when not in use. Periodically replace copper sulfate and clean copper rod with a

Impressed Current Systems.

through the electrolyte. • Feel for unusual heat. The displayed value is not continuous temperature is usually the more active area and becomes the anode of the corrosion c analog meter, the reference electrode is connected to the positive terminal to obtain a Corrosion Control 3:23 influence the cathodic protection circuit resistance. If these at register through NACE Headquarters, the Student ID will appear on their course confireducing electrolytic action on the anode. Oxygen can easily penetrate porous soils. Coin the rectifier current output. Refer again to Figure 5.11. 22 Moisture Content of Soil an anodic reaction occurs. There are also several multilayer systems available. The each changes in current flow on a pipeline • Localized pitting near or immediately adjacent bubbled while immersed in a solution having a definite concentration of hydrogen ions determining when adequate cathodic protection is achieved. I understand that if I kno	s but a sample of the input value measurements. © cell. Standard Hydrogen Reference Electrode (SHI an upscale reading. This voltage difference may be stachments © NACE International, 2006 1/2008 5: firmation form, student roster provided to the instant power supply cost. • Effective in protection in the supply cost. • Effective in protection in the supply cost of the supp	NACE International, 2006 7/2007 Basic Chemistry and The standard hydrogen reference electrode (SHE) is a generated by naturally occurring reactions or by stray 26 Field Measurements bypass an isolating fitting, a structor, and/or students' name badges. Second, it proving uncoated and poorly coated structures. This is usual	d Basic Corrosion Theory 2:26 Temperature Difference a laboratory reference electrode and is used to determ current reactions as discussed in the section "Cause fort circuit will be created. For a digital multimeter (I des a uniform environment around the anode; this greatly referred to as the active metal leaching from the all winding. 26 Testing Resistance Between a Pipe and Cause. Steady State Stray Current Measurement Indicational Course of the cell generation of the cell g	tes in the Electrolyte For temperature differences in mine the potential of other reference electrodes that is of Corrosion". • Attachments. Such changes will of DMM), all measurements are converted to DC volts that it increases anode life since most of the current ploy, such as zinc from brass (dezincification). Such Casing	an electrolyte, the area of metal in the higher at are better suited for field use. Also, when using an NACE International, 2006 1/2008 Underground prior to the analog-to-digital conversion. For those who lows electronically from the anode into the backfill, thus cable breaks are indicated if there is a sudden reduction point this current leaves the cathodic protection anode, al ways: • Structure-to-electrolyte potential changes • y a platinized electrode over which hydrogen gas is cure-to-electrolyte potentials is the only method of
Submerged Iron and Steel References SP0169 Control of External Corrosion on Under to a saturated copper-copper sulfate reference electrode (CSE), and one is a polarization may undergo virtually no corrosion. 147 = 1 b. (B), 6. The needle provides a continuous battery is connected across a known resistance. Remembering this will enable you to submission of the CP 1-Cathodic Protection Tester certification application is required the trench. E =I × R FINDING CURRENT Using the Magic Circle Cover the I to see the corrosive gasses or liquids. This means moving all four pins out to wider spacings so that an electrolyte. Use of an Ammeter When measuring current flow in an electrical circuit the anode. 18 Corrosion Rate	rground or Submerged Metallic Piping Systems R ion shift of 100 mV. For underground use, the zinus representation of the measurement, called an adetermine the direction of current flow in the circle defore certification will be issued. (C), 5. Above the mathematical relationship between Voltage and that the center point of your measurement location it, the ammeter is connected in series with the circle	P0285 Corrosion Control of Underground Storage Tanks electrode is packaged in a cloth bag containing the sample of the measurement value. Test leads should not uit with which you are working. As mentioned earlier, as, the environment becomes passive and corrosion rated Resistance E ÷ R Ohm's Law Formula for finding Curronis always centered between the two inside pins. Reference to the surface of the surface	a Systems by Cathodic Protection RECOMMENDED Come backfill as used around zinc anodes. Carbonates, be exposed to excessive heat or sunlight. However, the shorted isolating fitting or casing may be to blame. Set tend to decrease. Backfill material around the cable rent (I) Current = (E) Voltage (R) Resistance In other rence Electrodes (Half-Cells) General Reference electration. If anodes are not prepackaged with a special characteristic or larger. • For local cathodic protection to provide a end of the wire or cable. The more electronegative of	RITERIA There are three criteria that apply: two in for example, may lead to the formation of a passive me measurement is taken several times per second. Set the meter to the V DC scale. Successful comple should be free of rocks and foreign matter that mi words, to find Current Divide the Voltage by the Recodes, or half-cells, are important devices that permemical backfill, field installation of the anode will rurrent to a specific area on a structure. The length of the two electrodes is the anode; the more electrop	volve a structure-to-soil potential of -850 mV in reference film on zinc; in such environments galvanized structures Got a question? Consider the circuit in Figure 1.3. A zion of both the written and practical examination and ght damage the wire insulation when wire is installed in esistance. Similar measures are used in pipelines carrying it measuring the potential of a metal surface exposed to equire mixing the backfill on site and placing it around of the hole containing the anodes is then filled with a ositive of the two cells is the cathode. 15 Limitations of
Corrosion Control There are several ways to control stray current. Larger full-scale vo circuit. Hybrid meters that are electronic with analog displays (electronic amplifiers d the local anodes. 2 Electrical Equipment (Rectifiers)	oltage ranges can be made available by switching driving an electromechanical coil) are sometimes random an electromechanical coil) are sometimes random	resistors in series with the moving coil, which reduces eferred to as electronic meters (see Figure 1.14). Cons at Isolation Joint Bracelet Anode Anode Metal Pipe Type b over the R and you can see that R = E/I. Transformer is necessary to find the source and implement a solution charges. John Smith NACE CP 1-Cathodic Protection constant cathodic protection current. © NACE rosion may generate milliamperes worth of current, strategies.	the magnitude of voltage drop directly across the coil equently, in warmer electrolytes, current requirement ical Bracelet Anode Figure 8.16 Bracelet Anode Instalms Transformers may be used to increase or decrease in. Manmade dynamic stray currents come from such on Tester, Cert. Cathodic Protection (CP) Rectifiers International, 2006 1/2008 Underground Corrosion Cay current can involve hundreds of amperes. Damp coupling network, for example, can increase the longitudinal	Stray current may be defined as current flowing of the will be higher than in cooler ones. This is accomplation for Underwater Piping Offshore Anodes Offstwoltage or to isolate an incoming voltage source frosources as electrically powered rail transit systems CP rectifiers have exposed electrical AC and DC tenontrol 3:33 Germany DIN 30676 lists cathodic protonditions will cause the molten metal to spatter, creen	olished by polarizing local cathode potentials to those of more anodes for use in salt water are usually made of an im the outgoing voltage. These include telemetering and or mine railroads and arc welding operations.  The mine railroads are welding operations.  The country of the rectifier. 26 Exercise 1.1:  The country of metals in various atting a safety hazard. Add 1-1/2 inch of tap water to the
From: Month Year Address:	To: Year State/P: Describe in detail what are/were your cathodic y reconditioning is required. If a voltage gradient ring the rectifier current output. In a noisy area ear 2006 7/2007 Troubleshooting 9:10 At least once e of the pipe to prevent shielding of cathodic prote 50 mV polarized to CSE. If the casing has anodes se certain to mark each anode lead from bottom to m better than graphite. The Ag-AgCl electrode is a for example), resistivity is usually defined as the resistivity of the case of the province of the case of the province of the case of the province of the pr	rovince:  Month protection related duties in this job. The circuit board is crossed by a metallic structure such as a pipe, cable rphones may be necessary. Care should be exercised to ach year (usually at the time of the annual corrosion suction current from the pipe. Theory On a corroding surconnected to it, the difference may be smaller. Bare or top so that each can be identified in the junction box. also used in concrete structures. Connections to the structures between two parallel faces of a cube one cm	Zip/Postal Code:  layout is shown in below. The pH scale is illustrated it, foundation pile, etc., current will be created on the so avoid cracking or damaging anodes during handling arvey), rectifiers should be thoroughly and systematical face, there are hundreds of local, or microscopic, corresponding anodes may be used. Prepackaged anodes Galvanic anodes can be an economical choice for a callucture must remain mechanically secure and electrical on each side. Test Station Typically No. 12 AWG Test	Fax:  In Figure 2.3. The neutral point is 7. Current is frequentructure. Steel is more electronegative than copper and installation. Stray current pickup and a negatifully inspected. The initial corrosion-cell potential is cosion cells. American Water Works Association States are supplied in waterproof containers; the contact thodic protection current source under such conditudity conductive. This is called cathodic interference Wires & No. 8 AWG Wire for Bonding if Needed Ison	C.2 WORK EXPERIENCE FORM 2: nently abbreviated as amps, milliamps, or microamps. The written final examination consists of 100 we potential shift on the foreign structure occurs at the difference between the opencircuit electrode ndard D104 Automatically Controlled Cathodic Protection iner must be removed before installation. You can ions. When installed without backfill and where oxygen we are not associated with any website in anyway. Dlating Joint Pipeline Figure 8.10 Isolation Joint Test
© NACE International, to the bottom of the hole to vent off any gasses than may be generated by the electroly $4240700217$ )*. These anodes are available in rod, tube, or mesh form and are used in $\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{\sqrt{$	, 2006 1/2008 1:25 Basic Electricity Digital Meters ytic action of the anodes. This voltage drop is due fresh water, salt water and underground environmed Your phone number. If, after reviewing the mals of the cathodic sites polarize toward the potent all based on direct current. Current is obtained by The above ground portion is run, usually in conductive and the potent and the potent and the potent and the potent are successful to the potent of the potent and the potent are successful to the potent and the potent are successful to the potent and the potent are successful to the potent are successful to the potent and the potent are successful to the potent are successful t	s Basis of Operation A digital meter is based on integra to normal pipeline current. It is important to locate isoments, as well as embedded in concrete. 22 Coating nual, you want to postpone your classroom date to give itals of the anodic sites, corrosion current is reduced. As the electronegative measuring voltage across the current shunt and calculate, to the rectifier negative terminal. The cloth or cardiffereral The purpose of test stations is to provide access d, a short exists (or has existed) in the output circuit.	ted microcircuit technology. 25 Electrical Isolation	by other connections or piping. Type in your Studer	A slotted PVC vent tube is installed down at ID or Temporary Student ID (Example 123456 or mation and the corresponding bubbles for each category: ions for transferring to another course. Evaluate the at Electric resistance probes are also used to monitor age 1 of 3 6. The current then flows to the metallic ecords. The underground or underwater portion of this tion is just as important as accuracy in your data sheets, the Accuracy of Reference Electrodes", MP, 33, 11 (1994): or is probably no. Using the ohmmeter, measure the
Installing CP Components Header Cable to Other Anodes and Power Source 8:24 Insu	e-Zinc Battery Protective casing Pitch Seal Electronere formed. It is essential that clear, accurate data 700 Conclusions 1. • as bracelets clamped around ative terminal. © NACE International, 2006 7/200 Itill is similar to gravel and the concerns noted at alated Connection Earth Backfill Pigtail Wire Furn For a parallel circuit: • Voltage drop across each be $0 \text{ V R1} = 5 \Omega \text{ R2} = 4 \Omega \text{ R3} = 2 \Omega \text{ R4} = 0.95 \Omega  Firstensive be handled carefully to prevent damage to the$	olyte paste (ammonium chloride and zinc chloride) Air Sibe taken. A ready means of exiting the excavation must a pipe and connected to it with a welded pigtail connected Basic Chemistry and Basic Corrosion Theory 2:28 9. It sove apply also to this type of soil. Make and use as maished with Anode Anode Backfill Anode Figure 8.20 Horanch is the same and is equal to source voltage. 3 Elect, reduce the parallel part of the circuit to a single resistant.	Space Carbon and manganese dioxide mixture Zinc Set be in place (ladders). Resistance of groundbeds. Resistance with operations of the state of the	eparator Carbon rod Microsoft Illustration Negative sults Metal Copper Steel Zinc Magnesium Reference poured a charge-containing mixture of copper allowaread over a large area, are now using Internet accepte rate of corrosion increases appreciably below a allation The header cable trench is usually dug by a $\mathbb{R}^2$ NACE Internation 7: R1,2,3 = 1 1 = $\mathbb{R}^2$ 1 1 0.95 + $\mathbb{R}^2$ 2 $\mathbb{R}^2$ 3. Which plays an important role in the corrosion readers.	terminal Figure 2.17 Flashlight Battery as an Example of the Electrode Position Near Copper Near Steel Near Zinc by and magnesium starting powder as shown in Figure the ess for corrosion control data. 27 Exercise 1.2: Series pH of about 4. © NACE International, 2006 1/2008 backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to the specified depth in accordance to backhoe or trencher to backhoe or trencher to the specified depth in accordance to backhoe or trencher to b
backfill and anodes constitute what is known as the active column or anode area. Dryi continues over time, polarization occurs at both the anode and cathode. To estimate the Connection Rectifier T/R Switch Diode © NACE International, 2006 1/2008 Basic Elect reduce the risk to the public and the environment. Hourly Rate: \$20 - \$44Avg. For oil 1 Tag Out	ing of Soil In times of drought or very low soil mointh he voltage drop for a current of 5 amps, simply so ctricity 1:7 Electric Circuit The electric circuit is the immersed units, check color and level of oil. Place way of viewing metals in the order of their activity is will work if the stray current is not so large that it into not next section of the form (1 to 200) is for a civided by the number of resistors. 3:39 Disconnect of Electric Circuit	sture content, soil resistivity increases appreciably. Melve Ohm's Law for voltage. There are two reasons why he path followed by an electric current. R = 1 . For this e the steel rod (foreign structure) in the water in the trais shown in what is known as the galvanic series. Under it cannot be overcome with the cathodic protection curble answers to your exam questions. Often basic step-bet anode and take depolarized readings. During the acture of the cathodic protection currents are under the cathodic protection currents	easurement of electrolyte resistivity is covered in Chap an ohmmeter cannot be used. © NACE International, reason, regulations have been enacted in many indus- ary, as shown. Some of these bacteria live only in envir- erground contacts made accidentally when one line crap rrent. Tight soils may reduce depolarization effects or y-step troubleshooting techniques can determine the all course, we will get into (AC) Alternating Current and the current output capacity of the anode by extending at factor is revealed by the position of the two remains	pter 5. Coating Coating reduces the amount of curr 2006 1/2008 Basic Electricity 1:6 Electrical Schemstries and countries to make sure structures contain conments free of oxygen. Voltage drop across each cosses another. The question now is "What causes that the structure. The amount of energy required by a cause of the outage. This is the definition of a negate well. Where one or both structures have cathodic the anode surface area. © NACE International, 200 ing symbols. 10. 10 mA AMPS ++ PIPE ANODE F	atic Diagram Symbols Resistor Ground Battery aing hazardous products are adequately protected to element or source in the circuit is the same. 2 Lock Out / he current to flow in the first place?" Current flow is metal during the refining process determines the cive logarithm. 053 $\Omega$ If all the resistors in a parallel protection, there may be an interaction between the two. 16 1/2008 Installing CP Components 8:18 If concrete is injure 5.8 Direction of Current Flow in an Ammeter
Measurement Clamp-On Ammeters The second method of measuring current is with a (self-consumption). 12 Reference Electrodes (Half-Cells)	First, determine if input Addic Protection Tester Certification Application Sec copper water service line in contact with a steel of equipment or structures in the vicinity of AC post Measuring Current	C voltage is present. Inc. $10x = 130 x = $ Contion 1 Chapter 1 Basic Electricity Introduction	esult in action against my standing in the program on ciated with equipment grounds and safety bonding. Or crosion Control 3:30 You need to be aware that under gs ZZZ Gas Co. 12/89 12/91 24 Installer AAA Tank Instead during the examination are communication devices s	© NACE International, 2003 Page 3 of 3 CP 1 - CAT	CHODIC PROTECTION TESTER TRAINING MANUAL digital. Types of Stray Current Dynamic Stray Current thodic Protection Program Attestation. This is not the section courses taught through the years is that many circuit are like pressure drops along a length of pipeline. acteria, elevated temperatures, and dissimilar metals, sign ////////// Job Title Company Name Applicant and recorders. Pure direct current is produced by a
violet light. Each type of field coating will have a specific surface preparation required reading on a scale. A metallic short is a metal-to-metal contact between the casing and a typewriter or keyboard are not permitted. Check indicating meters for accuracy by componentials on the foreign structure at reference electrode positions D, E, and F. If the property too large to connect to a pipeline © NACE International, 2006 1/2008 Installing CP Co safety program. 15 50 + = 10 50 b. We are not responsible for the content or chlorine) generated by the anodic © NACE International, 2006 7/2007 Troubleshoo	ment that must be followed. In some cases, a lug of the carrier pipe. Voltage can be defined as: A. To comparing with calibrated portable instruments. It packaging container is torn or broken, the anode components 8:29 with a single thermite weld. DC Cot. In selecting an electrical isolating device, be centing 9:9 reaction cannot permeate away from the another isolating joints (flarange) Calculate current through R2? Some as In an operating cathodic protection system a number of the carrier pipe.	can be welded to the pipe or other structure and the calche average input over this time is then converted to a contract it is this chemical bonding that defines many of the proposhould not be used. 2 Construction Notes	ble connected to the lug by exothermic welding or a naligital value, a coded number, using an analog-to-digit perties of a substance. Voltage can be called an electron is circuit within the electrolyte has been discussed in the requirements, both from the standpoint of temperary UNDERGROUND CORROSION CONTROL Materials wires attached on either side of them to facilitate testater) and as high as $500,000~\Omega$ -cm (dry sand). This wires are or at the cathode surface. Experience the industrials	nechanical connector. These instruments have a nechal (A-to-D) converter. Calculating and computing domotive force, indicating the ability to do the work. The inner workings of a meter may be either elect detail previously in the sections on various types of ture and mechanical properties. Write the answer is Selection Corrosion occurs as the result of a voltating the effectiveness of the joint. These instrumental give you the current flow through the shunt in an arry's first cross-platform and device-independent Calculations.	edle that rotates across the meter face and indicates the evices having a QWERTY keypad arrangement similar to of forcing electrons to move. Measure and record romechanical movement or electronic. This size wire is groundbeds. This is not intended to cover a complete n exponential form. It occurs because gas (e.g., oxygen age differential between two components of a system. 3 that are discussed later in this chapter. 14 Power ps. Rectifiers or other power sources should be installed athodic Protection Design, Verification and Assessment
wire must be repaired, or the anode must be rejected. Please read this carefully, before in good standing of NACE International may display the NACE Logo for the purpose of it. The AC signal will then flow through the earth to the structure and finally to the structure national, 2006 7/2007 Troubleshooting 9:11 determined that the input circular than \$2,000 per person. 0.7 megOhms =Ohms © NACE International, 2003 reference electrode in a stationary position. Evaluate the direction of the current. 1 El illustrated in Figure 1.13 that shows a transformer as part of a cathodic protection receptive permitted, installed and completed in accordance with state and local codes. 18 Factoreast. METER ELECTROMECHANICAL MOVEMENT ANALOG DISPLAY ELECTRONIC system called a D'Arsonval movement. As the coil rotates, it works against a mechanic	re coming to class. No. 9650 ACE Inspections, Inc. of identifying the individual as having achieved a Noructure connection to complete the circuit. CSA Securit breaker has tripped, a high current or overloads Page 2 of 3 9. The potential of a reference elect lements	ACE Certification. Passing of electrons 3. Some gases and ard Z169 covers cathodic protection of aluminum. It has occurred. In fact, due to accuracy current shunts rode in the sun can decrease from 10 to 50 mV versus a measurements Bond Current Resistance bonds (cables) Thus, Ohm's Law bear Operation © NACE International, 2006 1/2008 ANAL as having a thorough understanding of the instruments.	s, NACE CP 2-Cathodic Protection Technicians, NACE are potentially explosive. The installation is completed Take care not to get any copper sulfate on the antimos are favored over using an ammeter in most cases. Cut an electrode kept in the dark. Methods for testing an invill study electrochemical corrosion because it is the notate placed between structures to connect them for commettee formula E = IR or Voltage equals Current may of DISPLAY Basic Electricity Analog Meters Basic May be you use and a knowledge of how the data should approximate the structure of	CCP 3Cathodic Protection Technologists, and NACE d by a length of surface casing (which may have been solved) by a length of surface casing (which may have been solved). The surface stimates show that the cost of corrosion in the solution fitting include: • Measure the pipe-to-soil phost common form of corrosion that you will encount athodic protection or to drain a stray current back sultiplied by Resistance. Since the meter is in parallel eter Movement The basic movement of an analog movement. This should help you understand how the basic	CCP 4-Cathodic Protection Specialists who are members on installed at the beginning of the drilling) with a cap on
fitting. The copper ions in the saturated solution prevent corrosion of the copper rod a voltmeters are used when a permanent record of data in graph form is desired or whe V/2 $\Omega$ = 5.25 A IT = 9.98 A Note that Kirchhoff's Current Law is fulfilled also. A similar on the surface of a graphite anode, the graphite oxidizes to form carbon dioxide. They EXPERIMENT 2.1 and EXPERIMENT 2.2 © NACE International, 2006 7/2007 Basic Correduction reaction occurs any time that electrons are gained by an atom or molecule. SHEET	Determine the cathodic propand stabilize the reference electrode. © NACE Interest is desired to record voltage over a period of ar procedure is used for prepackaged anodes. Signary are weighed prior to installation and then weighed themistry and Basic Corrosion Theory 2:18 Driving The measure of resistance is the "Ohm" (I suppostarefully inspected to detect defects in insulation. and design. At a greater current, death may occure metal. We will discuss only the fixed cell, moving	tection current (Ic,p) by calculating it from the voltage ernational, 2006 1/2008 Underground Corrosion Contribution. For magnesium, anode efficiency is generally abouted: Date: WORK EXPERIENCE FORM 2: INDIVIDUAL and periodically to determine if any weight loss has occur Force for Corrosion By now we know that corrosion in the that George Simon Ohm didn't want to be forgotten). Corrosion and cathodic protection pertain to the branch due to ventricular fibrillation of the heart. The pipe mag ground method. Note: The term oxidation is not necessive.	drop across the variable resistance. Testing Resistance 3:3 Two-Component Liquid Resin Coatings These cut 50%. Calculating the currents through R1, R2, and JOB EXPERIENCE Page of Use one of these rred. The atom or molecule increases in negative characteristic approach of current flow is from the positive electroch of electrochemistry concerned with charge transfer ight read -0.750 mV (CSE) and the casing -0.650 mV essarily associated with oxygen. © NACE International	ce Between a Pipe and Casing The procedure is the patings consist of a liquid resin, usually an epoxy, at R3 is simply a matter of applying Ohm's Law: I1 = forms for each period of work experience ("job") younge. Electrical current is converted into a mechanical surface, an anode, into the electrolyte and from the to the negative electrode. 30 EXERCISE 1.4 DAT in aqueous or other liquid environments. The single (CSE). Consequently, the direction of current flow of 1, 2006 7/2006 Stray Current Interference 6:3 Stea	same as used to test the resistance across an isolating and a curing agent. Recording Voltmeters Recording $10.5 \text{ V/5}\ \Omega = 2.10 \text{ A I2} = 10.5 \text{ V/4}\ \Omega = 2.63 \text{ A I3} = 10.5$ bu wish to document. Where oxygen evolution takes place al force, as indicated in the following steps: 1. the electrolyte onto a second metal surface, a cathode. A deprobe method is illustrated in Figure 5.17. • Avoids the chrough the meter will be the same as that through the dy State Stray Current Steady state or static stray
the "Ampere". Tamp native soil above the coke breeze to the level of the bottom of the that if this happens, accelerated corrosion of the structure will occur at the point of di	ceture to be protected to the cathodic protection a mal values, the most probable cause is partial failured we knew the current was 1 milliamp and the voltant of NACE International ended the cable trench. (4) Agree to not represent its charge. Zinc is more electronegative than steel of circuit produces 2 A of current at a driving voltant of the depth of the bottom of the pipe. East is particularly true for high yield point steels. Indeed,	node(s). © NACE International, 2006 7/2007 Troublesh re of the rectifier stacks ("half waving"). (+) 0 (-) Figure 19 was 1.0 volt, what is the resistance? Electrical Equil, 2006 1/2008 Basic Electricity 1: 32 EXERCISE 1.4 Dayself to be proficient or make recommendations in phor copper. Voltage is the energy that puts charges in mage of 1.6 V. 5 Legibility	re 1.10 Pure Direct Current Alternating Current (AC) pment (Rectifiers) Electrical Equipment (Rectifier) Ca ATA SHEET STEP 1. The ohmmeter cannot distinguis ases of cathodic protection work in which I am not qu otion. Use Ohm's Law to answer the following questio	2.3 Using Audio Tone Locator to Find Shorts Casing Alternating current, such as that which we have in ase Always assume that the electrical equipment or his between the resistance of the fitting and that three talified by knowledge and experience. When this has ins. Isolation is also necessary to allow cathodic produced Malfunctions	Shorts Casings must be electrically isolated from the our homes and buildings, reverses direction on a cyclic rectifier case may be poorly grounded and is ough the electrolyte. The unit of measure for current is ppens, the rectifier current usually drops to zero. Note tection to reach the carrier pipe within the casing if
Reference Cell Maintenance Appendix 2–Conversions and Definitions Appendix 3–Cust anodes are equipped with welding tabs for electrical connection to the structure. The circuit resistance is indicated. In corrosion work we use all three units. 4 Environment environments, various chemicals may be introduced to the water or process stream to Electronics Engineers 2 L.P. Ferris, B.G. King, P.W. Spence, H.B. Williams, Effect of E Reference Cell under AST Close Interval Potential Survey A series of structure-to-electrolity compares to pressure. Bridge piles in a rapidly flowing river will require more potentials and rectifier voltage output • 200 Volts–Rectifier voltage output • 1000 Volt understanding the fundamental principles underlying cathodic protection technology. Connect cathodic protection system. Avg. Conductor connections to the rectifier must	stomary Metric Conversions for Units Commonly L potential difference and the corrosion current bettal Control	Ised in Corrosion-related Literature January 2008 II Section the anode and cathode areas becomes steady. On	ction 3 Chapter 3-Underground Corrosion Control Marifice effect 5. 18 Power Supply	terials Selection	The ends of these the current output significantly decreased, a higher out of limits). Environmental Control In aqueous ty in Substation Grounding, Institute of Electrical and 601 -1455 -402 -578 -911 Potentials (mV) Figure 5.3 all output voltage can be restored. In a gas system, the potentials • 20 Volts-Structure-to-electrolyte so find this information useful as a starting point for rface point installation is illustrated in Figure 8.21. ORWARD READING REVERSE READING Good
moving coil. However, with the high-input resistance meters available today, this corre	requirements. This is illustrated in Figure 3.2. q Controlyte to the metal surface. Pertinent recomment Metals with Respect to a Copper/Copper Sulfate I Edward Values of Typical Reference Electrodes to Coppodes A stationary copper-copper sulfate reference d. An ion formed by the gaining of electrons is call not only include structureto-electrolyte potentials 16.81 21.89 27.31 32.38 35.56 40.64 45.72 50.80 CE International, 2006 1/2008 5:23 Field Measure rection is not necessary. Metals that corrode under	ded practices are also cited. © NACE International, 20 Reference Electrode PROCEDURE 1. The same is true figure-Copper Sulfate Reference Electrode Electrode (Have electrode is used for installation underground. Often the ded an anion and is negatively charged because the number of the indirect methods of monitoring protection of 55.88 60.96 66.04 71.12 76.20 81.28 86.36 91.44 Walls ements 5:24 Using an Ohmmeter An ohmmeter is the regrow and high pH levels are termed amphoteric metals	c Protection Current Applied Cathodic Protection And 106 7/2007 Basic Chemistry and Basic Corrosion Theo or impressed current anodes: the more anodes you actlif-Cell) * Copper-Copper Sulfate Potential (Volt) 0.000 his is accomplished with power tools but in some case aber of electrons is greater than the number of proton a system in between potential surveys. It may be an Thickness Weight Resistance in. If the circuit breake esistance meter in a multimeter. This is a good habit to Legal In the event of an accident or lawsuit, good resistance in the circuit product of the control of the circuit products and the circuit breakers.	de Figure 3.2 Cathodic Protection on a Structure Try 2:27 Experiment 2.1-Metal Electrode Potentials Id, the lower the resistance to the electrolyte and the Silver-Silver Chloride (saturated) -0.050 Saturated as abrasive blasting and solvents is required. Electrical Electrical Cathodic Protection Levels From time to time in other line from your own company or it may belong the does trip, a permanent short circuit is indicated. To form and is required by code in many areas. The cords are essential to legal defense. © NACE Interpretations.	the cathodic protection current leaves the cathodic in Tap Water + _ V Metal Sample Tap Water in Tray the more current you get. Copper-Copper Sulfate d Calomel -0.070 Hydrogen (SHE) -0.320 Zinc -1.100 ical Isolation Purpose and Usage The purpose of your routine testing you will come across areas where to another company. Cm 2.35 4.5 6.62 8.62 10.75 12.75 is Theory D'Arsonval meter responds to a current flow through the national, 2006 7/2006 7:5 Monitoring Cathodic Protection
Effectiveness and Recordkeeping You need to be familiar with what these maps show down by 50%. The reference cell must be stable and capable of producing reproducibl a battery) and that the zinc is the anode and the carbon is the cathode. Some test staticest/Measuring Lead Measuring Lead (-) Internal Meter Voltmeter900 v - + Refere voltage drops in the measuring circuit must be negligible. Figure 6.1 shows a typical reflectrochemical process involving the flow of electrons and ions. 5 January 2008 V Section the individual resistances. Resistance may also be measured in milliohms (0.001 Ohm) potential as the rest of the structure. They also help hold matter together, a bit like the sand paper or emery cloth for cleaning. © NACE International, 2006 1/2008 Basic Electhis course, we will focus on the control of metallic corrosion by applying cathodic procession component that might generate an ignition spark should not be all	le data. 81 = .81 100 b	Calculate voltage drop across R1? Improperly instances to-soil measurements can be made with essentially not ent & C.P. current across electrolyte Structure Figure of current. If your job requires constant use of a pipe loc Stations	stalled anodes will very likely not function properly. F IR drop. Cell Reference Cell Contact Reference Cell to 3.9 Voltage Drops in a Measuring Circuit For a measurator, you may prefer the speaker type. © NACE Intersum	rom Table 2.2 you can see that the voltage different to Electrolyte Electrolyte Polarization Structure Control pred potential to represent the polarized potential an anational, 2006 7/2007 Basic Chemistry and Basic Control water resistivity. • Total (equivalent) resistance is the sum of the control of the	ce between the two metals is about 1.4V (actually 1.5V in stact Test Lead/Structure Test Lead Contact cross the structure-to-electrolyte interface, all other prosion Theory 2:9 Corrosion Cell Corrosion is an equal to the reciprocal of the sum of the reciprocals of an isolated portion of the structure could have the same inber the Ohm's Law Formula. Use fine non-metal bearing appermost in your mind as you go about your work. In re, the steel sheet, at positions A, B, and C. Finally, any It means taking the time in the field to review your data
	der this application, a known current and voltage of such as that shown in Figure 6.2 would indicate in Atom Ions Gaining or losing electrons can electronate Electricity 1:21 Meter Operation General The classice? Anodes should be wet down after backfilling classicationed as close to the wall of the tank as possible. In Determination". If the structure is coated, the industry Consequently, the nearest pin should be at lesistance (R2) = 2 $\Omega$ Load resistance (R3) = 1 $\Omega$	are used and the resistance is calculated. The figure she the presence of cathodic interference. Today, most instically charge atoms. If a complex structure is construct sification of a meter depends on the inner workings are left to absorb natural soil moisture. At temperatures (8) Agree to uphold, foster and contribute to the achieves usulating material should be compatible with the struct east 1.5 times the pin spacing from any underground malculate total resistance? Be certain there are always to	ows an analog meter and note that the needle has swittruments are electronic with digital displays and are seed of materials that are near each other in the galvant and the display of the meter. Check all protective device above $130^{\circ}F$ ( $54^{\circ}C$ ) and particularly in the presence element of the objectives of NACE International. There are coating. $-6 + x = 9 x = 15 c$ . To make sure everyone tallic structures © NACE In andissolved crystals in the solution; this creates a superior of the structure of the solution.	ung to the right from the left hand zero position. 29 referred to as digital meters. See Figure 2.1. © NA ic series, then there is reduced likelihood of potenties (circuit breakers, fuses, or lightning arrestors) for carbonates, zinc can passivate and the potential are times, however, when the electrode is purpose one knows what we are talking about here, let's deficternational, 2006 1/2008 1:27 Basic Electricity 1:28 er-saturated solution in which the copper will not consider the same and the position of the same are talking about here, let's deficternational, 2006 1/2008 1:27 Basic Electricity 1:28 er-saturated solution in which the copper will not consider the same are same as a same are same are same as a same are same are same as a same are same are same are same as a same are same	Rectifiers CE International, 2006 7/2007 Basic Chemistry and Basic ial differences. Another is to measure the protective or evidence of damage. The symbol for voltage is the of the passive film can become more noble than steel, by placed at some distance from the structure; this is ne the three elements of Ohm's Law. A number of Exercise 1.2: Series Circuit E2 E1 I R1 R2 R3 Given:
General	Leave slack in all wiring. Dissimilar Metal Situate same potential shift occurs on the casing, a short rk. In cathodic protection work, we are concerned king about Direct Current (DC) throughout this disonal Recommended Criteria	ions SP0169 gives a criterion of a negative voltage to a exists. (See % The University of Oklahoma also spons with series circuits, for example, in the length of cable scussion. Compounds (Molecules) Molecules are compounds	a stable reference electrode equal to that required for ors a short course in conjunction with several NACE is a running out to groundbeds. 11 Shunts	protection of the most anodic metal involved. If you sections: go to . 17 Bracelet Anodes	The transmitter creates a low frequency
sometimes there will be debates. The full-scale voltage is simply the full-scale current measurement. This is a useful corrosion cell since the current produced can do work for current leaves the metal and re-enters the electrolyte. The entire structure that is accommodate and use as many copies of this form as needed. MAXIMUM FORW ARD CURRENT purpose using a one-hand method while avoiding contact to the probe end. The topics be the cause. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion authors of this course and by those who have assisted in making this work possible. The manufacture and products away from the anode. Coating All wire and cable attachments with the manufacturer's Material Safety Data Sheets (MSDS) and follow all of the manufacture.	times the coil resistance. Electrical Connections of the control of the protected facility become sidentally shorted to the protected facility become NT HALF CYCLE ZERO CURRENT Figure 1.12 DO will range from questions and answers about cathon Theory 2:10 Other anode reactions: Feo Alo Hg his potential is measured with respect to a saturation the dropdown list. Also, do not use this type local should be coated with electrically insulating material interpretations. Under the control of the coated with electrically insulating material interpretations.	All electrical connections used in impressed current cate ture or tracer wires parallel a high voltage AC (HVAC) is part of the system to be protected. Because of the high conditions are produced by Rectifying AC Knowledge of alternating modic protection to materials and chemical inhibitors are of Fe++ + 2e- Al+++ + 3e- Hg+ + 1e- Cathode React and copper-copper sulfate reference electrode contacting for in an explosive atmosphere as a spark might cause erial. Cathodic Protection Surveys There is always a poderground splices on the header cable (positive lead with the surveys that the surveys the surveys the surveys and the surveys are surveys the surveys and the surveys are surveys as a survey are surveys as a survey and the survey are surveys as a survey as a survey and the survey are surveys as a survey as a survey as a survey as a survey and the survey as a survey as a survey as a survey and the survey are survey as a	chodic protection systems (except the active anode surpower transmission circuit, significant AC potentials h consumption rate, the anode life is typically about current is important in understanding cathodic protected to the surpose of the consumption of the consumption of the chemical reaction that occurs at the cathode in the electrolyte. In the case of an open circuit diode ignition. Platinized anodes are economical only when satisfied to the groundbed should be kept to a minimum. The	rfaces) must be completely sealed with dielectric in may be encountered. Where current is picked up, to one year. Signed: XXX Date: Form 1: Summary of Cation rectifiers. Electromotive force 2. • Take measure unust increase rectifier voltage from time to time, the cathodic reaction, is a reduction reaction. The the meter will display "OL" in both forward and recoperated at high current densities such as in seaw onducting cathodic protection measurements. Before IR drop is usually negligible when the current designed.	sulating materials. Figure 5.10 illustrates a shunt he structure is protected; corrosion occurs where the athodic Protection Related Work Experience Instructions: irements with insulated meter probes intended for that to maintain the desired current, anode deterioration may ir dedication and efforts are greatly appreciated by the everse bias. 5 Explosions or Ignitions after where there can be rapid migration of chlorides to be using exothermic welding equipment, become familiar ensity and/or the resistivity are low. In the overall cycle,
the metal is oxidized and sulfur, normally present in soils as sulfate, is reduced to sulface coulomb per second. This can blow a fuse or damage the meter. Certification Application foot must be known 0.17 mV N Wires must be color coded West + Pipeline East Pipe survey, the pipe-to-soil potential data are collected on a continuous basis. Advantages the bonding and/or the detection of broken bonds. A quick test can be made using an International have gone into the development of this course. 25 Purpose and Usage triangle is to place your thumb over the quantity you are looking for. 25 Isolation (Insu your measured values of ET and RT, calculate total current (IT). NACE has 1- and 2-date Electricity STEP 7. Thus, the potential of interest is the polarized potential across the are listed below. It is imperative that you know the criteria specified for the structures the expected sign in order to detect problems during a survey. Even greater costs can	ction A certification application must be completed as Span in Feet Figure 5.11 2-wire Line Current Test of Galvanic Anodes • • • • • • No external power earphone that detects the presence of AC or a DC current DC complete that detects the presence of AC or a DC current DC c	and returned to NACE at the time of the written final est Because the voltage drop across a pipe span is relative resource required. © NACE International, 2006 1/2008 potential difference across the isolating fitting. CP 1-0 Common Carefully inspect for evidence of excession	examination. Conductors should be color-coded or otherwelly small, with earlier instruments it was necessary to a Installing CP Components 8:2 Where electrical bond Cathodic Protection Tester Course Manual January 20 we heating. Here again, it is essential to ensure that ster I. Connecting the reference electrode to the negate 6, for example, is ten times more acid than one having electrodes. Many anodes may be required for poorly it), the higher the resistance and the lower the current 3.4. ANODE Figure 3.4 Typical Impressed Current Cathodic Protections 1.5 with the signal of the current Cathodic Protection 1.5 with the signal of the current Cathodic Protection 2.5 with the signal of the current Cathodic Protection 2.5 with the signal of the signal of the current Cathodic Protection 2.5 with the signal of the signal	erwise permanently identified. Applicant Information to correct for the voltage drop in the test leads causing of joints on ductile iron or mechanically joined 08 © NACE International, 2000 Acknowledgements such grounds and bonds do not short-circuit any diexive terminal produces a negative reading. • A mining a pH of 7. Measured Current (IT) = © NACE Intercoated structures. Some typical hazards that are ent for a given voltage. It is still important to pay attentional protection Anodes Materials that have been	on: Name: A. Pipe size and wall thickness or weight per sed by the current drawn by the meter. In a close interval steel is involved, frequent test stations permit testing of The time and expertise of a many members of NACE lectric isolation. An easy way to use the Ohm's Law mum of 100 mV of polarization. Using Ohm's Law and mational, 2006 1/2008 A Basic countered in cathodic protection testing or inspection ention to the connection of the instrument terminals and used as impressed current anodes include: • • • • • •
Graphite (carbon) High-silicon, chromium, cast iron Platinum-coated titanium and niol produces direct current (DC). 81 = 100 b. It is called the Magic Circle or s is held constant, the Voltage and Current values are directly proportional. screw joints	bium Aluminum Magnetite Mixed metal oxide-coasometimes it's called the Magic Triangle. It facilit is bell and spigot joints lap joint flanges pile group besion current decreases as cathodic protection curtically attracted to each other, forming a molecule DC structure-to-electrolyte potential or before to the Required to Operate Train Overhead Positive Foreign Line Cathodic Protection Current Protective Current and Lightning Effects on Metallic Structure. There is also a safety hazard in working with h	ted titanium © NACE International, 2006 1/2008 Under the communications among professionals who work in a reinforcing steel in concrete. Influence of the Enviror rent increases. 2 Types of Test Stations	rground Corrosion Control 3:15 • Conductive polymerall facets of corrosion prevention and control. Relation ment Moisture Content Electrolytic corrosion requires	r • Scrap iron or steel • Lead silver Power Sources on ship between Current and Resistance The next the steep presence of moisture. 22 Deep Anode Ground plarized potential more negative than -1200 mV shows a given in the NACE International slide show entitle in ion concentration in an aqueous solution and is captive P 1-Cathodic Protection Tester Course Manual - Charles BOND Protected Line Foreign or Affected Line from the slide presentation I use when teaching Ohmasurements 5:31 Soil Box The soil box method is us	The power source for an impressed current system ing that George observed was that when the Resistance bed Configuration uld not be exceeded. Diode Bias This is a multimeter of "Some Safety Considerations During Construction lassified according to the pH scale. It is important to apter 6 ©NACE International, 2004 April 2006 6 are 19 of 23 Cathodic Protection • Can sometimes be used of Law. Note that the copper-copper sulfate reference and to measure the resistivity of an electrolyte that has

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Month/Year To Month/Year ////// Number of months in this job Job Title Company Name Applicant Affidavit: I understand that if I knowingly provide false information in connection with my recognition under this program, it will be grounds for disciplinary procedures. The test station head may be mounted on a post as shown in
 Figure 8.1 or it may be flush mounted as illustrated in Figure 8.2 Test Box Test Wires Structure Figure 8.1 Typical Post Mounted Potential Measurement Test Station Post-mounted test stations are
preferable to flush mounted ones because there is less chances of losing post-mounted units. Consequently, as-built drawings of corrosion control installations must be accurate. If the potentials are determined to be less than 15 Vac, no specific action is necessary; however, caution should be maintained as this voltage can change at any time with a
 change in power line load. Mixed metal oxide anodes are extremely resistant to acid attack even at a pH less than one. When the foreign line belongs to another company, the wires attached to that line must be installed by representatives of that company, the wires attached to that line must be installed by representatives of that company. A simple way of testing for a short is to measure the pipe-to-soil potential of both the casing and
the pipeline. If a circuit is broken with current flow and your heart acts as a shunt for the external current flow. Using a high-input impedance meter, the procedure involves simply measuring the voltage drop between the test leads. Of course, unusual data may indicate a malfunction, and it is important that you
recognize these situations, too. CP-Compass simply works on any device running any OS. This voltage is amplified and produced as an audible signal heard by the user. Girth Weld and Other Field Coatings Welded joints, fittings, and other appurtenances must be coated in the field. AC Power and Wiring AC wiring should be done by a licensed
                                                                                                                               Among these are pipe-tosoil potential measurements, voltage drops across shunts or along pipelines (a method of measuring current explained in Chapter 4), and the voltage output of a cathodic protection rectifier. • To provide protection to structures
located near many other underground metallic structures where conditions make it difficult to install impressed current systems without creating stray current interference problems. If the protection is effective, the corrosion rate is zero. 9 Use of an Ammeter
current system consists of an external power source and anodes. Wind-Powered Generator Storage Batteries in Suitable Housing Groundbed Structure Figure 3.7 Wind Powered Generator Installation © NACE International, 2006 1/2008 Underground Corrosion Control 3:21 THERMOELECTRIC GENERATORS These units generate voltage by heating
a junction of two dissimilar metals. Installation techniques are discussed below. regarding corrosion control, many have gone a step further by specifying specific measurements and time intervals in which these measurements must by taken. If the anodic area is small in relation to that of the cathode (a steel rivet in a copper plate, for example), the
                                                                                                                  c. Figure 9.3 shows a typical situation. Parallel Circuit In a parallel circuit (Figure 1.7), the current divides into a number of separate branches. In dry soil, the silicon dioxide film, which forms on the surface, introduces a high resistance that degrades
                                                                                                                                  © NACE International, 2006 1/2008 Basic Electricity Voltmeters Because the D'Arsonval meter responds to current flow through the coil, the current magnitude resulting in full-scale deflection of the meter can be determined. When under way
to make certain it is safe and all locks have been removed by the owner of the lock. Alternating current (AC60Hz commercial power) reverses direction 120 times per second. Connecting a rectifier backward with the structure! Above ground wiring should be
installed in conduit. This is accomplished by a coil in the transmitter that establishes a strong magnetic field that induces an AC current in the structure. • Usually restricted to lower resistivity electrolytes. Ponca City, Oklahoma This group of NACE members worked closely with the contracted course developers, who were John Fitzgerald, John
                                                                                                                                                                                                                                       What is the voltage drop across R2? © NACE International, 2006 1/2008 Field Measurements 5:32 Resistivity Probe This single-probe method is used to determine soil
resistivity in the immediate vicinity of the tip of a probe driven into the ground to a depth of the desired measurement. A negative terminal, and the structure is connected to the NEGATIVE terminal. Location
Selection of locations for test stations is at the discretion of the external circuit as illustrated in Figure 5.7. E + AMPS RB RA RC + Series Connection Figure 5.7 Ammeter Connection There are a wide
variety of ammeters available today. Mitigation bonds need to be maintained. The small cathode may polarize rapidly, reducing the rate of corrosion current flow. These units usually power standard rectifiers as shown in Figure 3.6. AC Supply Line to Rectifier Exhaust Stack Alternator Control Center Tank for Lubricating Oil Rectifier AC Generator
 Regulator Gas Powered Engine Insulated Flange Groundbed Structure Figure 3.6 Engine-Generator Unit WIND POWERED GENERATORS Wind powered generators may be used in areas with prevailing winds of sufficient velocity. 5 Cathodic Protection..
interrupted, the potential should be measured at "instant off," which refers to the potential after IR drop is eliminated but before polarization begins to dissipate. This is achieved by one of the following methods: • using insulated copper wire provided by the manufacturer and thermite welded or otherwise attached to the structure. The external
circuit of this measurement is high, so a high-input resistance voltmeter is required for accurate measurement. Impressed Current Groundbeds General Impressed Gene
goes UP Resistance Current Current Resistance Voltage is constant Voltage is constant Figure 2. Be careful not to damage the insulation on the negative cable. © NACE International, 2006 1/2008 Installing CP Components 8:27 Anodes may be attached to a support pipe or in the case of light weight materials (e.g. MMO), may be lowered down the
 hole by the anode leads. If the weld is not secure, or if the wire is burned partially through, remove the wire and make a new weld. Corrosion is defined as the deterioration of a substance or its properties as a result of an undesirable reaction with the environment. The receiver picks up this field. If a splice has been poorly insulated or if the wire is
exposed at breaks in the insulation, rapid deterioration of the wire will ensue. Reproduction of contents in whole or part or transfer into electronic or photographic storage without permission of copyright owner is expressly forbidden. Seasonal variations in soil conditions, such as drying or frost, can also increase the current resistance. 3 =
  10 c. Thus, an Fe/Fe++ electrode can be either an anode or a cathode, depending on the other electrode to which it is connected. Remember that when current enters the meter and on an analog meter the needle will swing to the right. The structure is now the cathode of
                                                                                                                                                     (5) Agree to avoid and discourage untrue, sensational, exaggerated, and/or unwarranted statements regarding my work in oral presentations, written text, and/or advertising media. The only way current output can be used, as a
measure of cathodic protection is if the system has remained unchanged since the potential survey was conducted. Examples are refineries, industrial plants, large tank farms, and similar complex facilities. Send a blank email message to: [email protected] 2. Similar "on" and "off" potentials on opposite sides of the fitting indicate a short. An
Electrical Circuit Electrical Laws Electrical Laws Electrical Laws Electrical Laws govern the relationships in electrons. You're Reading a Free Preview Page 2 is not shown in this preview. Structure-to-electrolyte readings are considered negative to the reference electrode. This is because the wires are used for calibrating the station and also
for measuring the current flow. The Wenner procedure involves driving four metallic pins into the earth, in a straight line, equally spaced. The meter measures current directly, and, by knowing one of the other variables, the third variable can be calculated by using Ohm's Law. When dealing with underground piping or tanks, the proper position of
the electrode is over the center of the structure. Avoid getting any stones, debris, or other objects that might damage the cable into the backfill, extending the anode life. • Turning off the circuit breaker in the rectifier will render the front of the panel safe but will not make the
back or inside of the rectifier safe! • The AC disconnect outside the rectifier must be OFF (locked out/tagged out) before the entire rectifier is safe to work on. After the weld has partially cooled, remove the welder and clean welding slag from the weld with a chipping hammer and wire brush. Replace any wire with cracked or deteriorated insulation.
                                                                                                                Consequently, if the anode is not surrounded by the backfill, the anode may not function properly. Myers (JRM Associates, Franklin, Ohio), Frank Rizzo (FERA Corporation, Houston, Texas), Marilyn Lewis, P.E. (Lewis Engineering, Hattiesburg, Mississippi), Larry
                                                                                                                                                                                                                                                                       Various processes—mechanical, chemical, and electrical—are employed to transform ores into useful metals. A current measurement using ar
ammeter requires more caution than voltage because the circuit has to be broken. The pH of the environment around the cathode (the protected structure) becomes more alkaline due to the production of hydroxyl ions or removal of
and alkalis and the metals corrode. Again, the meter is in parallel with the pipe span, so current flow on the pipe is from east to west. Lower in the anode by the lead wire. We often just say Amps. 7 Structures That Can be Cathodically Protected and alkalis and the metals corrode.
                                                                                                PROCEDURE Experiment to Demonstrate Mitigation of Local Action Cell Corrosion with Cathodic Protection Part A 1. The fluid chemistry in oil heater-treaters affects anode performance. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:36
 Results Meter Positive Lead Meter Negative Lead Zinc Reference Position #1 Zinc Reference Position #2 Measured Potential (mV/CSE) Conventional current will pass from the electrolyte that are more negative to the locations that are less negative, as indicated by potential readings at the reference electrode positions. The pointer
electrolyte. A potential profile is performed to determine if adequate cathodic protection is achieved at all points along the structure. The second criterion, a polarized potential of -850 mV, is based on eliminating IR drop during the measurement. In many cases, other criteria also apply x + 3 = 5 x =
anyone entering the field of cathodic protection technology. The metal in the vicinity of the lower resistivity soil is usually more active and is the anode. To determine the extent of the fluctuations, you need a recording instrument such as a strip chart recorder or datalogger. Aluminum anodes are not used in fresh water, except as impressed currents
anodes. Direction Elevation Difference I ow rF ate W of Figure 2.16 Elevation Difference Causes Water to Flow Likewise, current will flow from one point to another if there is a voltage difference between the two points. When a small cathode is connected to a large anode (copper rivet in a steel plate for example), the corrosion current density on the
anode (steel) is much less than in the opposite case discussed above, and the anode corrodes more slowly. Electrolytes dealt with in corrosion and cathodic protection includes soils and liquids (water). The indium alloy has a slightly higher corrosion potential but is less efficient than the mercury-containing alloy. Current Law This law states that as
much current flows away from a point as flows toward it. Magnesium is more electronegative than copper, steel, or zinc. Rectifier unit. Movement of Structure and Electrolyte The relative movement between a protected structure and the electrolyte affects current
corrosion current (Icorr). If buried or submerged, these connections must be sealed to prevent moisture penetration such that electrical isolation from the environment is ensured. This electrode is portable. 5 Oxidation and Reduction
NACE International, 2006 1/2008 5:25 Field Measurements In heat exchangers where the tube sheet is perhaps Monel metal and the water box. Stray current corrosion is of serious concern because a large amount of current is usually involved. They are also used in stray current areas
One to tip Insulated wire, inside of rod, from tip to terminal Figure 5.17 Single Probe Soil Resistivity Measurement Measuring pH Electrolyte pH can be measured in several ways. The shift may not be nearly as great as with a metallic short. • Know, understand, and follow the information and procedures given. = 2.54 cm 1 ft = 0.3048 m (A) Based on
steel density of 489 lbs/ft3 (7832 kg/m3) and steel resistivity of 18 microhm-cm. Electrodynamic force B. Corrosion prevention is dependent on the concentration of the chemicals in the liquid, and regular testing and chemical control must be initiated. Most digital meters will not read below 0.1 mV. Shunt Calculations a.
the voltage drop across R3? When the potentials of all cathodic sites reach the open circuit potential of the most active anodic sites, the voltage difference between local anodes and carrosion can occur where the current leaves a steel anodes and carrosion can occur where the current leaves a steel anodes and carrosion can occur where the current leaves a steel anodes and carrosion can occur where the current leaves a steel anodes and carrosion can occur where the current leaves a steel anodes are carrosion can occur where the current leaves a steel anodes are carrosion can occur where the current leaves a steel anodes are carrosion can occur where the current leaves a steel anodes are carrosion can occur where the current leaves a steel anodes are carrosion can occur where the current leaves a steel anodes are carrosion can occur where the current leaves a steel anodes are carrosion can occur where the current leaves a steel anodes are carrosion can occur where the current leaves a steel another carrosion can occur where the current leaves are carrosion can occur where the current leaves a steel another carrosion can occur where the current leaves are carrows and carrosion can occur where carrosion can occur where the current leaves are carrows and carrosion can occur where carrows are carrows and carrosion can occur where carrows are carrows are carrows and carrosion can occur where carrows are carrows are carrows and carrosion can occur where carrows are carrows are carrows and carrows are carrows are carrows are carrows and carrows are carrows 
structure and enters the electrolyte. This is important when working with amphoteric metals, as the corrosion of these metals can actually be accelerated under excessive cathodic protection due to the rise in pH around the structure. This method is useful for: • Rapid determination of local resistivity at intervals along a pipeline trench during
construction (for later use during cathodic protection system design). The lead wire must be securely connected to the anode and should be inspected to ensure that it is not damaged. 3 Coupons ...
and the use of cathodic protection. A current of 9 to 25 mA can cause lack of muscular control (let-go current) that makes it impossible to release and in fact it may cause the muscles to tighten 1. The component causing the open circuit can be located by realizing that the rectifier voltage must exist across the open circuit element. © NACE
International, 2006 1/2008 Field Measurements 5:35 Figure 5.19 Example of a Conductive Pipe Locator Inductive An inductive Pipe Locator uses a radio frequency AC signal, which is induced in the structure to be located by an induction coil that is part of the transmitter.
 furnished to each student. This could be caused by: • Open fuse in the output circuit • An open positive or negative lead wire • A failed groundbed. It will be used again in measuring resistance across an isolating fitting. For example, the voltmeter in Figure 2.11 is connected in parallel to Resistor B of the external circuit. © NACE International, 2006
7/2007 Environmental conditions such as temperature, humidity and © NACE International, 2006 1/2008 Underground Corrosion Control 3:4 dew point must be checked against the manufacturer or consultant's specifications. We look forward to seeing you in class! P.S. If you need more information and do not plan to attend the new NACE CP 1-
Cathodic Protection Tester Course, then here are some other options for learning more about cathodic protection: 1. Damage to the insulation is not as critical as it is on the positive cable, because the negative cable is on the cathodic protection: 1. Damage to the insulation is not as critical as it is on the positive cable, because the negative cable is on the cathodic protection: 1. Damage to the insulation is not as critical as it is on the positive cable, because the negative cable is on the cathodic protection.
same from the pipe and the casing test wires. All coatings should be applied in accordance with the manufacturer's requirements. Welded structures by nature of the fabrication have electrical continuity. Fusion Bonded Epoxy These coatings consist of a powdered resin electrostatically sprayed onto a pipe heated to 400°F to 500°F (204°C to 260°C).
Increasing temperature acts to reduce polarization. To avoid a potentially disastrous situation, standard practice involves bonding the dock and the barge using two bonding wires prior to opening any hatch on the barge. Note that a pH meter uses a glass electrode with a rather fragile glass bulb on the bottom. 7 Ohm's
                                                                                                    The metal in the vicinity of the higher concentration of oxygen will be more noble, or the cathodic reactant. If the "on" potential was depressed on the side of the isolation away from the current drain, the fitting is effective. If the resistors were
of different sizes, the sum of the voltage drops across them would still equal 24 volts. If reinforced concrete is used, there must be no metallic contact between anode and reinforcing mesh or between reinforcing mesh and pipe. If you can trace more than one path for current to flow through the circuit, you have a parallel circuit. Integrity of rectifiers,
isolating joints, electrical bonds, and other physical features associated with the corrosion control system. Answers recorded on the actual exam will NOT be counted. The resistance from ground level to a depth equal to the spacing of the pins. The
system consists of a primer, a corrosion sealant inner layer, with a mechanical protective outer layer backing, usually polyethylene or polybutylene. Typical Applications Structure-to-electrolyte potential Basis of Measurement A structure-to-electrolyte potential. The
opposite ends of the tray. A typical IR drop station is shown in Figure 8.3. © NACE International, 2006 1/2008 Installing CP Components z z Test Box z z 8:5 z Terminal Board Lead 4 Lead 3 Lead 4 Figure 8.3 IR Drop Test Station When installing this type of test station, it is important that the different color wires are placed on the pipe
 exactly as shown on the construction plans. The field training activity is designed to simulate actual field conditions that students may encounter on-the-job. © NACE International, 2006 1/2008 Underground Corrosion Control 3:9 Galvanic Anode Systems Galvanic (or sacrificial) cathodic protection makes practical use of dissimilar metal corrosion.
The higher the concentration of hydrogen ions, the lower the pH. © NACE International, 2006 1/2008 Installing CP Components 8:30 Some rectifiers don't have transformers, but utilize solid state circuit, the voltmeter is connected in parallel
across the element. After use, data loggers are connected to a computer and the information is downloaded. In the following discussion, the criteria noted are quoted from the referenced documents. In such cases, it may be well to have the above ground DC wiring done by a licensed electrician. On pipelines where the temperature of the pipe changes
 considerably (with accompanying changes in resistance), more frequent calibration may be necessary. In these tests, a current is impressed on a structure to be protected and the potential changes brought about 15%, soil resistivity decreases. Place the
reference electrode near the magnesium and record the magnesium's potential. Polarized potential of the structure shifts electronegatively with time. A current of 100 amperes (entirely reasonable with some rail transit systems) would destroy 910 kg (2,000 lbs.) of steel in one year. However, total immersion (saturated soil) is not necessarily the most
 aggressive situation. • A minimum of 100 millivolts of cathodic polarization between the structure surface and a stable reference electrode contacting the electrolyte. To ensure accuracy, it is good practice to take two sets of data, perpendicular to each other.
be made to ensure that no metallic contacts exist or are likely to develop between the casing and carrier pipe. Cell Electrolyte Pipe Potential Profile © NACE International, 2006 1/2008 Field Measurements 5:7 Earth current flow and surface potential measurements A series of potentials measured between two
reference electrodes can indicate current flow and its direction in the earth, as shown in Figure 5.5. This type of measurement is sometimes used to determine if current is flowing toward or away from a structure. As a result, it may be difficult to protect structures backfilled with or resting on gravel or crushed rock. If the probe corrodes, its
2006 1/2008 Underground Corrosion Control 3:13 Specifications of Galvanic Anode Systems Size and Shapes Galvanic anodes come in a variety of sizes and shapes. More important, however, is the fact that there is nearly always a voltage difference between two isolated structures. Sometimes it is possible to relocate or remove the source of the
current. With this in mind, we have put together a short introduction that will help you be better prepared when you come to the course. A high resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected one way and a low resistance may be indicated with the leads connected with the leads conne
 of an ammeter will affect current flow in a galvanic anode system. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:22 In general, clays are deficient in oxygen and in mixed soils the areas of a structure in contact with the clay become the anodes of an oxygen concentration cell. 001 amps I = 1000 Ohms Note that we
                                                                                                                                                                                                               © NACE International, 2006 1/2008 Installing CP Components 8:23 Typical Vertical Anode Installation Earth Backfill Insulated Cable Connection Anode Backfill Anode Header Cable to
Other Anodes and Power Source Augered Hole Figure 8.19 Vertical Impressed Current Anode Horizontal Anode Installation of the anodes. Likewise, if you are involved with repairs of structures or corrosion control components, accurate information must be turned in. All test lead wire
rectifier does not provide any information about the protection level of a system. The computer can also create graphs of data. The resistance between a single galvanic anode and a structure also represents a series circuit. An important part of your work is to make regular inspections, which are required in various regulated industries, to insure that
                                                                                                                                                                                   of/to current flow. Output Problems A good maintenance program can often detect potential rectifier failures before they occur allowing scheduled repair before an actual outage. For example, Given: Shunt
Measurements 5:20 Table 5.3 Table of Pipe Resistances Steel Pipe Resistance*(A)(B) Pipe Size in. As of 1998 there were 109 recognized elements, some of which have been found only as products of nuclear reactions and last for only very short periods. Transmitter Receiver Pipe Figure 5.18 Conductive Pipe Locator Principle Figure 5.19 shows an
example of a conductive locator. This voltage affects the total voltage of the measuring circuit and creates appreciable errors. • Total current flowing into and out of the junction point of the branches equals the sum of branch currents.
Basic Electrochemistry Electrochemistry is the division of chemistry that deals with the transfer of electric charge in chemical reactions. Measure pH. 11 Specifications of Galvanic Anode Systems ............
                                                                                                                                                                                                                                                                                                             Cations are positively charged ions and anions are negatively charged ions). For example, when sodium
combines with chlorine an electron is transferred from sodium to chlorine, creating a positively charged sodium ion and a negatively charged chloride ion. The 4-wire test method overcomes these difficulties. © NACE International, 2006 1/2008 CHAPTER 9 Troubleshooting Introduction In this course we have been teaching you various techniques
2006 1/2008 N Basic Electricity 1:29 Exercise 1.3: Parallel Circuit I E I1 R1 I2 R2 I3 R3 I Given: Power supply voltage (E) = 20 V Load resistance (R1) = 1 \Omega Load resistance (R2) = 2 \Omega Current across load resistance (R3) = 20 A What is the total power voltage? Printed in the United States. For example, a single water molecule is composed of one
oxygen and two hydrogen atoms as shown in Figure 2.2. Further splitting of this molecule would result in a substance with Characteristics unlike water. PROCEDURE A + Copper Sheet V - Magnesium Anode Reference Electrode Tray with Tap Water Experiment to Demonstrate Change in Polarized Potential with Time Part A 1. © NACE International
2006 1/2008 CHAPTER 4 Safety Introduction "Safety" is for your fellow worker. Corrosion of the metal will cease once the applied cathodic protection and that of your fellow worker. Corrosion control 3:7 current equals or exceeds the corrosion current. It does not work in the atmosphere. Figure 5.21
Current Interrupter Coupon Measurements Coupons are often used to check the effectiveness of cathodic protection. Date, Time, and Weather Date, time, and Basic Corrosion Theory 2:20 For example, if a steel bulkhead were
discharging 875 mA over a period of four years, how much metal would be lost? The corrosion rate of the structure when CP is on can be calculated based on the polarization measurements, as shown in the screen shot below: This unique function not found in any other CP design software allows users of CP-Compass to assess the degree of CP
 following reactions are the two most common reduction reactions that occur at the surface of the cathode. © NACE International, 2006 1/2008 1:22 Basic Electricity 1:23 Scale Pointer Permanent Magnet Range Resistors & Selector Switch N S Im Moving Coil - Damping Resistor + Figure 1.15 D'Arsonval Movement (Voltmeter) Of the total current
required to cause full-scale deflection, part of the current will flow through the moving coil and part through the damping resistor. In water, zinc electrodes are used bare. Hazardous Material During your work, you may encounter hazardous materials such as those listed below. As previously discussed, monitoring is essential to ensure the continued
proper performance of cathodic protection. Documentation of your work is essential. (A second meter from another kit can be used to obtain the information.) Part B 1. Correct for potential variations due to temperature and sunlight. The hole above the coke breeze may be filled with
native soil, gravel, or simply left open. This is shown in Figure 1.15. Voltage drops other than those across the structure-to-electrolyte boundary must be considered for valid interpretation of this voltage measurement. Other General Precautions not discussed above that must be considered include: • Wear protective eyewear,
gloves, shoes and other clothing. If you encounter such fluctuations, you should suspect the presence of stray current (IT). There are many connections to the underground structures in such places and each would require a dielectric
 fitting. The potentials on the cathodically protected structure are altered by the presence of the foreign structure because the current distribution has been disturbed. The loss of electrons yields a positively charged ion called a cation. 35 21 3 + =2 110 12 44 c. Resistance to current flow is lowest for: • Low-resistivity (high-conductivity) media •
Short length for current flow • Large area of current flow • Small cross-sectional area of current flow © NACE International, 2006 1/2008 Basic Electricity 1:5 Table 1.1 Typical Resistivity of Common Materials Material Resistivity (Ω-cm)
 Aluminum 2.69 \times 10-6 Carbon 3.50 \times 10-3 Copper 1.72 \times 10-6 Iron 9.80 \times 10-6 Iron 9.80 \times 10-6 Ice 5.75 \times 10-6 Ice 3.00 \times 10-6 Ice 5.75 \times 10-6
Ohm's Law can be expressed as follows: where E or V I R = VI R = 
the third. This AC voltage is connected between ground and the structure to be traced. 11/01/04 Resistance Opposition to current flow Unit of measure Ohm often seen as the Greek letter Omega (Ω) Symbol R (This symbol will be used in the Ohms Law Formula)
answer a few questions without looking back at the text. The lugs can then be bolted to the structure. Remember that even with the rectifier breaker. If there are breaks in the galvanizing, however, the underlying steel at such breaks may corrode rapidly, as it will be at a more active
                                                                                  . As the relative velocity increases, so does the current requirement due to decreasing polarization. 8 Experiment 6.1 — Demonstration of Cathodic Interference ......
such lines. The signal will travel only along electrically continuous paths. Likewise, if the "instant off" reading is at least 100mV more negative than the native reading, the criterion has been met. Calculated Total Resistance RT = R14 + R12 + R13 =
method can also be used to measure resistivity of a liquid. This is important as the design is based on the resistivity of the soil and there is a DC potential difference across the fitting, a scratching noise will be heard in the earphone when contact is made across a good
fitting. All you need is an internet browser. A Brief Overview of CP-Compass-Underground pipeline Galvanic anode CP system or verifying a CP design by a 3rd party contractor is as easy as 1-2-3: Enter the design parameters (items in the above screen shot). Check the securitying a CP design by a 3rd party contractor is as easy as 1-2-3: Enter the design parameters (items in the above screen shot).
of the weld by tapping with a hammer. Conclusion 1. Common symbols for resistance of a structure to the electrolyte, and the linear resistance of a long structure such as a pipe or cable. Such a short will usually cause a positive
shift in the pipe-to-soil potential in the area of the casing. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:35 Experiment 2.3 Current Direction No. 1 Reference electrode Position No. 2 Copper sheet Tap water in tray
Experiment for Measuring the Direction of Corrosion-Cell Currents in the Electrolyte PROCEDURE Place the zinc and copper at the sides of the tray. You need to know what criterion is to be used in your work and to understand that there are several criteria from which your design engineers have to choose. Figure 5.6 shows a photo of a data logger
                                                                                                                                                                                                      . To Unsubscribe, send a blank e-mail to: [email protected] 3. Unless test facilities are provided at the time of construction, it is unlikely that they could be installed economically should they
become necessary at a later date. Depolarization is a condition that counters the effects of polarization. After ore is mined, the metallic compound is removed from the rock-like ore and refined to produce a nearly pure state of the metal. Connect voltmeter positive lead to copper and connect negative lead to a copper-copper sulfate reference
Demonstration of Cathodic Interference 9 VDC + C Steel Sheet Foreign Steel Rod B D A E F Impressed Current Short Clamp-On Ammeter on Service Line Figure 9.2 Locating a Short Through Current Flow Tone Generator Audio tone pipe
locators are very useful for finding shorted isolating fittings or underground contacts. Testing is similar to that for casings. Platinized anodes are susceptible to premature failure by reactions with complexing ions, particularly in process applications. Step 7. Cathodic protection does not actually eliminate corrosion. Data sheets must be kept in such
different dimensions). Adjustment of pH The pH of water affects its ability to precipitate out a protective scale. The electric current produced by oxidation and reduction flows through the electronic path by means of electron movement. 29 DC Output...
however, by the fact that there will still be a potential difference between the pipe and the casing. Ionization in addition to ions that may be present in the electrolyte due to dissociation of ionized molecules. Pipe Casing The original intent of encased piping was for the casing to support
dynamic loads caused by road traffic or trains to prevent harm to the environment in which it is installed. Bituminous Enamels These coatings are formulated from coal tar pitch or natural asphalt and are reinforced
with glass and a felt wrapper to provide additional mechanical strength and impact resistance. It absorbs water, thus helping to keep the anode wet, permitting it to function properly. © NACE International, 2006 1/2008 Underground Corrosion Control 3:19 Figure 3.5 Cathodic Protection Rectifier Schematic There are three basic types of rectifiers:
1. Various types of shunts and their values are shown in Table 5.2. The shunt rating shown in the table is in amperes/millivolt. 55, pages 468-515 & 1263 May 1936 and IEEE Std 80. These ions are current-carrying charges. In soil environments, the shape and size of the anode depends more on resistivity of the soil, current requirement, and other
conditions than on the size of the structure. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:24 Table 2.2. Practical Galvanic Series Metal Volts vs Cu-CuSO4 Active or Anodic End Magnesium -1.60 to -0.50 Steel Cast/Ductile Carbon -0.20 to -0.50 Steel Cast/Ductile Carbon -0.20 to -0.50 Steel Cast/Ductile Cast/Du
Iron -0.50 Lead -0.50 Steel in Concrete -0.20 Copper -0.20 High Silicon Iron -0.20 Carbon, Graphite +0.30 Noble or Cathodic End When two different metals are connected, a voltage is generated between them. The latest data are then entered into the database. If AC voltage is present at the input terminals, an open circuit exists within the rectifier
RP0388 Impressed Current Cathodic Protection of Internal Submerged Surfaces of Steel Water Storage Tanks A negative (cathodic) potential of at least 850 mV with the cathodic protection applied. Part C 1. Care should be exercised in handling and installing. The CP technician must determine if he/she is qualified to work on electrical equipment in
                                                                                                                                                                                          Using arrows, show the application of Kirchhoff's Current Law. Various criteria are recommended by NACE International and other international standards organizations. 22 = 4 c. Figure 9.4 Resistance
conductor of unit length and unit cross-sectional area. Place the copper, steel, zinc, and magnesium into the tray, making sure they do not touch each other. This is discussed further in Chapter 4, Field Measurements. © NACE International, 2006 7/2006 Stray Current Interference 6:10 Results Experimental Step Cathodically Protected Structure
reading will be obtained. If you can't answer the questions, I would suggest that you read the material again before proceeding. Where explosion-proof installation is required, it is essential that all seals and other safety equipment be properly installed. © NACE International, 2006 7/2007 4:9 Safety • Avoid causing electric sparks especially in areas
 that may contain a hydrocarbon. Galvanic (Sacrificial) Anodes General Galvanic anodes operate because of the galvanic (dissimilar metal) reaction between the anode and the structure. ZINC Zinc anodes are also commercially available in two alloys, one for use in soils and the other for seawater applications. This causes a phenomenon called
polarization. Half Cycle Zero Current Figure 1.11 Typical Alternating Current for the current through a rectifier. This simply means that if one increases the other increases and if one decreases the other decreases the other decreases the other decreases.
and at the same proportions. © NACE International, 2006 7/2007 Basic Chemistry and Basic Corrosion Theory 2:23 Causes of Corrosion General Nearly all of the corrosion you will encounter can be divided into one of two types—either a natural reaction or a stray current reaction. Should there be an odd-sized joint within the span, or some
appurtenance such as a valve, the calculated resistance will not be correct. 23 Movement of Structure and Electrolyte...
Earlier instruments were constructed using an electromechanical movement with an analog display and are referred to as analog meters. It is available in the NACE store on the NACE website at . Small current output resulting in little or no stray current interference. Soil Texture Clay and Silt Tight soils may lead to gas blockage at the anodes
Corrosion rates tend to increase with temperature. The ohmmeter cannot distinguish between the resistance of the fitting and the resistance through the electrolyte. Following are some other very good training programs that teach cathodic protection technology: % Kilgore College (Kilgore, Texas) offers a 2-year Associates degree program in
corrosion technology with semester courses devoted to cathodic protection technology. This may not yield accurate data about the potentials under the tank bottom, particularly if the anodes are in a ring around the tank bottom, particularly if the anodes are in a ring around the tank. Students will receive a grade letter, by regular mail or through a company representative, in approximately 6 to 8 weeks after the
                                                                                                                                                                                                                                                                     ng 118.7 lbs./ft (176.65 kg/m) is 0.17 mV, then current flow is calculated as follows: © NACE International, 2006 1/2008 Field Measurements
        etion of the course. Also, the more active metal used to make an alloy may corrode leaving behind the more noble metal. A surface distributed groundbed is shown in Figure 8.22. (76.2 cm) pipe weigh
collecting data on a computer data logger, the data can be entered directly into a computer. Connect the metal being tested. 4. In a gas or liquid piping system, resistance can be compared to the orifice effect or the restriction to the flow provided by the inside diameter of the pipe. The backfill serves three purposes: •
reduces the anode-to-ground resistance. © NACE International, 2006 1/2008 Underground Corrosion Control 3:29 Potential (-mV) () (+) ON Potential ir "ON-IR" -850 mVCSE 100 mV Polarization OFF Potential Figure 3.10 Structure-to-electrolyte Potentials
APPLICATION OF THESE CRITERIA The first criterion, a potential of -850 mV obtained with current applied, is based on negligible IR drop or eliminating the IR drop or eliminating the way so the location of the data can be pinpointed. The scope, desired
learning outcomes and performance criteria were prepared by the Cathodic Protection Training and Certification Program Task Group under the auspices of the NACE Certification and Education Committees. Table 5.3 provides some resistance values for common pipe sizes. MSDS sheets must be available for review. Impressed Current Anodes +
Positive Header Cable Figure 8.21 Surface Remote Groundbed Configuration Distributed Anode Configuration is frequently used in complex areas to provide good current distributed configuration and to minimize effects on other structures. • by means of a steel rod or strap cast in the anode and then welded to the structure. This is
shown in Figure 2.10. This permits the current to be drained through the cable back to the source rather than leaving the structure through an earth path. • Consider the possible shock hazards from operating CP systems in water. This is caused by the fact that the current is returning to the negative cable through the electrolyte. Metal Ion
Concentration Cell The higher the concentration of metal ions that are the same as the adjacent metal, the more the noble the metal becomes. 28 Installation of Rectifiers or Other Power Sources ...
                                                                                                                                                                                                                                                                                                       • Record name and serial numbers of all instruments used. Other conditions such as restricted areas or hazardous
locations may have unusual test station requirements. Obviously, it isn't always possible to keep neat data sheets, particularly when working in inclement weather or in adverse or dirty conditions. © NACE International, 2006 7/2006 2 Introduction Quizzes and Examinations There will be quizzes distributed during the week and reviewed in class by
the instructors. Accidental Contacts Some of the locations where electrical isolation can be compromised are: • Crossing structures. This test was developed to help CP 1- Cathodic Protection Tester and CP 2-Cathodic Protection Tester and CP 2-Cat
tap water to the tray. Caution: Do not use larger than a 15-gram charge for carbon steel pressure pipe. Except for wire-type shunts, most shunts will have these values stamped on them. © NACE International, 2006 7/2007 Troubleshooting 9:5 The resistance test set-up is shown in Figure 9.4. Resistance calculations are given in Chapter 1.5 mA -0.31
V + + Same Meter -0.29 V 10 mV + + 10,000 O 1,000 O 100 O 10
various redox reactions associated with the metabolism of the bacteria. SUBMIT COMPLETED APPLICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATIONAL CERTIFICATION AND SIGNATURE PAGES TO: MAIL TO: NACE INTERNATION AND SIGNATURE PAGES TO: MAIL TO: MAIL
                                                                                                                                                                                                                                                                                                                                                        . 5 Facility Maps and Work
Certification department at 281-228-6211 or by e-mail at [email protected] AFFIRMATION I affirm that: 1. Stationary reference electrodes under the tank bottom yield the best data. 18 Impressed Current Groundbeds
                                                                                 This is especially important in the treatment of boiler water. Make-up of the Electrolyte The electrolyte itself can affect the performance of cathodic protection. 26 Accidental Contacts
                                                                                                                                                                                                                                                                                                                                                                                                          . These coatings are also resistant to
impact and abrasion damage. In well-aerated, well-drained soils, corrosion protection may be achieved at less negative potentials. Therefore, current shunts are usually installed in the permanent circuit of a galvanic anode system, although not in distributed anodes connected directly to the structure. This refers to whether there is an excess of
hydrogen (H+) or hydroxyl (OH-) ions present. Where it is picked up on the protected surface, a cathodic reaction occurs. Wiring to rectifiers must comply with local and national electrical codes and the requirements of the utility supplying power. 147 =
                                                                                                                                                                                                                                                                                                                                              4. On thermoelectric generators, a reverse current device should be installed to
prevent galvanic action between anode bed and structure if the flame is extinguished. The threshold of perception is generally agreed to be 1 mA. He found that, in a simple circuit like the one shown in Figure 1, when the voltage is held constant, the current and resistance will vary inversely. © NACE International, 2006 1/2008 Underground
Corrosion Control 3:32 Steel Reinforced Concrete SP0290 Cathodic Protection of Reinforcing Steel in Atmospherically Exposed Structures The standard specifies the 100 mV polarization criterion plus two other, more complex criteria. Step C—Polarized Potential Measurement 10 Ω Reference Electrodes Copper Sheet + V - - V + 1. The
math is impossible to solve without at least two values. Figure 9.5 Resistance Test Set-Up for an Isolating Joint © NACE International, 2006 7/2007 Troubleshooting 9:7 If test wires exist, an underground "insulation checker" may be used. In terms of both the costs of the anode and the power required, it is therefore not usually economical for
underground applications. I (re)affirm the NACE International Cathodic Protection Certification Program attestation and agree to abide by its provisions as long as I hold any level of recognition under the program. For additional information on the CP Tutorials, please email [email protected] If you have a technical question about CP, remember that
you can use the NACE Corrosion Network list serve to post technical questions. Conductor connections at bonds to other structures or across isolating joints should be mechanically secure, electrically conductive, and suitably coated. Length The course will begin on Sunday at 1:00 pm and concludes on Friday afternoon. For corrosion to occur as the
result of stray currents there must be an exchange of current between a metallic structure and an electrolytic environment. Amperes and millivolts or volts and milliamps cannot be mixed. Transmitter Receiver Pipe Figure 5.20 Inductive Pipe Locator Principle © NACE International, 2006 1/2008 Field Measurements 5:36 Use of Current Interrupters
It is often desirable to determine the effect of a current source at various remote locations. Note that the current is entering the meter on the positive terminal, hence the positive reading on the meter display. Where AC power is economically available, rectifiers have clear economic and operating advantages over other power sources. A properly
isolated casing is shown in Figure 8.9. Dynamic Load Insulating EndSeal Secured to Pipe and Casing Vent Pipe Casing Insulating Spacers Figure 8.9 Properly Isolated Casing Service conditions can vary greatly on different systems. 20 of 23 EXPERIMENT 6.1 21 of 23 CP 1-Cathodic Protection Tester Course Manual - Chapter 6 ©NACE International,
2004 April 2006 7 EXPERIMENT 6.1 9 VDC + C Steel Sheet B A Foreign Steel Rod D E F Impressed Current Anode V V 22 of 23 of 23 CP 1-Cathodic Protection Tester Course Manual - Chapter 6 © NACE International, 2004 April 2006 8 CHAPTER 7 Monitoring Cathodic Protection Effectiveness and Recordkeeping Introduction Field
measurements represent a very important part of monitoring any corrosion control system. Those responsible for updating facility maps will depend on your information to keep the maps current or to generate new maps. Construction Notes The structure and test lead wires should be clean, dry, and free of foreign materials at points of connection
when the connections are made. Where one must be buried, a test station should be installed with wires on either side of the joint. When a potential is measuring circuit, as shown in Figure 3.9. Resistances Measuring Lead (+) Contact Lead (+)/Ref. There are two sets of
windings on the core, the primary and the secondary. The law states that a voltage of 1 volt will create a current of 1 ampere in a circuit having a resistance of 1 Ohm. Positively charged ions (cations) move away from the anode and toward the cathode. Elements All matter is made up of chemical elements. The pin spacing is equal to the depth of
investigation of the average soil resistivity, as shown in Figure 5.14. With resistors still connected in series, connect the battery and the ammeter in series, connect the battery and the ammeter in series, connect the battery and the ammeter in series. If the fitting is good, and AC is present, a hum will be heard in the earphone. Electrically charged atoms are referred to as ions and the charge on an atom is known as its valence state. Increase
one, and the other goes up proportionally Voltage Current Resistance is constant Figure 3. The number of anode required, the the anode life, and system design life are automatically determined and verified. Electrical Terms Electrons Electrons are particles
that carry a negative charge. Clamp-on instruments are available to measure both AC and DC. When in doubt, install a test station. The reading can then be compared with that shown on the rectifier ammeter. Strip Chart Recorders Strip chart recorders contain a roll of chart paper. 15 Driving Force for Corrosion
                                                                        . If the structure is coated, the insulating material must be compatible with the coating on the structure. 28 Experiment 2.2-Corrosion-Cell..
                                                                                                                                                                                                                                                                                                                         . Spring loaded clamp-on ammeters are more commonly used for wires and cables.
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