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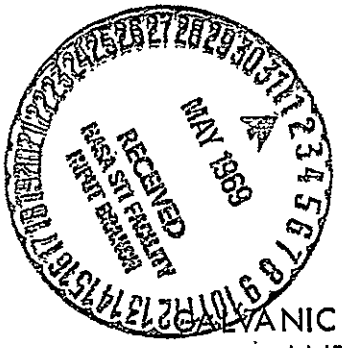

GALVANIC CORROSION AND CATHODIC PROTECTION

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PREFACE

This bibliography concerns itself primarily with galvanic corrosion and cathodic protection. Galvanic corrosion is corrosion associated with the current of a galvanic cell made up of dissimilar electrodes. It is also known as couple action.[1] Cathodic protection is the reduction or prevention of corrosion of a metal surface by making it cathodic by the use of sacrificial anodes or impressed currents.[2] Galvanic corrosion is one of the basic mechanisms of corrosion and excluding protective coatings, cathodic protection is one of the most important protection systems used in the fight against corrosion. One unique example of cathodic protection is the system used to protect the foundation pilings of the Vehicle Assembly Building.

Cape Kennedy has been described as "a corrosion engineer's paradise".[3] The Kennedy Space Center and Cape Kennedy area is subject to extreme conditions of wind, salt water, salt atmosphere, temperature variations, ultraviolet exposure, contaminated ground water and humidity all of which combine to make the ideal conditions for atmospheric and underground corrosion.[4] This atmosphere and the many materials used in the space program have made the problems of corrosion of vital interest.

The Kennedy Space Center alone has over fifteen (15) separate specifications dealing with corrosion. However, this problem is not limited to Kennedy Space Center. It has been authoritatively estimated that the United States pays an annual corrosion bill of roughly 12 billion dollars.[5] Of this enormous sum, the Department of Defense and NASA together spend about 6 billion dollars trying to prevent corrosion and repair of corrosion damage.[6]

1. Uhlig, H. H., The Corrosion Handbook. Wiley, 1948, p xxviii
2. Ibid, p xxvi
3. Pinney, S. G., "Corrosion Control at the Cape". Materials Protection, April 1967, p 38
4. Ibid
5. Schmidt, J. and R. G. Neswald, "Controlling Corrosion". Space/Aeronautics, Oct. 1968, p 64
6. Ibid

Arrangement

The Bibliography is arranged alphabetically by title and includes periodical articles and documents.

The following sources were consulted for the compilation of this bibliography.

Chemical Abstracts 1963-1968

Corrosion Abstracts 1963-1968

Engineering Index 1963-1968

Galvanic Corrosion - A Report Bibliography June 10, 1968 Defense Documentation Center

Lubrication Corrosion and Wear - A Continuing Bibliography 1962-1967 National Aeronautics and Space Administration Special Publication 7020, 7020 (01), 7020 (02)

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ADVANTAGES OF HIGH DENSITY POLYOLEFIN FOR CATHODIC PROTECTION CABLE INSULATION. L. A. Hugo, et. al. Materials Protection Feb. 1962 p 38-40, 42-44

"Experience and accelerated test data are given on insulating materials commonly used on cathodic protection cables. Reasons for failure of some types and some advantages of high molecular weight, high density ethylene copolymer materials as to weight and cost are given. Problems involved in stripping these copolymer materials are discussed and means of overcoming the problems are recommended." NACE

ADVANTAGES OF USING APC RECTIFIERS FOR CATHODIC PROTECTION. R. Ferry. Materials Protection Aug. 1968 p 26-29

"Unique environmental and economic factors in sea water cathodic protection favor the use of automatic potential control APC rectifiers. Two APC systems, saturable-reactor and silicon-controlled, are presented in this article. The saturable-reactor rectifier and the SCR rectifier are examined in detail with a comparison of their specific adaptabilities and applications. Recommendations for sea water automatic potential control are given including choice of rectifier-reference electrode and anode." NACE

ALLOYS FOR IMPRESSED CURRENT ZINC ANODES. R. C. Weast. International Lead Zinc Research Organization Digest Oct. 1963 p 62-63

"Identification of the full range of commercially available zinc alloys satisfactory for use as anodes for protecting both galvanized and porcelain enameled domestic hot water tanks. Evaluation of anode current efficiency, open circuit anode potential, polarized potential of zinc alloys when used as an anode and current flow between the anode and cathode when an external emf comparable to that supplied by a thermoelectric generator is in the circuit." RML

ALUMINIUM LIGHTHOUSE. Engineering, London Jan. 25, 1963 p 147

"Al panels supplied by Reynolds Metals Co. and porcelain-enamelled by H.H. Robertson Co. have been used on the exterior of the 50m high lighthouse at the mouth of the Chartleston harbour. Stainless steel bolts with melamine laminate washers were used to eliminate galvanic corrosion, and oversized bolt-heads to prevent wind-damage." AA

ANNUAL PROGRESS REPORT 1963. ('STATE OF THE ART' REPORT). Admiralty Committee for the Prevention of Corrosion and Fouling, London, England ACC/57/64; AD-444 049 Feb. 1964 13 p

A section on cathodic protection is included in this report. Board approval was given for fitting automatically controlled impressed current cathodic protection systems to all new construction ships, but not for fitting systems to existing ships.

ANNUAL PROGRESS REPORT 1965. Navy Department Committee for the Prevention of Corrosion and Fouling, London, England ACC/59/66; AD-488 752 Feb. 1966 36 p

Papers on protective coatings, cathodic protection, underwater paints, machinery corrosion, sea water systems, and organization for corrosion control are included in this annual report.

ANODE DESIGN FOR SHIPBOARD CATHODIC PROTECTION. R. L. Benedict. Materials Protection Dec. 1965 p 36-38

"Remote anode system can be installed on ship's hull if proper consideration is given to anode geometry and voltage and area of anode shield. Anode location should be in areas where mechanical abrasion of paint is least likely to occur. Data are presented to show both lead-platinum and platinized titanium anodes have been successfully used in cathodic protection of ships' hulls." NACE

ANODIC ANTICORROSION PROTECTION OF STEEL. M. Prazak. Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div. Transl. into English from Hutnicke Listy (Prague), v 11 no. 11 1956 p 644-648 FTD-TT-64-21/1+2; AD-435 641; N64-23315 1956 14 p refs

"The difference between cathodic and anodic methods of applying anticorrosion protection to steel materials is explained, on the basis of potential polarization curves of steel in sulfuric acid solutions." STAR

ASPECTS OF CORROSION OF METALS. E. C. Ellwood. Transactions of the Institute of English Shipping, Scotland 1964 p 87-113, discussion p 113-124

"The aspects of corrosion considered comprise effect of electrolytes, inhibitors, paint and metallic coatings, O, stray currents, and cathodic protection, and specific types of corrosion, with special reference to engineers' practice." AA

AUTOMATIC CATHODIC PROTECTION FOR WATER TANKS. V. D. J. Pollitt. American Water Works Association Journal Feb. 1966 p 234-8

"Automatic cathodic protection is a new tool available for control of corrosion. If an automatic system is properly designed and installed, and adequately serviced, it does not have many of the limitations of conventional cathodic protection systems; and it constitutes a major contribution to water utility industry. To appreciate the value of automatic control, one must have a knowledge of fundamentals of corrosion." Author

AUTOMATIC CONTROL OF POWER STATION CATHODIC PROTECTION SYSTEMS. W. Matthewman, J. Malster and A. D. Wallis. Corrosion Technology April 1963 p 92-94

"The use of impressed current cathodic protection on power station circulating water systems is increasing. This is probably due to the consistently better performance of installations generally and notably, of present-day anode materials. With the increase will arise new maintenance problems. In this article the authors describe experimental equipment developed for the automatic control of such cathodic protection system." Authors

AUTOMATIC POTENTIAL (VOLTAGE) REGULATOR TO PROTECT UNDERGROUND INSTALLATIONS AGAINST CORROSION. I. K. Parra and N. V. Petina. Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div. Transl. into English from Automatika, AKad. Nauk UKr. RSR (Kiev), no. 2, 1962 FTD-TT-62-1521/1+2 N64-23090 14 Feb. 1963 p 92-95 refs

"A static potential regulator is described that maintains the potential difference at the level required for cathodic protection of underground installations (such as pipelines) from corrosion. The circuit diagram is presented for an automatic cathodic protection station that is contactless, based on magnetic boosters and germanium diodes, and has no rotating parts." STAR

BULKHEAD STABILIZATION SURVEY, STUDY AND REPORT AT VARIOUS LOCATIONS. C. J. Foster. Consulting Engineers, New York AD-646 001 1 Dec. 1965 82 p

"Corrosion of steel in sea water occurs by electro-chemical reaction. Electricity is conducted by sea water (electrolyte) leaving the metal and entering the (solution) sea water causing a loss of metal where the current leaves the piling. Corrosion is accelerated when a film of salt water is deposited in the splash zone providing a good electrolyte with a plentiful supply of oxygen from the atmosphere in an alternately wet and dry environment." Author

CATHODIC CHARACTERISTICS OF MILD STEEL IN SUSPENSIONS OF SULPHATE-REDUCING BACTERIA. G. H. Booth and A. K. Tiller. Corrosion Science Aug. 1968 p 583-600 refs

Experiments with Desulfovidrio vulgaris have shown that the organisms can depolarize the cathodic areas of a mild-steel surface. An additional negative potential is required to confer cathodic protection on steel in the presence of the bacterial cells.

CATHODIC POLARIZATION OF SPENT ZINC-CONTAINING PAINTS IN SEA WATER. A. G. Khanlarova, et. al. Directorate of Scientific Information Services, Ottawa, Ontario T 424 R AD-626 432 May 1965 9 p

"The use of cathodic protection simultaneously with protective coatings of zinc paint for the preservation of steel structures, marine petroleum equipment, and ships makes possible a reduced expenditure of electric current and an increase in the period of effectiveness of the paint coatings." Author

CATHODIC PROTECTION COATINGS. P. Clark. Corrosion Technology Apr.1965 p 19-22

"Protective coating serves as insulation for cathodic protection system and appearance is generally unimportant; however, coating itself must be durable and corrosion resistant; petroleum, petroleum jelly, bitumen, coal tar and plastic bases; influence of coatings on current required for cathodic protection; selection of proper current density for given environment." El

CATHODIC PROTECTION FOR DISTRIBUTION SYSTEMS. E. Manners. Corrosion Prevention and Control Jan. 1962 p 29-33

"Equipment and procedure for protecting steel underground gas pipelines from galvanic, concentrated cell, bacterial and stray current corrosion. Effects of current density, soil resistivity and coating materials." RML

CATHODIC PROTECTION FOR MARINE CORROSION CONTROL. E. P. Anderson. Corrosion Prevention and Control Jul. 1963 p 27-29

"This article gives a description of the Capac system which has been developed for the cathodic protection of ship hulls, propellers, and rudders. The system includes a Pt-Pd anode and a Ag rod electrode." RML

CATHODIC PROTECTION FUNDAMENTALS. J. A. Lehmann. Revision of the paper "Fundamentals of Cathodic Protection" presented at North Central Region Conference NACE, Oct. 1-3, 1963, Kansas City, Mo. Materials Protection Feb. 1964 p 36-41

"The fundamentals of cathodic protection are discussed using a simple dry cell battery as illustration. The application of cathodic protection is explained and methods are suggested for maximum efficiency. Galvanic and impressed current systems are described. Emphasis is placed on cathodically protecting pipelines. Current variables for maximum protection are discussed." NACE

CATHODIC PROTECTION IN CONGESTED AREAS. L. H. West. Journal of the American Water Works Association June 1964 p 721-726

"Corrosion engineers are being called upon increasingly to protect buried structures in the congested urban areas near large cities and in the so-called "pipeline alleys" -- those areas in which several underground lines have been laid in close proximity to each other. Usually, it is also very important to have plenty of current reaching metal surfaces and to have safe pipe-to-soil voltages at these locations, because of greater-than-average hazards and costs of leakage. An important danger to be avoided is, of course, effects upon unprotected structures. The risk of such damage can be kept to a minimum by careful design. Another possibility, however, is to have all structures in an area electrically bonded and cathodically protected as one single unit." Author

CATHODIC PROTECTION IN MOLTEN FLUORIDE SALTS AT 1200 F. L. K. Matson, et. al. Corrosion July 1966 p 194-198

"Corrosion is a major problem in Fluoride Volatility Process for recovery of nuclear fuel... Experiments were carried out at Battelle on a laboratory scale to determine the feasibility of using cathodic protection to reduce attack in process vessels. Polarization curves were developed in simulated operating conditions for materials of interest, i. e., Inor-8, Zircaloy, and graphite, polarization characteristics were obtained by use of a poentiostat using platinum as reference electrode and graphite as an anode." NACE

CATHODIC PROTECTION IS NOT ALWAYS SUCCESSFUL ON FERROUS STRUCTURES. L. P. Sudrabin. Materials Protection Feb. 1966 p 49-50

"Examples of accelerated corrosion on carbon and stainless steel surfaces continuously or intermittently heated, intermittently wetted, and cathodically protected after alternate immersions in electrolyte and exposure to oxidizing agents." NACE

CATHODIC PROTECTION OF ALUMINUM. C. Groot. Materials Protection Nov. 1964 p 10-13

"Cathodic protection of aluminum, an amphoteric metal, is discussed in terms of potential-ph diagrams. Such protection is shown to be possible in acid solutions but cathodic corrosion is encountered in basic media. Cathodic corrosion and anodic protection have long been observed. Whether cathodic protection is possible in a given system must be determined by experiment." NACE

CATHODIC PROTECTION OF ALUMINUM IN ACID MEDIUM. K. G. Sheth and T. L. Rama Char. Australian Corrosion Engineering Jan. 1964 p 17-20

"The corrosion of Al and its alloys in hydrochloric acid solutions can be prevented by the impressed current cathodic protection method. The current required for complete protection will be less in the presence of suitable corrosion inhibitors in the acid." Authors

CATHODIC PROTECTION OF BUOYS AND OFFSHORE STRUCTURES. E. L. Littauer. Transactions of the Marine Technology Society Symposium, Washington, D.C. Mar. 1964 p 218-232

"Theory of corrosion of iron in sea water and in fresh water is discussed, principles of cathodic protection are given and use of method for protection ofbuoys and offshore structures is described. Highly successful zinc alloy galvanic anodes and lead platinum bielectrodes used in impressed current systems are considered. Experience has shown that cathodic protection is a highly successful and economical method of protecting steel structures in marine environments." LDA

CATHODIC PROTECTION OF CASING IS A GOOD INVESTMENT. W. C. Koger. World Oil Jan. 1963 p 71-74

"Study of casing cathodic protection as applied to wells in the Hugoton gas field of the mid-continent area revealed that: cathodic protection is economically attractive; casing failures are significantly reduced; application of cathodic protection on a "hot-spot" basis is effective and economical and; subsurface potential profile and surface E-log I methods of determining and evaluating current requirements are effective." INCO

CATHODIC PROTECTION OF HEAT EXCHANGERS USING ONCE THROUGH CIRCULATING WATER SYSTEMS. G. G. Page. Corrosion Prevention and Control Feb. 1964 p 19-26

"The theory of cathodic protection is described and applications of the process are discussed. Zinc galvanic anodes are considered and a reference is made to the use of lead-silver impressed current anodes. Attention is drawn to the dependence of the performance of galvanic anodes on their composition." ZDA

CATHODIC PROTECTION OF JETTIES. P. B. Cherry. Corrosion Prevention and Control Jul. 1965 p 26-28

"Article briefly discusses advantages of platinized Ti anodes for corrosion protection of jetties. Design, automatic control, and operation of these anodes are briefly described." INCO

CATHODIC PROTECTION OF KORT NOZZLES. N. S. Dempster. Materials Protection Feb. 1965 p 24-27

"Describes corrosion problem occurring on Kort nozzles of two tugs. Severe pitting occurred on shroud plate in line with propeller blade tips. Deterioration of welds occurred in just a few months, and perforation of the plate occurred in two years. Coatings were damaged by high water velocity through nozzle. Cathodic protection was installed to eliminate pitting attack, using high purity zinc anodes. System has prevented corrosion on shroud plate for six years service with annual replacement of anodes." NACE

CATHODIC PROTECTION OF MOORING BUOYS AND CHAIN. PART I. INITIAL FIELD TESTING. R. W. Drisko. Naval Civil Engineering Lab., Port Hueneme, Calif. Rept No. TN 728 AD-617 259 7 Jun. 1965 27 p

"A study was conducted into the feasibility of cathodically protecting a fleet mooring. The original cathodic protection system utilized sacrificial magnesium anodes with automatic control heads designed to maintain the desired potential level. This system did not operate satisfactorily. A modification using uncontrolled zinc anodes gave a higher level of protection to the buoy and riser chain but insufficient zinc was present on the ground legs to provide the necessary potential." Author

CATHODIC PROTECTION OF MOORING BUOYS AND CHAIN. PART III. FIELD STUDIES WITH CABLES PROVIDING ELECTRICAL CONTINUITY. R. W. Drisko. Naval Civil Engineering Lab., Port Hueneme, Calif. Technical Note N-914 AD-820 996L Aug. 1967 11 p refs U.S. Govt Only

"An investigation was continued into the cathodic protection of a fleet mooring with sacrificial anodes... The completed system provided full protection to the underwater portion of the buoy and to the entire ground tackle." TAB

CATHODIC PROTECTION OF OFFSHORE STRUCTURE. A. E. Hiller and D. A. Lipps. Materials Protection June 1965 p 36-39

"The article describes a graphite anode cathodic protection system installed on a large offshore structure used in mining of sulfur. Graphite anodes in groundbeds had impressed current from rectifiers. System proved inadequate because of damage from boat anchors, extensive fishing in the area, and hurricanes. Lead alloy anodes were substituted. These were suspended from the structure so they could be pulled up during bad weather." NACE

CATHODIC PROTECTION OF OFFSHORE STRUCTURES. J. A. Burgbacher. Materials Protection April 1968 p 26-29

"Information in this article is derived from a review of Shell Oil Co.'s cathodic protection of offshore structures in the Gulf of Mexico, offshore Louisiana. Aluminum galvanic anodes and impressed current systems, cathodic protection systems used, are described. Laboratory and field tests to measure output and determine effectiveness of aluminum anodes are presented. Costs of aluminum anodes and impressed current systems are compared for new and existing structures." NACE

CATHODIC PROTECTION OF OIL WELL CASINGS. B. W. Bradley and R. D. Bates. Materials Protection July 1966 p 33-35

"At Bisti Field in New Mexico, failures due to leaks in Shell Oil Company's oil well casings had become serious problem. External corrosion was theorized as a cause of failures and cathodic protection was installed to reduce problem. The article discusses why cathodic protection was chosen, the unique design of this particular system and the problems encountered in its operation." NACE

CATHODIC PROTECTION OF PROCESS EQUIPMENT. A. A. Brouwer. National Association of Corrosion Engineers Technical Committee Report. Publ. 59-9 1965 2 p

"Ten case histories describing application of cathodic protection to chemical processing equipment are reported." LDA

CATHODIC PROTECTION OF SCREENED STRUCTURES. M. Unz. Materials Protection Feb. 1965 p 34-50

"Reports on investigation of drainage field over screened steel surfaces which are defined as metallic structures, surrounded by conductive cage. Method of analysis is presented for determining system of protection. Examples given from pipeline practice are corroding steel pipeline, prestressed concrete pipe, and parallel underground lines. Questions of bonding are discussed and practical rules are given for approach to similar problems." NACE

CATHODIC PROTECTION OF SEWAGE TREATMENT PLANTS. F. O. Waters. Materials Protection Mar. 1964 p 26, 30-31, 33-34

"Describes the cathodic protection system on the moving rake arms of a sewage treatment plant which suffered severe corrosion only two years after the start of operation. Discusses operational experience with the cathodic protection system using rectifiers to impress a current on graphite anodes. Experience showed this system to be more economical than adequate coatings for the sedimentation tanks." NACE

CATHODIC PROTECTION OF SHIPS OPERATING IN ICE. R. P. Rennie and M. J. Turnbull. Materials Protection Apr. 1966 p 44-45

"Discusses method of preventing corrosion on ships which operate for long periods in water where extensive amounts of ice are present. Controlled and uncontrolled cathodic protection systems for ships' hulls operating in these conditions, as well as protective coatings for protection during ice-free seasons, are outlined." NACE

CATHODIC PROTECTION OF STEEL IN PRESTRESSED CONCRETE. B. Heuze. Materials Protection Nov. 1965 p 57-62

"Discusses procedure for applying cathodic protection to prestressed concrete structures. Outlines situations that cause corrosion of steel in concrete, and describes tests that can be used to determine extent of cathodic protection needed to protect existing corroding structures and projected structures. Shows in detail how cathodic protection can protect prestressed concrete structure." NACE

CATHODIC PROTECTION OF STEEL PIPE LINES. M. J. Kirlew. Australasian Corrosion Engineering May 1966 p 9-13

"Complete control of corrosion problem is only achieved by application of cathodic protection early in life of pipe line; economics are based on balance between coating efficiency, inspection, stray current problems, and expected life of pipeline; arresting of corrosion by cathodic protection is possible and can be economically sound even in old pipe lines." E.I.

CATHODIC PROTECTION OF TRAWLERS AGAINST CORROSION DAMAGE. M. G. Duff. Fishing News International Jan. - Mar. 1963 p 65-67

"Discusses the economic and technical aspects of cathodic protection. Zinc alloy galvanic anodes are considered." ZDA

CATHODIC PROTECTION OF WATER-LINE AREAS. Navy Department, London, England Committee on Prevention of Corrosion and Fouling; Hull and Structure Sub-Committee AD-478 955 1966 10 p

"The effect of cathodic protection on intermittently immersed water-line areas has been studied. Corrosion was greatly reduced in sea-water compared with that in NaCl solution and the degree of protection was greater at higher frequencies of immersion. The protective effect of cathodically deposited chalk is discussed." Author

CATHODIC PROTECTION PERFORMANCE OF LEAD-ALLOY ANODES AT ALTERNATE HIGH AND LOW VELOCITIES. I. Geld. Naval Applied Science Lab. NASL TMI AD-428 690 Feb. 4 1964 6 p

CATHODIC PROTECTION SAVES STATEN ISLAND'S FERRY TERMINAL. L. P. Sudrabin and H. Emsig. Materials Protection Feb. 1965 p 53-55

"Discusses method of cathodically protecting H and sheet piling at Staten Island Ferry Terminal in New York Harbor. Installation and connection of rectifiers to 71 one-percent, silver-lead alloy anodes are considered. Effects of system after nine months operation are discussed." NACE

CATHODIC PROTECTION - SOMETHING OLD - SOMETHING NEW. G.G. Page. Corrosion Technology Apr. 1962 p 89-93, 112

"The development of cathodic protection methods is described. Applications of cathodic protection for the prevention of corrosion on structures subjected to marine, soil, and chemical atmospheres. Facts necessary for the assessment of a corrosion problem and the possible application are outlined. Future trends in cathodic protection are discussed." PMR

CATHODIC PROTECTION - THE ANSWER TO CORROSION PREVENTION OF UNDERGROUND STRUCTURES. L. H. West. Materials Protection July 1968 p 33-34

"Cathodic Protection is sometimes thought to be a cure-all for corrosion of underground structures. It should, however, be considered only as one portion of corrosion control program. The purpose of this brief paper is to present a guide for comprehensive engineering of a corrosion program. Included is discussion on failure repair, replacement, coating and cathodic protection, heavier wall thickness, changes in construction practices, etc. Two major classifications, which require somewhat different considerations, are (1) new construction and (2) existing structures." NACE

CHEMICAL AND GALVANIC CORROSION PROPERTIES OF HIGH-PURITY VANADIUM. C. B. Kenahan, D. Schlain and W. L. Acherman. Bureau of Mines, Washington, D. C. BM-RI-5990 N62-13665 1962 26 p refs

"Vanadium is protected by contact with magnesium, aluminum, and steel SAE 4130 in substitute ocean water, by magnesium and aluminum in 3-percent NaCl solution, and by magnesium in tapwater. Vanadium protects copper in substitute ocean water. When vanadium and stainless steel are coupled in sulfuric acid solutions, both metals are usually unaffected by contact, whereas the corrosion rate of titanium in sulfuric acid is greatly reduced by contact with vanadium." Authors

CHEMICAL CORROSION PROCESSES. L. F. Epstein. General Electric Co., Valecitos Atomic Lab. In NASA, Lewis Research Center Proceedings of the NASA-AEC liquid-Metals Corrosion Meeting, Vol. I N64-20786 1964 p 27-34

"This is a discussion of the role in corrosion processes of impurities in alkali metal systems. The assumption is made that whenever a trace amount of impurity has a very strong effect on corrosion, a chemical process is responsible for the behavior of the system. It can reasonably be predicted that corrosion will be chemically controlled in these systems, and that the effect of oxygen as an impurity will be important in determining the behavior of the system." STAR

A COMPARATIVE REVIEW OF ELECTROCHEMICAL METHODS OF ASSESSING CORROSION AND BEHAVIOUR IN PRACTICE OF CORROSION AND PROTECTION. M. Pourbaix. Corrosion Science Oct. 1965 p 677-700

"After a reminder behaviours of metals and alloys which are susceptible to corrosion in aqueous media are related to measured electrode-potential, an exposition is given of special position occupied by methods for study and control of corrosion based on measurement and interpretation of these potentials. Various fields of application of these methods are reviewed and scientific data and instances of industrial application are given for each of the following: cathodic protection, corrosion-resistant alloys, corrosion inhibitors, water treatment, anodic protection, miscellaneous procedures." AA

COMPATIBILITY OF PAINTS WITH CATHODIC PROTECTION. A. F. Routley, Paint Technology Apr. 1967 p 28-31

"The factors affecting successful use of fully integrated cathodic protection/paint systems, such as those employed by the Navy, are surveyed and procedures for assessment of suitability of paint systems are discussed. Impressed current cathodic protection systems utilizing lead alloy anodes and galvanic zinc anode systems are considered. Paint testing techniques are described and interpretation of test results is dealt with." LA

COMPUTER MONITORING OF CATHODIC PROTECTION RECTIFIER DATA. PART 1. G. S. Jones, Jr. Pipe Line Industry Mar. 1967 p 37-42. PART 2. Ibid. Apr. 1967 p 75-77

"Texas Eastern Transmission Corp. developed a computer program to compile data on 650 rectifiers protecting over 10,000 mi of pipeline. Part 1 discusses setting up of computer program, input data (basic rectifier information, bimonthly rectifier inspection data, and bimonthly power consumption and cost data), and output reports... Part 2 summarizes programs results, costs, savings, and benefits. Since 1963 the systems effectiveness increased from 52 to 59 percent. Total current output increased 40 percent while in same period, power cost increased only 18 percent." GA

CONCLUDING EXPERIMENTS ON THE CATHODIC PROTECTION OF CAST IRON PROPELLERS. H. H. Collins. B.C.I.R.A. (British Cast Iron Research Association) Journal Sept. 1963 p 623-634.

"Protracted trials with the tailshaft Mg anode show that, in suitable cases, cathodic protection can completely prevent the pitting of cast iron propellers. The current density necessary for complete protection appears to vary with the severity of the pitting attack. Ships which are not subject to very severe attack may only require about 30 mA/ft^2, while ships subject to very severe attack may require as much as 80 mA/ft^2." BTR

CONSIDERATIONS IN DESIGN. PART 6. C. Lipson. Machine Design Jan. 2, 1964 p 121-124

"Discussion of stress-corrosion cracking and high-temperature corrosion as influenced by factors, such as metal composition, structure, time, environment and stress. Methods of galvanic-corrosion control." RML

CONTROLLING CORROSION. J. Schmidt and R. G. Neswald. Space/Aeronautics Oct. 1968 p 64-73

"Both industry and government are learning, from stop-gap fixes and loss-of-use, that attention to aerospace corrosion had best begin at the beginning - before the design freezes, before weight-happy analysts move in... Probably the most pervasive type of concentration cell in aerospace vehicles today, and the hardest to completely eliminate, is the oxygen-differential cell... It is suggested that dissimilar metals be joined with caution, nonconductive separators be used and galvanic cells be sealed from the environment." Authors

CONTROLLED RECTIFIER SUPPLIES CORROSION PROTECTION. R. F. Stengel. Design News Oct. 2, 1963 p 42, 45

"In this device an insulated Zn measuring electrode attached below water level reports actual potential difference between hull and water to a control unit. The unit compares it with a preset potential level adequate to provide corrosion protection. A difference signal is used to adjust a magnetic amplifier. Transformed and rectified amplifier output is conducted through insulated protective hull anodes and returns to ship through surrounding water. Electrolytic action causes salts dissolved in sea water to deposit preferentially at pores and defects in hull paint coatings. Effect protects hull base metal and reduces paint requirements." INCO

CORROSION. T. P. Hoar. International Science and Technology Dec. 1963 p 78-85

"To prevent electrochemical corrosion reactions (theory of such reactions is discussed) from occurring, several steps can be taken: corrosion-resistant alloys can be chosen; less resistant metals may be isolated from the environment by inert coatings; potential driving the process can be lowered (cathodic protection); or the surface potential can be held at a level where metal is essentially passive (anodic protection). The article reviews significant developments taking place in all of these areas and discusses new sensitive electronic instrumentation (potentiostat) which is yielding insights to the more intractable problems such as very slow corrosion and stress-corrosion cracking." INCO

CORROSION. H. Leidheiser. Chemical and Engineering News A65-22208 Apr. 5, 1965 p 78-92

The research on and problems associated with corrosion are discussed. Corrosion problems reviewed include stress-corrosion cracking, cavitation damage, hydrogen embrittlement, the low-temperature oxidation of intermetallic compounds, and corrosion caused by bacteria.

CORROSION AND CATHODIC PROTECTION OF UNDERWATER SURVEILLANCE SYSTEMS - A GENERAL REVIEW OF THE PROBLEM. B. F. Brown, et. al. Naval Research Lab., Washington, D. C. NRL MR 1436 AD-635 765 June 1963 10 p

"A general review of the problem of corrosion of metallic assemblies for underwater surveillance is given, based on two years observing deep sea corrosion and on extensive technical discussions with personnel in contractors' plants and in Naval activities having cognizance over surveillance systems. Recommendations to minimize corrosion failures in such systems are given." Author

CORROSION AND ITS PREVENTION. Mining Journal March 30, 1962 p 313-315

"Methods of preventing corrosion in mining equipment, underground and immersed structures and fabricated parts. Use of paints, plastic coatings, non-ferrous metal coatings and cathodic protection." RML

CORROSION AS A PROBLEM TO THE AIR FORCE. R.C. Drebelbis. Rand Corp., Santa Monica, Calif. P-3080 AD-611 877 N65-22212 March 12, 1965 7 p

"The following recommendations are made to the Air Force to insure an effective corrosion control program. (1) recognition of corrosion as a major problem at top side in DOD and USAF, (2) trained engineers to insure compliance with existing design, procurement, production, modification and maintenance directives at all levels, (3) eliminate the small economies in procurement and production that later develop into costly maintenance and modification requirements, (4) provide for and enforce proper cleaning and protection of weapon systems and ground support equipment in the field." TAB

THE CORROSION BEHAVIOR OF STAINLESS STEELS IN SEA WATER. M. H. Peterson and T. J. Lennox, Jr. Naval Research Lab., Washington, D. C. NRL MR 1795, AD-657 938 June 1967 27 p

"The corrosion behavior of several series of stainless steels is discussed. Photographs of typical attack in both experimental panels and operational equipment are shown. Because of the susceptibility of stainless steel to pitting, its use in sea water should be avoided in new designs. The 300 series, however, may be used if provided with cathodic protection. The 400 series stainless steels are unsuitable for use in sea water even if provided with cathodic protection." Authors

CORROSION CONSIDERATIONS PERTINENT TO THE USE OF ELECTROMAGNETIC SHIELDING GASKETS. R. A. Rothenberg. Frequency Technology Dec. 1968 p 32-37

This report discusses the corrosion problems associated with electromagnetic shielding gaskets, and effective methods of corrosion prevention. The section on galvanic corrosion discusses the conditions necessary for its occurrence. A galvanic table which shows permissible couples of some of the common metallurgical categories is included.

CORROSION CONTROL. Department of the Air Force. AFM 88-9, chapter 4 EM 1110-1-184 1 Aug. 1962 564 p refs

"This manual contains information and instructions for determining the need for corrosion mitigation of buried and submerged metal structures, for the application of corrosion-prevention methods, including the selection of materials, and for the care and adjustment of cathodic protection systems for optimum performance." Author

CORROSION CONTROL AT THE CAPE: ENVIRONMENT AT CAPE KENNEDY IDEAL FOR CORROSION. S. G. Pinney. Materials Protection Apr. 1967 p 38-39

"This article discusses some of the Cape's corrosion problems and methods used to correct them. It deals primarily with above ground structures. Solutions presented for various design errors and application problems can apply to any part of the country and might be included in any maintenance coating specification." Author

CORROSION CONTROL METHODS. Pipeline Engineer March 1968 p 128-132, 135-137

Corrosion engineers use five classes of tools to control underground external corrosion: (1) coatings, (2) galvanic anodes, (3) rectifier-ground bed installations (4) insulators and (5) bonds. Each of these methods is discussed and evaluated, and cost comparisons are given. General procedure for locating and protecting hot spots is described.

CORROSION EVALUATION OF HIGH-SILICON ALUMINUM ALLOYS. H. C. Bowen. Battelle-Northwest, Richland, Washington BNWL-125 N66-12932 Sept. 1965 23 p

"A battery of tests was performed on four high-silicon aluminum alloys containing nickel and/or magnesium. The tests included high and low flow isothermal and nonisothermal 140°C water tests, galvanic couples, stress corrosion cracking tests, and tests in 400°C steam and 360°C water. The HDA-1 and -4 were decidedly superior to the other two alloys in the nonisothermal high flow, 360°C water, and 400°C steam tests which are considered the tests of most significance. The HDA-4 had better resistance in high temperature water and is considered the most promising alloy." Author

CORROSION FATIGUE AND STRESS CORROSION CRACKING OF AN ALUMINUM-5% MAGNESIUM-4% ZINC ALLOY TOTALLY IMMERSED IN 3% NaCl AND OTHER CORRODENTS. P. J. E. Forsyth and E. G. F. Sampson. Royal Aircraft Establishment, Farnborough (England) AD-478 909 Aug. 1965 44 p

"The effects of both anodic and cathodic polarization have been studied. Marked changes in crack growth rate were observed when a fatigue specimen was alternately made anodic and cathodic in a 3% NaCl solution against either a platinum or aluminum electrode with an externally impressed current." Authors

CORROSION IN THE ELECTRICAL POWER INDUSTRY. L. L. Goodman. Corrosion Prevention and Control Jan. 1962 p i-iii

"Effects of soil conditions, gas, current and weathering on corrosion of electrical transformers, power station foundations, cables, lines, conduits and pylons. Preventive measures include cathodic protection, enclosure of motors, varnish and coating procedures. Criteria for selection of construction materials." RML

CORROSION IN THE NUCLEAR POWER INDUSTRY. Corrosion Technology March 1962 p 68-70

"A review is given on the corrosion of reactor alloys, covering corrosion and hydrogen absorption of Zircaloy subjected to steam at high temperatures and pressures; corrosion of Inconel and Nb alloys in pressurized water reactors; oxidation of Be in CO_2 at high temperatures; galvanic corrosion of fuel cans during underwater storage; and high temperature oxidation and ignition of Mg can alloys." NSA

CORROSION OF LEAD WHEN EXPOSED TO FLUCTUATING CURRENT. J. Der. Australasian Corrosion Engineering Nov. 1965 p 9-15

"In metropolitan-and to certain extent in rural areas-large proportion of cable sheath corrosion is due to electrolysis. Faults are due to stray current action (anodic and cathodic), concentration cells, and other causes. There can be a combination of two or more types of attack and the resultant attack will change in time as well as in position." Author

CORROSION OF SILVER-PLATED COPPER WIRE. W. T. McFarlen. Wire and Wire Products Dec. 1965 p 1922

"Describes results of an investigation carried out to determine causative factors and mechanisms involved in corrosion of silver-plated copper wire. Effects of coupling Ag to Cu and role of O on couple was discussed. Results of laboratory tests on corrosion products and studies of silver-copper galvanic cell are summarized. Current manufacturing techniques used to eliminate this corrosion problem are given." BTR

CORROSION OF TUBE AND PIPE ALLOYS DUE TO POLLUTED SEA WATER RESULTS OF SHIP TRIAL USING ORGANIC INHIBITOR. Navy Dept., London (England) Committee for the Prevention of Corrosion and Fouling, Machinery Sub-Committee CDL Report GYZ AD-472 834 1965 9 p

"Laboratory investigations showed that the type of attack experienced on aluminum brass heat exchanger tubes and copper-nickel-iron sea water pipes in polluted sea water was due to the formation of a complex cuprous sulphide film. This surface film was electrically conducting and acted as the site for the cathodic reaction,, the anodic sites where the corrosion occurred being breaks or defects in the sulphide film. In the presence of sodium dimethyl dithiocarbamate (S.D.D.) these copper alloys formed chelate films which are non-conducting and consequently cannot provide a cathodic reaction site." Author

CORROSION OF UNDERGROUND TELEPHONE CABLES. Corrosion Prevention and Control March 1963 p 23-25, 31

"A lead alloy containing 0.05-0.15% Sb proved to be the most satisfactory. Types of corrosion, conditions favoring it, and instruments measuring the changes in logitudinal current are discussed. Cathodic protection installed in one area of application brought about considerable savings." LDA

CORROSION PREVENTION OF THE BOSTON CALLAHAN TUNNEL. L. P. Sudrabin. Materials Protection Nov. 1967 p 16-18

"This paper concerns the development of corrosion prevention methods for the Lt. William F. Callahan, Jr. Tunnel between Boston and East Boston, Mass. The tunnel contained several unusual structural features which proved challenging from a corrosion standpoint. An impressed current cathodic protection system which was applied to protect the steel components of the tunnel is explained." NACE

CORROSION PROBLEMS ASSOCIATED WITH THE USE OF TITANIUM FASTENERS TO CONNECT ALUMINUM COMPONENTS. E. E. Nelson and J. G. Williamson. National Aeronautics and Space Administration. Marshall Space Flight Center, Huntsville, Ala. NASA TM X-51167 MTP-P&VE-M-63-13 N64-11381 30 Sept. 1963 17 p

"Corrosion studies have indicated that Ti-6A l-4V alloy fasteners can be used to connect aluminum components without significant corrosion on the aluminum component in normal atmospheric environment. However, exacting installation procedures must be followed for adequate control of galvanic corrosion." Authors

CORROSION PROBLEMS IN LAKE MARACAIBO. F.G. Baptista and H.F. Finley. Corrosion Prevention and Control Sept. 1963 p 31-37

"A description and discussion of the corrosion control program of the Creole Patroleum Corp. Lake Maracaibo, (Venezuela). Ordinary paints and galvanizing provide adequate protection to steel equipment situated in the area above the highest splash and spray zone. The company's floating craft are cathodically protected with Zn anodes used in place of Mg anodes which were abandoned after the salinity of the lake had increased." ZDA

CORROSION PROTECTION OF MAGNESIUM AND MAGNESIUM ALLOYS. E.L. White and F. W. Fink. Defense Metals Information Center, Columbus, Ohio DMIC Memorandum 205 AD-469 906 June 1965 36 p

"This memorandum describes many of the coating systems and design methods which are used to reduce corrosive attack on both galvanically coupled and uncoupled magnesium assemblies." TAB

CORROSION PROTECTION OF UNDERWATER BODY OF WAGB'S. E. L. Parker. Coast Guard, Washington, D.C. Testing and Development Div. AD-469 686 Aug. 1965 58 p United States Government Only

"This report summarizes the results of various test programs of corrosion protection used on the icebreaker hulls (WAGB). It discusses the present corrosion rates encountered with no corrosion protection and presents possible approaches to corrosion protection of the class ship." Author

CORROSION RESISTANCE AND DURABILITY OF FASTENERS IN AIRCRAFT STRUCTURES. J. Viglione and I.S. Shaffer. Naval Air Engineering Center, Philadelphia, Pa. Aeronautical Materials Laboratory NAEC-AML-2529 AD-651 189 26 Jan. 1967 39 p refs

Galvanic corrosion between steel fasteners and aluminum structures in aircraft has been a problem of long standing. This document is a report on research on whether the rounding of countersunk holes and/or fastener heads would improve the corrosion behavior at the fastener locations or affect the fatigue strength of 7075-T6 aluminum alloy joints assembled with cadmium plated steel countersunk head screws.

CORROSION RESISTANCE OF LEAD ALLOY ANODES IN SEA-WATER AT HIGH TEMPERATURES. E. Sato, M. Kashiwabara and S. Yoshida. Anti-Corrosion Methods and Materials Apr. 1966 p 27-30

"Corrosion characteristics of lead alloy anodes for cathodic protection in sea-water, at high or normal temperatures, were not available in detailed reports. Sea-water intake at normal temperature, and gas condenser fitted with lead alloy anodes in high-temperature sea-water, were tested to examine corrosive nature of alloys." Authors

CORROSION RESISTANCE OF STRANDED STEEL WIRE IN SEA WATER. J. H. Rigo. Materials Protection Apr. 1966 p 54-58

"Discusses testing program in which stranded steel wire specimens were immersed in shallow sea water atmosphere to test corrosive results these conditions imposed on various zones of specimens. Results of a 29-month test indicate there are different and distinctive corrosion rates in various zones of full immersion, splash, low tide, high tide, mud, and atmosphere. Cathodic protection, preferred and alternate finishes are discussed as protective measures for specimens." NACE

CORROSION TECHNOLOGY CHART GUIDE (6). CATHODIC PROTECTION AND INHIBITION. Corrosion Technology Dec. 1965 p 28-29

"Essential data are presented for design of groundbeds, anode spacing and connection in parallel, and choice of materials for sacrificial or impressed current anodes. The relevant characteristics of zinc and magnesium sacrificial anodes and lead alloy or lead/platinum impressed current anodes are included. The comparative current densities required for various protective coatings and for protection of bare steel in various environments are given in two tables. Reactions involved in protection by anodic and cathodic inhibitors are explained in a diagram and compounds used in practice are listed in a comprehensive table showing materials protected and appropriate corrosive environments." LDA

CORROSION THEORY AND CHEMICAL PLANT PROTECTION. H. A. Holden. Chemical and Process Engineering Nov. 1962 p 574-577

"Author discusses importance of some current concepts relating to fundamental corrosion mechanisms, particularly the latest theories on atmospheric corrosion of steel and importance of 'ammonium corrosive potential'. Recent developments in cathodic protection of chemical plant are discussed, including use of platinized Ti anodes and introduction of Cathostat (which introduces automatic control of quanity of electricity supplied to structure based on its potential). A section is devoted to new protective coatings, particularly Ni coatings." INCO

CRITERIA FOR CATHODIC PROTECTION, HIGHLY RESISTANT COPPER DETERIORATES IN SEVERELY CORROSIVE SOILS. W. J. Schwerdtfeger. Materials Protection Sept. 1968 p 43-44

"Tests were conducted by National Bureau of Standards to establish amount of cathodic protection necessary for copper in severely corrosive soil. It is generally assumed that copper has a higher resistance to corrosion in soils than do other commonly used metals, but author has found other interesting data. He discusses experimental methods plus results of those tests which concern copper corrosion." NACE

CURRENT DENSITY REQUIRED FOR CATHODIC PROTECTION. Central Dockyard Lab., Portsmouth, England AD-478 951 1965 21 p

"Laboratory investigations have been made of the dependence of current demand on cathodic potential, waterspeed and temperature for steel and copper cathodes." Author

CURRENT DENSITY REQUIRED FOR CATHODIC PROTECTION. L. J. E. Sawyer, et. al. Journal of Applied Chemistry Apr. 1965 p 182-190

"Laboratory investigations of dependence of current demand on cathodic potential, water speed and temperature for steel and copper cathodes." Author

CURRENT DISTRIBUTION IN CATHODIC PROTECTION SYSTEMS. C. L. Wilson. Anti-Corrosion Methods and Materials. July 1967 p 12-14

"Design of typical cathodic protection installation can generally only be achieved within an accuracy of about 20 percent, due to an apparent lack of knowledge of performances of electrolytic cells in general. The distribution pattern of currents for pipes with single anode units and pipes with coaxially placed single anodes is discussed." GA

DESIGN FOR "ANTI-CORROSION". Mechanical World and Engineering Record Dec. 1963 p 541-542

"Considerations in the prevention of corrosion by material selection and product design. Techniques for avoiding galvanic corrosion, recirculated water, at discontinuities, and in tanks with porous insulation and trapped water pockets. Local corrosive effects from settling of contamination products." RML

DESIGNING AUTOMATIC CONTROLS FOR CATHODIC PROTECTION. L. P. Sudrabin. Materials Protection Feb. 1963 p 64-67

"Describes the application of automatic potential control of components of various systems such as traveling screens, intake and discharge cooling water flumes and steel piling where varying tides and salinity cause a change in corrosivity. Also discusses use of highly sensitive systems that operate on a d-c signal of less than one microampere to measure the structure potential in high resistivity electrolytes to avoid polarization of reference electrodes. The achievement using unusual coatings and cathodic protection by applying sufficient current to protect, but avoiding excess current which accelerates damage to the coating system, is also covered." NACE

DEVELOPMENT OF CATHODIC ELECTROCATALYSTS FOR USE IN LOW TEMPERATURE H_2/O_2 FUEL CELLS WITH AN ALKALINE ELECTROLYTE. Third Quarterly Report Jan. 1 - Mar. 31, 1966. J. Giner, A. C. Makrides and R. J. Jasinski. Tyco Labs., Inc., Waltham, Mass. NASA-CR-75199 N66-26759 1966 102 p

"A variety of metals, alloys, intermetallics, refractory metal compounds, and dispersed metals, alloys, and carbides were tested for corrosion resistance and activity as oxygen electrodes in potassium hydroxide at 75°C as part of an effort to improve the over-all efficiency of hydrogen-oxygen fuel cells." STAR

DEVELOPMENT OF DIELECTRIC SHIELDS FOR CATHODIC PROTECTION APPLICATIONS. I. Geld and M. A. Acampora. Naval Applied Science Laboratory, Brooklyn,N. Y. TM 18 AD-800 112L 22 July 1966 18 p Department of Defense Only

"The present study deals with performance of another series of shields subjected to high sea water velocity and an applied potential of 20 volts." Authors

THE DEVELOPMENT OF ZINC ALLOY ANODES FOR CATHODIC PROTECTION OF MARINE STRUCTURES. P. J. Knuckey and N. S. Dempster. Australasian Corrosion Engineering Oct. 1963 p 15-22

"Brief treatment of the theory of cathodic protection, discusses the advantages of the zinc anode galvanic system and traces the development of effective zinc anode. An outline is given of the work proceeding at Defense Standards Laboratories, Maribyrnong, on the assessment of zinc alloy anodes for the Department of the Navy. The mechanism of alloying elements in off-setting the influence of iron is also under concurrent investigation." Authors

DIELECTRIC SHIELDS FOR CATHODIC PROTECTION APPLICATIONS: PROGRESS REPORT. I. Geld and M. A. Acampora. Naval Applied Science Lab., Brooklyn, N.Y. AD-830 119 8 Apr. 1968 38 p refs DOD only

"Major objective of this investigation was to develop dielectric shield systems resistant to high water velocity, elevated potentials, and high current densities. Studies were conducted at sea water velocities of 23 miles an hour at potentials of 10 and 20 volts, applied." Authors

DIRECT EVIDENCE FOR THE CATHODIC DEPOLARIZATION THEORY OF BACTERIAL CORROSION. W. P. Iverson. Science 25 Feb. 1966 A66-22303 p 986-988 refs

"Cathodic depolarization of mild steel by Desulfovibrio desulfuricans was demonstrated with benzyl viologen used as an electron acceptor. Direct measurement of the cathodic depolarization current indicated a maximum current density of $1_{u}a/cm^{2}$. Aluminum alloys were also cathodically depolarized by the organism." Author

DISSIMILAR METALS. H. Bronson. Product Engineering June 16, 1963 p 104

"The mechanism of corrosion in steel by considering the position of the dissimilar metal in galvanic series, presence of the electrolyte and generation of the electric current due to the electrolyte. Methods of preventing corrosion between dissimilar metals." RML

DOES CATHODIC PROTECTION CAUSE INTERNAL CORROSION? M. A. Riordan. Pipe Line Industry March 1967 p 49-50

"Extensive field experience by users of cathodic protection and technical analysis show internal corrosion does not occur as a result of externally applied cathodic protection current. If internal corrosion could occur it would be much more likely with salt water than with normal oil, production or gas stream, and resistance comparisons with salt water show internal corrosion is extremely unlikely." GA

ELECTROCHEMICAL ASPECTS OF HOT SOLID SALT STRESS CORROSION CRACKING OF TITANIUM BASE ALLOY. ELEVATED TEMPERATURE STRESS CORROSION OF HIGH STRENGTH SHEET MATERIALS IN THE PRESENCE OF STRESS CONCENTRATIONS. Materials Research Lab., Inc., Richton Park, Ill. N66-16195 Nov. 1965 p 20-35

"It is shown that the corrosion of titanium in the presence of hot solid salt occurs due to an oxygen differential cell. Cracking always occurs at the cathode of this cell and the cracking can be prevented by impressing an anodic current on the stressed specimens." Author

ECONOMIC ASPECTS OF CATHODIC PROTECTION. G. L. Daly. Materials Protection March 1966 p 55-58

"Discusses effects of early application of cathodic protection, justification for coating pipeline, uses of various systems, maintenance program for a pipeline, and costs and savings involved. Example is given of actual costs and savings of a specific installation." NACE

ECONOMICS OF SHIPS CATHODIC PROTECTION. J. H. Morgan. Corrosion Technology Nov. 1964 p 53-55

Corrosion protection of ship hulls by sacrificial anodes, impressed current, cathodic protection, and painting is discussed, methods and equipment are reported.

EFFECT OF CONTINUED CATHODIC PROTECTION ON CURRENT REQUIREMENTS. M. E. Parker. Materials Protection July 1964 p 32-33

"Case history data of conductance measurements made on three sections of high-pressure gas transmission lines. One section was coated with polyethylene tape, others with coal tar enamel. It was determined the effective conductance coating on pipeline is influenced by coating deterioration and polarization. When coating is stable, such as polyethylene and is not mechanically damaged, trend in conductance under continuous cathodic protection may be downward." RML

EFFECTS OF ZIRCONIUM ON THE CORROSION RESISTANCE OF STEEL. V. S. Kovalenko and E. L. Zats. Metal Science and Heat Treatment Mar. - Apr. 1964 A65-23440 p 223, 224

"It was found that: (1) the corrosion resistance of carbon steel in water is increased by the addition of 0.10 to 0.16% Zr, (2) the increase of the corrosion resistance of steel containing Zr is due to the decrease of the activity of the anodic process resulting from the increase of the thermodynamic stability of the anodic phase or its passivation, and (3) the effect of Zr on the cathodic process manifests itself in the formation of a large number of microcathodes which do not affect the corrosion rate." IAA

ELECTROCHEMICAL BEHAVIOR OF EXPERIMENTAL SUBMARINE-HULL STEELS IN SYNTHETIC SEA WATER. E. Williams. United States Steel, Monroeville, Pa., Applied Research Lab. U.S.S./ARL Project # 40.001-008 (1) Sept. 30, 1964 13 p

"As part of the Applied Research Laboratory's submarine-hull-steel development program, corrosion studies were conducted to determine the electrochemical properties of weldments of two 5Ni-Cr-Mo-V steels and HY-80 submarine-hull steel in synthetic sea water." Author

ELECTROCHEMICAL PROCESSES OF OXYGEN AND HYDROGEN PEROXIDE IN METAL CORROSION AND PROTECTION. G. Bianchi, et. al. Milan Univ. (Italy) Lab. of Electrochemistry and Metallurgy AFOSR 66213 AD-645 807 11 Oct. 1966 15 p

"The possibility of carrying out the galvanic anodic protection of stainless steel in aerated acid solutions is brought into evidence. This protection can be obtained by coupling stainless steel with a cathode metal (such as platinum) showing a low overvoltage in the oxygen cathodic reduction process." Author

ELECTRONIC EQUIPMENT, NAVAL SHIP AND SHORE: GENERAL SPECIFICATION. MIL-E-16400F(NAVY) 24 Feb. 1966 68 p

Pages 23-28 contain information on the use of dissimilar metals in contact with each other. A reprint of a table on sea water corrosion of galvanic couples from Corrosion Handbook by H.H. Uhlig, Wiley, 1948 is included.

ELIMINATING CATHODIC PROTECTION INTERFERENCE. PART 2. SOLUTIONS. M. D. Orton. Gas Age Jan. 1968 p 28-31, 45-46

"Interference current density pickup (ma/sq ft) provides some measure of the cathodic protection in a limited area, but tends to cause corrosion in some not-so-obvious areas. It is measured through pipe-to-soil (P/S) potential calculation and use of a nomograph relating potential change, soil resistivity, corrosion rate and current density. Anodic interference problems can be solved by use of resistance bonds to provide a path through which the interference current can be drained back to its source." GA

ENGINEERING AND ECONOMIC PROBLEMS INVOLVED IN CATHODIC PROTECTION OF LACLEDE GAS SYSTEM. J. C. Vogt. Materials Protection Feb. 1962 p 34-37

"Rapid increase of company sales, miles of main, and growing leak frequency forced a decision to protect cathodically all new mains and distribution systems. Tests on galvanic-anodes were made in 1948 and a high pressure transmission line was protected later. Added cost of complete cathodic protection is estimated to be 10% and to be fully justified already, less than nine years after start of protection program." NACE

EVALUATION PROCEDURE FOR MARINE UNDERWATER PAINT SYSTEMS. W. A. Anderton and J. R. Brown. Pacific Naval Lab., Esquimalt (British Columbia). Reprint 66-7 AD-642 449 4 Dec. 1965 11 p

"An evaluation procedure is described for the prediction of the performance of paint systems applied to ships' bottoms. Results are obtained with the steel panels cathodically protected and also when unprotected." Authors

EXPERIMENTAL USE OF PLATINISED TITANIUM FOR GROUNDBEDS. J. R. Walters. Corrosion Prevention and Control Oct. 1964 p 18-21

"Ground-beds installed for cathodic protection of telecommunication cables are, in general, required to handle currents of up to about 10A and there is therefore no necessity to provide expensive low-resistance earth electrode systems. Resistance to earth of an earth system buried in soil of uniform resistivity depends on physical dimensions and depth at which electrode is buried, and is also directly proportional to soil resistivity. A resistance to earth in ohms of about one-thousandth of mean soil resistivity in ohm/cm is acceptable for currents of less than 10A." Author

EXPLORATION OF NEW METHODS FOR PREVENTING GALVANIC CORROSION BETWEEN MAGNESIUM AND STEEL. D. K. Steeling. Aberdeen Proving Ground, Maryland. Coating and Chemical Lab. CCL Report 136 N63-12373 8 Jan. 1963 13 p refs

An investigation was made of new methods for treating magnesium-steel couples after the two metals had been assembled and placed in electrical contact with each other. A phosphate anodizing treatment proved to be ineffective when applied to such couples. This treatment offered considerable corrosion resistance to magnesium alone when the operating conditions of the treatment were closely controlled.

FAILURE, THEN SUCCESS ON DEEP WELL ANODE GROUNDBED. J. F. Tatum. Materials Protection July 1965 p 80-84

"When available materials are used in conjunction with experience and technical advice to design groundbed for 20 year life and when this installation fails with only six years service, questions arise as to cause of failure. Corrective changes must be made in groundbed design. Article describes such installation plus factors leading to decision for replacement. Complete details are given on replacement installation. Replacement groundbed was built in original hole with high silicon iron anodes, backfilled, and vented. Groundbed had initial circuit resistance of 0.388 ohm (anode-to-earth resistance 0.30 ohm). At end of 6-month period, circuit resistance is 0.458 ohm." NACE

FIFTEEN YEARS OF CATHODIC PROTECTION ON MARINE PIPELINES. A. C. Toncre. Materials Protection Oct. 1965 p 63-65

"Describes several cathodic protection systems used on 50 kilometers of submerged pipelines in offshore area of Venezuela. Problems involved are discussed. Data are presented to show effect of continual cathodic protection on apparent coating conductance and current requirements for 15-year period." NACE

FOUNDATION PILING CORROSION: MECHANISMS AND CATHODIC PROTECTION. L. P. Sudrabin. Materials Protection Oct. 1963 p 54-56, 58, 61-64

"Describes techniques for obtaining an approximation of corrosion rates occurring on existing steel piling. Also presents design criteria for cathodic protection of foundation piles. Discusses case histories to show survey and design of corrosion control for four foundation piling installations." NACE

THE FUTURE OF CATHODIC PROTECTION. Corrosion Engineer June 1962 p i-iii; Supplement to Corrosion Prevention June 1962

"Reviews and discusses the present position and the future of cathodic protection. Zinc anodes are considered. It is concluded that there is a good future for cathodic protection but the technique needs more publicity and elimination of the less efficient anti-corrosion methods by scientific studies." ZDA

GALVANIC ANODES--INFLUENCE OF ANODE MATERIAL ON SYSTEM DESIGN. P. V. Palmer. Corrosion Technology Sept. 1962 p 227-230

"The best results from cathodic protection can only be obtained if systems are designed to exploit the properties of the materials and equipment used. A common error is the assumption that the principles of design are comparable for Mg and for low potential anodes of Zn and Al. The important differences are herein examined and design principles discussed." CA

GALVANIC CORROSION BEHAVIOR OF WEAR-RESISTANT MATERIALS FOR MECHANICAL SHAFT SEALS. D. C. Vreeland. Marine Engineering Lab., Annapolis, Md. MEL-242/66 N66-37392 AD-635 592 July 1966 15 p

"Galvanic corrosion effects between various candidate mating materials and Monel have been investigated by the exposure of couples in seawater. The 14 materials exposed included seven cobalt-chromium alloys, six sintered carbide materials, and one copper-lead-tin alloy. The results indicate that galvanic coupling to Monel had no adverse effect on the corrosion behavior of five of the cobalt-chromium alloys, and one of the sintered carbide materials." TAB

GALVANIC CORROSION MUST BE AVOIDED. SURVEY OF ELECTRICAL GROUNDING PROBLEMS. W. K. Abbott and C. M. Schillmoller. Materials Protection Dec. 1962 p 48-60

"Discusses hazards associated with present practice of selecting galvanically incompatible materials in electrical grounding systems. Examples are given of detrimental effects of metallic copper electrodes when connected to steel piping, lead cable sheaths and other underground structures in grounding of power stations, industrial plants and residential electrical installations. Three possible methods are suggested for controlling corrosion on grounding systems: isolation, cathodic protection or elimination of highly cathodic grounding materials." NACE

GALVANIC CORROSION OF ALUMINUM ASSEMBLIES BY STAINLESS STEEL WIRE INSERTS. T. S. Humphries and E. E. Nelson. National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Ala. NASA-TM-X-53404 N66-19762 2 March 1966 20 p

This report presents data on the galvanic corrosion of bare and plated stainless steel inserts in aluminum assemblies. The silver plated stainless steel inserts that were tested caused severe galvanic corrosion of the aluminum assemblies and, therefore, are not recommended for use with aluminum.

GALVANIC CORROSION REDUCED IN ALUMINUM FABRICATIONS. National Aeronautics and Space Administration, Marshall Space Flight Center, Huntsville, Ala. B65-10140 May 1965 1 p

Titanium alloy fasteners dipped in zinc chromate primer were installed while wet in protective coated aluminum panels to reduce galvanic corrosion. Moisture tight seals at fastener points were also provided.

GALVANIC PROTECTION BY METAL SPRAY METHOD. TECHNICAL REPORT. J. Knanishu. Rock Island Arsenal Lab., Rock Island, Illinois RIA-63-1419 N63-18283 1 May 1963 47 p

"The metal flame-spray method of application was used to develop techniques whereby bimetal junctions may be treated with an optimum coating to combat galvanic corrosion. Steel, Al, and Mg, stainless steel and Cu 'buttons' were used in making up the corrosion couples. A successful procedure to produce reliable adhesion was developed. Where good adhesion procedures were maintained, excellent galvanic corrosion resistance resulted. Pure tin metal-sprayed coatings as a guard against galvanic corrosion. Corresponding test panels were exposed in the 5% salt-spray (fog) cabinet and outdoors. There was a correlation between the results obtained in the salt-spray (fog) test and the outdoor test." STAR

GALVANIC SERIES OF METALS AS RELATED TO CORROSION. E. C. Tinsley. Rock Island Arsenal Lab., Ill. RIA-66-469 N66-29157 AD-631 962 Feb. 1966 22 p refs

"A revised electromotive series has been prepared for use by design engineers. Tables were prepared from experimental data and from available literature references. This work provides information as to the location of various alloys previously not included in the electromotive series. The use of the improved table will be of value to the designer for his selection of compatible materials, and enable him to hold the possibilities of galvanic corrosion to a minimum." Author

"GUARDALOY" ALUMINUM SYSTEMS. F. A. Hughes & Co., Ltd. Surrey, England Corrosion Prevention and Control June 1965 p 21

"Cathodic protection anodes, and their use for external (ships) hulls and for internal protection, is described, with photographs and diagrams. Alloy specification is carefully controlled, and method of grain refining greatly enhances performance. Compared to earlier alloys, current capacity and output potential are improved, and there is economy in operation." AA

HEAVY DUTY COATINGS ON SHIPS' BOTTOMS. T. A. Banfield. Corrosion Prevention and Control July 1965 p 23-25

"Everyone will be aware of present high level of ship prices, even if they are not directly concerned with the shipping industry. It is clearly necessary to preserve such costly capital investments by most efficient methods available... Techniques, such as cathodic protection and dehumidification, find marine applications, and provide useful protection against corrosion of steel hulls in vicinity of bronze propellers and internal corrosion of cargo tanks." Author

HOW ANODIC PROTECTION HALTS CORROSION. H. A. Webster. Canadian Chemical Processing March 1963 p 48-50, 55, 56

"A description of various techniques including cathodic and anodic protection, passivation and immunization of carbon steel, 316 and 304 stainless steel is given." RML

HOW TO MINIMIZE GALVANIC CORROSION. CF Littlefield and E. C. Groshart. Machine Design 9 May 1963 p 243-244

"A selection chart for determining the galvanic compatibility of various metals and their alloys in moist and salt-laden atmospheres. Methods for minimizing galvanic corrosion are based on a selection of metals according to potential differences, atmospheric control and protective coatings." RML

HOW TO PREVENT RUSTING. British Iron and Steel Research Association 1963 35 p

"This booklet replaces an earlier publication, THE PREVENTION OF CORROSION, which first appeared in 1954. During the intervening eight years considerable progress has been made in corrosion prevention. The most notable developments include the introduction of plastic-coated steel sheet, the recognition of the importance of blast-cleaning when preparing steelwork for painting, improvements in the application of metal coatings by spraying, hot-dipping and electrodeposition and a marked increase in the practical uses of cathodic protection." RPI

HULL PROTECTION BY IMPRESSED CURRENT. Marine Engineering/Log Aug. 1964 p 58-59

"Installation of automatic, impressed-current cathodic protection system (Capac) on fleet of 15 tankers of Keystone Shipping Co. has met with success in arresting corrosion on immersed areas of hulls, propellers and rudders during the past 5 years. Engelhard technical engineers, called in to answer corrosion problem, recommended Capac system. Pt is used as anode material. Cast polyester plastic, reinforced with glass fiber, serves as supporting structure for Pt portion of anode. Insulating dielectric shields of an epoxy material called Capastic, are troweled onto sandblasted hull, surrounding each anode to provide broad current distribution Ag-AgCl halfcell provides means of evaluating required protection. Reference electrode is a cylindrically shaped glass-reinforced polyester structure enclosing a fine Ag rod and screen." INCO

HYDROGEN EMBRITTLEMENT RESULTING FROM CORROSION, CATHODIC PROTECTION AND ELECTROPLATING: SECOND QUARTERLY REPORT. E. Gileadi and M. Fullenwider. Pennsylvania University, Philadelphia, Electrochemistry Lab. AD-476 904 Dec. 1965 20 p

"The work of this quarter has been directed entirely toward the development of the Barnacle Electrode, a portable, non-destructive device for the 'in-situ' determination of hydrogen concentration in steel structures." Authors

HYDROGEN EMBRITTLEMENT RESULTING FROM CORROSION, CATHODIC PROTECTION, AND ELECTROPLATING: THIRD QUARTERLY REPORT. L. Nanis and J. McBreen. Pennsylvania University, Philadelphia, Electrochemistry Lab. N64-33713 AD-446 525 1 Aug. 1964 15 p refs

"The permeation rate of hydrogen through iron membranes was studied as a function of potential in various electrolytes. Graphs of permeation rate are presented for different solutions and as a function of potential, of solute concentration, of the square root of cathodic current, and of temperature." STAR

HYDROGEN EMBRITTLEMENT RESULTING FROM CORROSION, CATHODIC PROTECTION, AND ELECTROPLATING. Final Report 14 May 1965 to 13 May 1966. E. Gileadi. Pennsylvania University, Philadelphia. Electrochemistry Lab. EL FR May 1965 - May 1966, AD-641 089 Sept. 1966 32 p

"A technique was developed and the apparatus built for a fast, nondestructive method for the determination of hydrogen content of a large specimen. Also, a study of the basic factors which determine the solubility and the rate of diffusion of hydrogen in metals was undertaken." TAB

IMPRESSED CURRENT CATHODIC PROTECTION. B. M. Taylor and W. M. Strasburg. Naval Ship Systems Command Technical News Vol. 16 1967 p 18-19

"Although initial cost of an installed impressed current system is higher than an installed galvanic anode system, it is more flexible, has a longer service life, and can significantly reduce hull maintenance. Flexibility of impressed current system is demonstrated by its adaptability to environmental changes such as salinity, temperature, dissolved gases, paint integrity and ship's speed. The cost of such a system can be amortized over a ten year period compared with a galvanic system which requires periodic anode replacement at two to four year drydocking intervals." IMS

IMPRESSED CURRENT CATHODIC PROTECTION SYSTEM ABOARD USS WILKINSON (DL-5). I. Geld and M. A. Acampora. Naval Applied Science Lab., Brooklyn N. Y. AD-800 112L July 1966 9 p

"Initial observations were made of a cathodic protection system recently installed on the USS WILKINSON (DL-5). An important objective of the system is to protect an unpainted HY-80 sonar dome from corrosion. Data are presented on the systems operation and efficiency, and measures are recommended for improvement of this and future installations." TAB

IMPRESSED CURRENTS TO CURB CORROSION. E. L. Littauer. Chemical Engineering Sept. 1964 p 156, 158, 160, 162, 164

"Control of corrosion by means of impressed electric currents, either anodic or cathodic, can yield appreciable savings in the chemical industry. These savings come about through use of low-cost construction materials that would be rapidly attacked in absence of protection. Discussion covers theoretical presentation of corrosion process, thermodynamic stability, cathodic protection, anodic protection, application of cathodic current protection and some successful applications reported in other papers." INCO

INFLUENCE OF ANODES ON SOLUTION pH IN SALT CROCK TESTS. R. C. Weast and D. C. Melrose. Materials Protection March 1965 p 82

"Shows that one type of anode can alter pH of electrolyte in salt process as cathodic protection proceeds in lab tests. Suggests that anode be used which does not lower pH of electrolyte during test. Shows that graphite anodes are attacked by oxygen products at anode, resulting in some carbon dioxide being dissolved in electrolyte." NACE

INTERNAL CATHODIC PROTECTION. C. Plumpton and C. Wilson. Corrosion Prevention and Control Jan. 1959 p 31-6; March 1959 p 49-54; May 1959 p 53-8; Oct. 1959 p 49-52 Dec. 1959 p 34-40

This series of articles begins with a general discussion of cathodic protection principles. Other articles discuss specific structural applications and the uses of live anodes.

INSIDE AND OUT. Flight International 12 Aug. 1965 A65-31372 p 255-258

"Joints are particularly liable to corrosion; there are three basic methods to improve resistance to corrosion - cathodic protection, waterproofing of the joint by application of a sealant, and the painting of all surfaces before assembly." IAA

INSTALLATION OF MODERN DEEP WELL GROUND BEDS. T. R. Statham. Materials Protection Sept. 1966 p 21-22

"Installation of a deep well anode ground bed for sacrificial cathodic protection of underground metallic structures is discussed in detail in this article. Method includes logging of a 300-ft hole for soil resistivities, installing anode clusters at each of lowest resistance strata, and pumping coke breeze backfill slurry into a hole." NACE

INTERNATIONAL CONGRESS ON METALLIC CORROSION. London 10-15 April 1961 Butterworths 1962 refs (Ref/TA462/I61)

Section VII. Cathodic and electrolytic protection. p 363-402 contains 6 articles which represent the best technical knowlege in this field in 1961.

INVESTIGATING THE OHMIC RESISTANCE OF ETHINOL COATINGS/ISSLEDOVANIYE OMICHESKOGO SOPROTIVLENIYA ETINOLEVOGO. L.A. Suprun and V.P. Bardina Department of the Navy, Washington, D.C. Translation into English from Trudy TsNI IMF Issue 57 1964 p 37-42 Translation 2061 AD-627 822 1964 9 p

"The relation of the amount of ohmic resistance to the area of a painted surface is determined from numerous measurements. The data obtained are necessary for calculations and full scale tests of the electrochemical shields on the underwater portions of the hulls of ocean-going ships." TAB

AN INVESTIGATION OF COATING USED AS ANODE SCREENS IN CATHODIC PROTECTION. V.P. Bardina et. al. Department of the Navy, Washington, D. C. Translation 2062 N66-23186 AD-628 196 1964 13 p

"This article cites the results of laboratory tests involving a series of non-metallic coverings in still and moving sea water during the simultaneous activity of an electric current at various voltages. On the basis of these experiments epoxy and ethynolene coatings are recommended for experimental use on vessels as anode screens in cathodic protection." Author

INVESTIGATION OF STRESS CORROSION CRACKING OF HIGH STRENGTH STEELS. INFORMAL MONTHLY REPORTS. S. Brelant. Aerojet-General Corp., Azusa, Calif. Structural Materials Div. N64-22532 AD-600 899 3 June 1964 5 p

"These tests show that by application of the proper amount of cathodic current, stress corrosion cracking of maraging steel may be stopped. However, if the current is increased over this critical amount, no protection is furnished." Author

INVESTIGATION OF THE EFFECTIVENESS OF SOLDER-WIPING OF MONEL WATER BOXES. J. A. Bauman. Navy Marine Engineering Lab., Annapolis, Md. Mel 90/66 AD-637 518 Aug. 1966 17 p

"Tests of four model condensers were conducted with natural sea-water circulation for a period of 26 months. In addition, corrosion data were obtained in relatively short duration tests of galvanic couples. The tests have demonstrated the continued need for solder-wiping, as well as for provision of zinc anodes, to achieve maximum protection against galvanic attack of tubes and tube sheets." Author

INVESTIGATION OF THE MECHANISM OF STRESS CORROSION OF ALUMINUM ALLOYS. G. C. English and W. King. Aluminum Co. of America, New Kensington, PA. Quarterly Report No. 2 AD-602 120 1964 45p.

"The work consisted of cathodic protection studies, anodic polarization measurements, and an evaluation of the stress corrosion performance of the various samples of 2024 and 7075 alloy plate that were prepared to reflect a range of susceptibility to stress corrosion. A metallographic examination of these samples with the electron microscope using the thin foil transmission technique and with the light microscope is described and finally, the measurement of magnetic susceptibility and electrical conductivity is discussed." GRR

INVESTIGATION OF THE MECHANISM OF STRESS CORROSION OF ALUMINUM ALLOYS. THIRD QUARTER REPORT. June 1, 1964 to Nov,. 30, 1964 G.C. English and J. McHardy. Aluminum Co. of America, New Kensington, Pa. AD-608 842 30 Nov. 1964 50 p

"This report summarizes work on the development of a suitable experimental technique for the precise measurement of the potentials required for cathodic protection as a means of establishing the potential of phases in an alloy; and to measurement of these potentials in 7075 alloy in tempers susceptible to stress corrosion."

INVESTIGATION OF MECHANISM OF STRESS CORROSION OF ALUMINUM ALLOYS. G. C. English. Aluminum Co. of America, New Kensington, Pa. Alco Research Labs. Final Report for Dec. 1963 - Feb. 1965 N65-35437 AD-615 789 Feb. 1965 103 p

"The cathodic protection of 7075 alloy in corrosive, acid chloride solution was investigated. Considerable evidence indicates potential reflected metallurgical structure rather than extraneous conditions such as alkalinity produced by cathodic reactions." Author

INVESTIGATION OF THE MECHANISM OF STRESS CORROSION OF ALUMINUM ALLOYS. J. McHardy. Alcoa Research Labs. Aluminum Co. of America, New Kensington, Pa. N66-33644 AD-633 767 16 Feb. 1966 137 p

This document reports on basic investigation of the mechanism of stress-corrosion cracking in aluminum alloys of the 7075 series. The main experimental technique uses cathodic protection to control the corrosion of specimens in an aggressive electrolyte capable of producing stress corrosion failure rapidly.

LAB AND FIELD EVALUATION OF PIPELINE COATINGS IN TERMS OF CATHODIC PROTECTION CURRENT REQUIRED. J. N. Hunter, Jr. Materials Protection Feb. 1964 p 50-53, 56, 58-59

"Describes a coating evaluation program conducted by a pipeline company and discusses results regarding physical properties of coatings and their behavior under cathodic protection. Defines an economical corrosion control system as that in which applied cost of coating plus subsequent cost of cathodic protection is a minimum. Therefore, pipeline coating evaluation is made in terms of current required for cathodic protection. Company's experience with laboratory tests is described, showing that data from two tests would give necessary information: the blunt rod indentation and salt crock tests. Compares laboratory and field data, showing some surprising results." NACE

LABORATORY INVESTIGATION OF THE EFFECTS OF CATHODIC PROTECTION ON THE CORROSION OF THE GALVANIZED COATING ON GALVANIZED STEEL. T. E. Backstrom. Bureau of Reclamation AD-428 513 1 July 1963 7 p

"An investigation was made to determine the possible benefit of cathodic protection to the service life of galvanized iron or steel... Controlled laboratory tests showed that: (1) cathodic protection reduces general corrosion of the galvanized coating significantly; (2) cathodic protection does not eliminate corrosion of the galvanized coating entirely, as local pitting corrosion occurs to some extent; and (3) the equilibrium concentration of alkali at the cathode is too low to promote alkali corrosion of the cathodically protected coating." GRR

LANTZ TELLS NEW YORK SOCIETY ABOUT USE OF ZINC DUST AS PAINT PIGMENT. American Paint Journal 16 Sept. 1963 p 42-43, 46

"The talk reported was given by W. J. Lantz at the September meeting of the New York Society for Paint Technology. Both zinc-rich and zinc dust/extender pigment paints were discussed. The importance of the correct pigment volume concentration for optimum performance of the paints was stressed. The expected service life of zinc-rich coatings ranges from 10-25 yr. The mechanism of the protection afforded by the zinc-rich paints appears to involve galvanic action, chemical action and barrier action. In a highly loaded zinc dust paint film, the initial action is by galvanic processes." ZDA

LEAD ALLOY ANODES FOR CATHODIC PROTECTION IN VARIOUS ELECTROLYTES. S. Tudor and A. Ticker. Revision of a paper titled, "Electrochemical Behavior of Lead Alloy Anodes in Various Electrolytes" presented at 18th Annual Conference, NACE, March 17-22, 1962, Kansas City, Mo. Materials Protection Jan. 1964. p 52-59

"The article contains data describing use of lead-silver anodes in cathodic protection systems operating in sea, fresh, and brackish waters. Lead samples were operated in various electrolytes to determine deterioration rates. Variables investigated include current density, specific resistance of the electrolytes, alloy composition, mechanical damage to protective coatings, and galvanic couples with other materials." INCO

LEAD AND LEAD ALLOYS-CORROSION RESISTANCE. PART 2. J. F. Holmes. Corrosion Technology Feb. 1963 p 45-47

"The application of Pb and Pb-alloys in cable sheathings and for cathodic protection of rods and tubes is explained. A determination of the grain structure of Pb coatings and the effect of alternate current on their corrosion resistance and inertness is given. Chemical engineering applications are discussed." RMI

LEAD/PLATINUM ANODES FOR MARINE APPLICATIONS. D. B. Peplow and L. L. Shreir. Corrosion Technology April 1964 p 16-18

"Tests have been carried out on lead/platinum bi-electrodes in sea-water at 50 A/ft^2 for one year to determine the effect of lead alloy composition on the growth of the lead peroxide. The results indicate that small additions of tellurium or bismuth to a 1% A9/Pb alloy are effective in reducing the formation of lead peroxide. Lead/platinum bielectrodes of suitable lead-alloy composition are considered to provide an inexpensive anode material for power-impressed cathodic protection systems for marine applications." CT

LEAD-PLATINUM BIELECTRODES FOR CATHODIC PROTECTION: ADVANTAGES IN MARINE APPLICATIONS. L. L. Shreir. Platinum Metals Review April 1968 p 42-45

"The insertion of small pieces of platinum into the surface of lead or lead alloy anodes causes a remarkable change in their behavior as electrodes. Such lead-platinum bielectrodes are inexpensive, robust and easily fabricated and can be used successfully for the cathodic protection of marine structures. In this article the author describes the principles involved and reviews ten years of experience in a variety of applications." PMR

LIFE OF AN ICE BREAKER: HER EXTERNAL CORROSION PROBLEMS IN THE ICY NORTHUMBERLAND STRAIT. R. P. Rennie and M. J. Turnbull. Materials Protection April 1964 p 50-52, 54, 57

"Case history of hull corrosion of an ice breaking vessel operating in Canada's Northumberland Strait, and methods of coating and cathodic protection undertaken from the time the ship was launched in 1946 to present date were given . The special problems of providing protection of an ice breaking vessel that open sea-going ships never encounter were explained." NACE

MAGNESIUM FOR ANODES. Corrosion Prevention and Control April 1965 p 15

"Lloyd's Register of Shipping has included recently, among amendments and additions to register's rules for construction and classification of steel ships, prohibition of magnesium anodes in all tanks except those used solely for water ballast. This follows on United States coastguard's recommendation that they should be removed from their ships. Magnesium anodes are perhaps most popular for anodic protection, but following investigations showed strong probability number of explosions in oil tankers have resulted from sparks caused by portions of wasted magnesium anodes breaking off and striking metal in their fall, anodes have been removed from many British tankers and replaced by zinc or aluminum. There has been controversy in this matter and perhaps all are not entirely in agreement yet with proposition magnesium constitutes source of explosive sparks. Nevertheless, safety of shipping is paramount and magnesium anodes are condemned, unless or until it can be shown conclusively another agency initiated explosions that have occurred." CPC

THE MANY FACES OF CORROSION. L. H. Seabright and R. J. Fabian. Materials in Design Engineering A63 12006 Jan. 1963 p 85-91

This article contains a survey of the 13 basic types of corrosion in metals. The galvanic series of metals, anodic and cathodic, is reviewed and the principles of galvanic corrosion are outlined. A review of current theories on the corrosion of metal is given, with reference to the electrochemical and the galvanic series.

MAPEL SYSTEM OF CORROSION PREVENTION AND CONTROL. Corrosion Prevention and Control Jan. 1966 p 12-13

"Over the last few years cathodic protection has been increasingly used for protection against corrosion of sea-water cooled power stations. Financially, projects of this type have been one of major growth factors of cathodic protection companies. Cost of fabricating components of corrosion resistant materials or coating with plastic is often expensive and not always satisfactory, but cathodic protection offers a completely satisfactory alternative. Cathodic protection is complementary to coatings and will assist in reducing coating deterioration over its normal period of wear and tear." Author

MARINE CORROSION STUDIES: DEEP OCEAN TECHNOLOGY, STRESS CORROSION CRACKING, CATHODIC PROTECTION. Second Interim Progress Report. B. F. Brown, et. al. Naval Research Lab., Washington, D. C. NRL-1574 N65-27111 Nov. 1964 p 51 ref

Studies on the effect of cathodic protection on crevice and pitting corrosion of stainless steel; current distribution along a wire rope cathode; cathodic protection of wire rope; pressure on a steel cathode in a sodium chloride solution; and an aluminum anode cathodic protection for a Coast Guard vessel are discussed in this report.

MARINE CORROSION STUDIES: THE ELECTROCHEMICAL CHARACTERISTICS OF SEVERAL PROPRIETARY ALUMINUM GALVANIC ANODE MATERIALS IN SEA WATER. T. J. Lennox, Jr., et. al. Naval Research Lab., Washington, D. C. R NRL MR 1792 N67-38172 AD-656 899 May 1967 37 p

"The series of experiments covered in this report was designed to obtain the electrochemical efficiency, electrochemical potential, and current output versus time data for five proprietary aluminum alloys using full-size anodes in sea water under conditions which approach those encountered in service." Author

MARINE CORROSION STUDIES: STRESS-CORROSION CRACKING, DEEP OCEAN TECHNOLOGY, CATHODIC PROTECTION AND CORROSION FATIGUE. Third Interim Report of Progress. B. F. Brown, et. al. Naval Research Lab., Washington, D. C. NRL-Memo-1634 N66-14232 AD-621 743 July 1965 97 p refs

"Cathodic protection to 5652 foot ocean depths is studied. A status report is given on the current distribution along a wire rope cathode; inoperative galvanic anodes related to improper chemical composition of the zinc; determination of the effective driving potential, and effective c.c. resistance of galvanic anodes." STAR

MARINE CORROSION STUDIES. STRESS CORROSION CRACKING, DEEP OCEAN TECHNOLOGY; CATHODIC PROTECTION, CORROSION FATIGUE. Fourth Interim Report of Progress. T. J. Lennox, Jr., et. al. Naval Research Lab., Washington, D. C. AD-639 599 May 1966 125 p

"The interim progress report is used to make available the information derived from incompleted studies. In addition, selected abstracts are included to indicate the existence of new information in related study areas." Author

MEASUREMENT OF GALVANIC INTERACTIONS. R. A. Legault. Electrochemical Technology Feb. - March 1964 p 70-73

"A single, rapid and versatile method is described, based on potential probe measurements, for determining the electrochemical interaction between any two electrically conducting systems. Bimetallic systems, including zinc and cadmium chromate primer were among those investigated. The results show the effectiveness of the method in evaluating the corrosion protection afforded to metal substrates by the coatings." ZDA

THE MECHANICAL INFLUENCE OF CORROSION OF METALS. PART 2. E. A. G. Liddiard. Corrosion Technology April 1963 p 95-97

"Investigation of the influence of corrosion when combined with static stress, either internal or applied, on the brittle fracture of 70/30 brass, mild steel, austenitic stainless steel, high carbon steel, Al and Al-Cu alloys. Cathodic protection and stress relieving are cited as a method of prevention of stress corrosion." RML

METALLIC CORROSION -- FURTHER CHEMICAL ENGINEERING ASPECTS. H. A. Holden. Chemical and Process Engineering May 1964 P 241-244, 248

"Review of metallic corrosion studies. Includes discussion of stress corrosion, corrosion mechanisms, crevice corrosion, cathodic protection and retardation by means of coating and painting." RML

METALS PROTECTION IN THE MARINE ENVIRONMENT. L. J. Nowacki and W. K. Boyd. Battelle Technical Review June 1964 p 9-14

"A review is presented of established protective systems including organic coatings (Al pigmented vinyls), antifouling coatings and cathodic protection (Al sacrificial anodes)."

METHODS FOR LOCATING REMOTE ANODE GROUND BEDS. J. F. Norton. Materials Protection Sept. 1965 p 36-40

"Discusses trigotrignomic and electrical or practical methods of locating remote anode ground bed to provide wide current distribution to metallic structure to be cathodically protected. Briefly gives advantage and disadvantage of remote ground bed." NACE

METHODS FOR STRIPPING COATED ANODES. I. Geld, et. al. Naval Applied Science Lab., Brooklyn, N. Y. R TR I N67-15078 AD-639 963 3 Oct. 1966 12 p

"Occasionally, paint is inadvertently applied to the platinum anode components of ship cathodic protection systems, rendering them inoperative. Removing the paint by abrasive blasting involves danger of eroding the relatively soft platinum. Electrolytic and solvent methods were studied to determine effectiveness for stripping the Navy underwater vinyl paint system."

MICROBIOLOGICAL CORROSION - SULFATE REDUCING BACTERIA AND CORROSIVE INFLUENCE ON METALS. B. N. Tripathi. Journal of Scientific and Industrial Research Sept. 1964 p 379-389

"Detection of corrosive locations and mechanisms of corrosion reaction including cathodic depolarization, anodic stimulation, electrochemical cell action and chemical action of ecological materials. Forms of corrosion, rate of penetration, presence of Fe^{2+} in medium, effect of anchorage and effect of galvanic current." CA

MODEL TESTS OF ELECTROCHEMICAL PROTECTION AGAINST CORROSION OF SHIPS' HULLS AND DETERMINATION OF EFFECT OF PROPELLERS ON THE CONDITIONS OF FUNCTIONING OF THIS PROTECTION/MODEL 'NYYE ISPYTANIYA ELEKTROKHIMICHES-KOY ZASHCHIY KORPUSOV MORSKIKH SUDOV OT KORROZII I OPREDELENIYE VLIYANIYA GREBNOGO VINTA NA REZHIMY RABOTY ETOY ZASHCHITY. L. A. Suprun, V. P. Bardina and A. A. Vysotskiy. Dept. of the Navy, Washington, D. C. Translated into English from Trudy TsNIIMF Issue 57 1964 p 3-25 Translation 2063 AD-628 193 1964 30 p

"This article discusses the methodology of model tests of electrochemical protection and the nature of distribution of potential over the hull of a ship with different versions of protection and cathode shields." Author

MODERN CATHODIC PROTECTION PRACTICE. R. Holland. Engineer, London Feb. 1968 p 210-213

"A general discussion on the principles of cathodic protection, anode materials and division of anodes into galvanic and impressed current anodes is presented. Materials mentioned included Mg, Zn and platinized Ti. Presence of Al 0.5% in Zn anode reduces the deleterious effect of Fe. Al anodes marketed for marine use, their application in buried and marine structures, ships hulls and ships tanks are also given." AA

MULTIMETAL COATINGS PROCESS FOR COMPOSITE STEEL. Interim Report. J. Doss. Rock Island Arsenal Lab., Rock Island, Ill. AD-427 131 Oct. 24, 1963 14 p

"Al, steel and Mg trimetal assemblies were simultaneously coated in order to decrease galvanic corrosion and to develop coatings to be used for recoating structurally united components containing dissimilar metals. The composite specimens were processed in modified stannous pyrophosphate solutions. The trimetal assemblies containing various alloys of Al were also processed in the stannous pyrophosphate solution. Composite specimens containing a large Al panel and a small Mg panel, or the reverse, were processed in the stannous pyrophosphate solution. Solutions containing other tin compounds were investigated as solutions to coat trimetal assemblies." Author

NEW WELDED ALUMINUM ANODES OFFER HURRICANE PROOF CATHODIC PROTECTION FOR OFFSHORE STRUCTURES. J. D. Baribault. Oil and Gas Journal 18 April 1963 p 91-94

"New Al alloy, Alcoa's CB-75, makes possible a permanent, self-regulating cathodic-protection system. Shell Oil Co., has tested new anodes on a large self-contained steel drilling platform. Over a 4-month period, field readings on structure indicate that anodes should easily surpass their design protective life of 25 years. New anodes were welded to structure jacket legs and bracing during fabrication onshore. Two test anodes of same alloy were suspended from structure. Shell plans on using alloy to protect all fixed equipment it installs in Gulf of Mexico. Design data are tabulated." INCO

THE OCCURRENCE AND PREVENTION OF CORROSION. W. E. Edwards. Bureau of Yards and Docks, Pearl Harbor, Hawaii N66-18493 AD-625 900 Dec. 1965 11 p

Corrosion could be eliminated in the planning, design and construction stages through the proper choice of materials and methods. Cathodic protection will usually save many times its installation cost wherever it may be required in corrosive environments.

PERMANENT ANODE IN IMPRESSED-CURRENT CATHODIC PROTECTION SYSTEMS. C. A. Curtis. Corrosion Technology Oct. 1959 p 296-8; Nov. 1959 p 332-4, 242

These articles discuss the properties, uses and limitations of the principal materials employed as anodes in impressed-current cathodic protection systems.

POLARIZATION CELLS FOR EARTHING CATHODICALLY PROTECTED CABLE SYSTEMS. V. T. Morgan. Corrosion Science March 1965 p 225-237

"Polarization cells used for earthing sheath of cathodically protected cables are described; these permit flow of shortcircuit current from cable sheath to earth but are easily polarized by protective current. A unit was developed of 33=kV cable in coated steel pipe; cathodic protection being obtained as 1 amp with sheath isolated and 150 amp with it earthed." MA

POTENTIOSTATIC CORROSION STUDIES OF IRON, TYPE-304 AND TYPE-321 STAINLESS STEEL. Technical Report June 1964 - May 1965. H. A. Porte. Naval Civil Engineering Lab., Port Hueneme, Calif. R423 N66-17119 AD-624 269 Dec. 1965 40 p refs

The electrochemical characteristics of iron and two types of stainless steel were investigated. The effect of cathodic pretreatment was studied. Electrochemical polarization curves proved to be useful in predicting which of a group of alloys would be the most corrosion resistant in a particular environment.

PLATINUM IN ANODES - CATHODIC PROTECTION APPLICATIONS - PARTS 1 and 2. G. W. Walkiden. Corrosion Technology Jan., Feb. 1962 p 38-40, 44

"Review paper provides balanced overall picture of use of Pt-anodes in cathodic protection systems... At present, only two types of supported Pt electrode can be widely recommended. One is Pt-Pd alloy foil anode and other is platinized Ti anode." INCO

PRACTICAL GALVANIC SERIES. C. M. Forman and E. A. Verchot. U. S. Army Missile Command, Redstone Arsenal, Alabama. Structures and Materials Lab. RS-TR-67-11 AD-823 185 10 Oct. 1967 38 p No Foreign

"The prime objective of this work was the development of a practical galvanic series of metals and alloys to aid in the selection of compatible materials for missile systems. This was accomplished by studying the various metals and alloys coupled with a 110 copper alloy standard as the reference electrode, and monitoring potentials with a self-balancing potentiometric-type recorder. Each couple was partially immersed in a 5% salt (sodium chloride) solution. The effects of coatings and platings on the galvanic relationships existing between metals and alloys were also studied. Coatings and platings were studied with aluminum, magnesium, and steel as the substrates." Author

A PRACTICAL LOOK AT CORROSION CONTROL COSTS. D. P. Price. Gas March 1963 p 129-133

"Reviews some of the economic analyses which were originally applied to justify coatings and cathodic protection and further illustrates why these basic studies should continue to apply to most of our corrosion elimination studies today." INCO

PRACTICAL SELECTION OF MAGNESIUM ANODES FOR NEW AND EXISTING LINES. N. R. Thresher. Pipe Line News Aug. 1964 p 43-44, 46

"Basic factors for selecting and disposing Mg-anode materials for cathodic protection of pipeline systems. These consider dimensional and insulation aspects of pipe, jointings, operating pressure and significance of leak history records for useful performance-environment information. Several practical pipeline situations are given for which anodic protection is designed and electrical characteristics of systems are presented graphically." RML

PRELIMINARY EVALUATION OF CORROSION PREVENTION AT TITAN II MISSILE BASES. Ralph M. Parsons Co., Los Angeles, Calif. BSD TR 64-331 AD-450 360 18 Jan. 1961 25 p refs

"This report reviews briefly the fundamentals of corrosion and methods of protecting underground steel structures against corrosion. The results of a preliminary corrosion protection analysis are presented, and recommendations are made for a course of action to insure adequate corrosion protection for each of the Titan II bases." TAB

PREVENTING CORROSION. W. D. Mogerman. Discovery Feb. 1965 p 14-18

"Brief history of corrosion prevention is given, with particular reference to ships and bridges. Cathodic protection, past and present, and use of inhibitors are also discussed." RPI

PREVENTION OF STRESS CORROSION CRACKING BY CATHODIC PROTECTION. L. Fairman. Corrosion Technology Sept. 1965 p 9-12

"Cathodic protection has been used on industrial scale for protection of pipelines and underwater structures for many years. It has not, however, been applied to structures in which, although general corrosion resistance is high; there is likelihood of failure by stress corrosion cracking. Purpose of investigation reported here was to determine effect of cathodic polarization in range of commercial alloys were liable to this type of failure." Author

PREVENTION OF TITANIUM STRESS CORROSION CRACKING. I. Geld and S. H. Davang. Naval Applied Science Lab., Brooklyn, N. Y. AD-800 111 L 19 Aug. 1966 14 p DOD only

"A state-of-the-art survey revealed that shot peening, coatings and/or cathodic protection have possibilities as stress corrosion cracking preventive measures." Author

PRINCIPLES OF DESIGN OF CATHODIC PROTECTION SYSTEMS FOR THE HULLS OF ACTIVE SHIPS. J. A. H. Carson. Pacific Naval Lab., Esquimault (British Columbia) Rept. 64-2 N65-17412 AD-457 734 Sept. 1964 48 p

This report presents an engineering approach to the design of cathodic protection systems for ship's hulls. The effects of dissolved oxygen concentration, ship speed, temperature, salinity, type and condition of hull paint and efficiency of current distribution on current requirements are discussed.

PRINCIPLES OF STRESS CORROSION CRACKING AS RELATED TO STEELS. J. F. Bates and A. W. Logniow. Corrosion June 1964 p 189-197

"This article is a general educational treatment of stress-corrosion cracking phenoma occasionally confronting design, operations, maintenance and research engineers. It reviews: (1) Possible mechanisms: electrochemical dissolution, alloying, and hydrogen embrittlement of steels in solutions and liquid metals. (2) Aspects of the electrochemical mechanism and the alternate mechanical-electrochemical mechanism. (3) Stress corrosion cracking in ferrous alloys and proposed stress corrosion mechanism as they relate to these alloys. (4) Effects of steel composition, mechanical properties, heat treatment, stress level, cold work, welding and corrosive environment on the susceptibility to stress corrosion cracking. (5) Preventive measures: stress relieving, cathodic protection, alloy selection and modification of environment." NACE

PROBLEMS OF ADHESION WITH CATHODIC PROTECTION. W. A. Anderson. Official Digest Oct. 1964 p 1210-1224

"Vinyl coated steel used in bottoms of ships is tested to discover the effect of cathodic protection on adhesion of vinyl coating. Photographs of observed steel panels are included." RML

PROBLEMS OF SHIP'S PROPELLER PROTECTION. A. Domanski and J. Birn. Proceedings of the International Conference on Marine Corrosion and Fouling, Cannes, France. June 8-12, 1964 p 19-30

"Factors involved in corrosion of ship's propellers are briefly discussed and results of investigations reported in literature on application of cathodic protection techniques to propellers are surveyed. An account is given of investigations on protection of cast steel propellers, and a highly successful cathodic protection system for brass propellers is described which utilizes zinc anodes and a short-circuiting device which allows a flow of current from zinc anodes on ship's hull to shaft of propeller." ZDA

PROGRAMMED PROTECTION USING SMALL RECTIFIERS. G. L. Quincy. American Gas Journal Sept. 1963 p 26-29

"Discusses the use of cathodic protection for steel gas pipelines to minimize corrosion." BTR

PROTECTING OFF-SHORE OIL INDUSTRY INSTALLATIONS AGAINST CORROSION/. ZASHCHITA ET KORROZII MORSKIKH NEFTEPREMYSLEVYKH SOORUZHENIY. V. F. Negreyev, A. G. Khanlarova and R. G. Gadzhiyeva. Dept. of the Navy, Washington, D. C. Translated into English from Nedra (Mineral Resources) Publishing House, Moscow, 1964 Translation 2076 AD-627 255 1965 361 p

This book discusses corrosion and corrosion protection of off-shore oil industry installations. It includes a chapter on electrochemical protection in sea water.

PROTECTION OF FLOATING PONTOONS FROM CORROSION--PART I. INSTALLATION AND INITIAL PERFORMANCE OF TEST FLOATS. R. W. Drisko. U.S. Naval Civil Engineering Laboratory, Port Hueneme, Calif. Technical Note N-886 Internal Working Paper AD-815 512L 17 April 1967 18 p U.S. Gov't Only

This document reports on a test program aimed at reducing maintenance costs of recoating deteriorated pontoon camel floats. After six months service to the fleet, the test floats were in good condition with no coating deterioration noted. The cathodic protection systems were providing electrical potentials that insured complete protection from corrosion to any exposed steel.

PROTECTION OF MOORING BUOYS - PART V. FOURTH RATING INSPECTION. R. W. Drisko. U. S. Naval Civil Engineering Lab., Port Hueneme, Calif. TR R 355 AD-611 410 4 Jan. 1965 48 p

"Three test buoys were cathodically protected with a system using a sacrificial magnesium anode, a control head, and a remote ground cable. Although the potentials produced on these buoys by this system were outside of the range desired for complete protection, the system allowed only light rusting and no pitting. When the system on each of these buoys was modified by replacing the magnesium anode with a zinc anode united directly to the ground cable, potentials reached the desired magnitude." Author

PROTECTION OF MOORING BUOYS - PART VI. RESULTS OF FIFTH RATING INSPECTION. R. W. Drisko. U. S. Naval Civil Engineering Lab., Port Hueneme, Calif. Rept. R 385 AD-616 886 June 1965 47 p

"Three of the test buoys were cathodically protected with zinc anodes. The level of protection was great enough to mitigate rusting on the underwater portions of these buoys." TAB

PROTECTION OF MOORING BUOYS - PART VII. RESULTS OF SIXTH RATING INSPECTION. R. W. Drisko. U.S. Naval Civil Engineering Lab., Port Hueneme, Calif. TR 431 AD-624 799 Dec. 1965 46 p

"Three of the test buoys were cathodically protected with zinc anodes. The level of protection was high enough to mitigate rusting in the underwater portions of these buoys." TAB

PROTECTION OF MOORING BUOYS - PART VIII. RESULTS OF SEVENTH RATING INSPECTION. R. W. Drisko. U.S. Naval Civil Engineering Lab., Port Hueneme, Calif. TR R 458 AD-636 422 June 1966 52 p

"Three of the buoys were cathodically protected with zinc anodes. The level of protection was high enough to mitigate rusting in the underwater portions of these buoys." Author

PROTECTION OF MOORING BUOYS - PART IX. RESULTS OF EIGHTH RATING INSPECTION. R. W. Drisko. U. S. Naval Civil Engineering Lab., Port Hueneme, Calif. NCEL TR 531 AD-654 173 June 1967 45 p

"Three of the buoys were cathodically protected with zinc anodes. The underwater portions of these buoys were receiving protection from corrosion 28 months after anode installation." Author

PROTECTION OF MOORING BUOYS - PART X. RESULTS OF NINTH RATING INSPECTION. R. W. Drisko. U. S. Naval Civil Engineering Lab., Port Hueneme, Calif. NCEL TR 542 AD-659 478 Sept. 1967 37 p

"Three of the buoys were cathodically protected with zinc anodes. The underwater portions of these buoys were receiving protection from corrosion 33 months after anode installation." TAB

PROTECTION OF POWER STATION COOLING SYSTEMS. W. Matthewman. Corrosion Prevention and Control Oct. 1964 p 21-24

"The Central Electricity Generating Board operates many power stations using sea or estuarine water as a cooling medium. In these circumstances the circulating water system is susceptible to corrosion. Generally the only positions which cause concern are those where dissimilar metals are in contact. Equipment requiring protection would be main turbine steam condensers, whole inventory of auxiliary coolers, main and auxiliary circulating water pumps, large valves, strainers and essential pipework. There may also be intake structures, outfall structures and jetties. As the problem is universal, the maximum benefit will be gained by applying a standard remedy; this could well be cathodic protection." Author

PROTECTION OF SHIPS' HULLS. P. V. Palmer. Chemistry and Industry 20 April 1963 p 642-643

"A review of the relative merits of sacrificial anodes and impressed current systems of cathodic protection is given. Zn anodes, with longer life and lower potential than Mg, are less harmful to paint coatings and, being self-regulating allow more anodes to be used, more than doubling the time between servicing. Impressed current schemes use small flat anodes which give little resistance to water flow, while the current can be varied at will; the required current density under moving conditions may be 10 times higher than under static ones. The difficulties with rudder leading edge protection and those encountered with protection against electrolytic attack of propellers were discussed." ZDA

PROTECTION OF SHIPS' HULLS AGAINST CORROSION. V. M. Stepanov. Department of the Navy, Washington, D. C. Translation 953 AD-632 837 1966 10 p

This report discusses galvanic corrosion and methods of protection of ships' hulls in sea water.

PROTECTION OF SHIPS' HULLS BY AUTOMATICALLY CONTROLLED IMPRESSED CURRENT CATHODIC PROTECTION. J. H. Morgan. Corrosion Prevention and Control Jan 1968 p 12-14

"A discussion is given of engineering and design aspects which have been developed to overcome difficulties associated with placing of equipment on ship's hull, with changing environment through which ship operates and with changing conditions of speed and loading. Lead alloys appear to be one of most suitable materials to make reasonably permanent electrochemical anodes at a sensible cost. Lead anode forms a peroxide film, which is slowly dissolved; 1/2 in. thick lead has a life of 20 years in sea water. To insulate anode form hull a non-absorbent and chemically inert material must be used. Plastics are ideal for this and polyester glass fibre holders are employed to achieve this in a streamlined form." LDA

PROTECTION OF TWO MARINE INSTALLATIONS IN PERSIAN GULF. C. Naghshineh. Materials Protection Jan. 1966 p 16-18

"Discusses coating methods and cathodic protection procedures for protecting 20-inch submarine pipeline in Persian Gulf and 25,000-ton steel loading jetty on small island in gulf. Cathodic protection of pipeline involved zinc collar anodes and impressed current system." NACE

PUMP CORROSION PROBLEMS. Staff Feature. Materials Protection Jan. 1964 p 9-16

"Case history information is used to show some of the various types of corrosion problems encountered in pump operations. Discusses the problems between users and manufacturers of specifying proper materials of construction for specific corrosive services. Also describes pump failures resulting from galvanic attack, improper heat treatment, changes in process fluids, and combination of corrosion and abrasion. Problem of attaining long service life on pumps in corrosion service is discussed. Emphasizes importance of weighing economic factors involved in pumps. Section is devoted to pump seals and packings." NACE

RECENT ADVANCES IN CATHODIC PROTECTION. J. H. Morgan, Corrosion Technology April 1965 p 11-15 Dec. 1964 5 p

"Principles of corrosion protection are briefly described and survey is made of some developments made in field. Both galvanic anode and impressed current protection systems are dealt with. Zn and Al-Zn alloy galvanic anodes are considered and attention is drawn to high efficiency." ZDA

RECENT ADVANCES IN CATHODIC PROTECTION OF SHIPS. N. S. Dempster. Australasian Corrosion Engineering June 1964 p 9-19

"Principles of cathodic protection are discussed and a description is given of various cathodic protection systems employed, with particular reference to their use on ships of Royal Australian Navy. Protection of ships by underwater paints is briefly dealt with. Zinc alloy anodes are considered to be most suitable for hull protection of active ships, and are extensively used by Royal Australian Navy for this purpose." ZDA

REGULATING BIAS ON SHIP'S HULL. E. L. Littauer and O. G. O'Brien. Electronics Aug. 1965 p 84-87

"Cathodic protection can prevent corrosion on steel plates, but voltage applied must be controlled within precise limits under differing conditions of temperature, vessel speed, and salinity of seawater. Article discusses anodic corrosion and cathodic protection system. Output anodes for this system are of Pb with embedded Pt pins. Roughly 100 ships are now using electronic corrosion protection systems and in future few ships will be built without them. This method also has applications for stationary objects as well - bridge piers, tunnels, offshore oil rigs, and canal locks. Corrosion control by cathodic protection is presented in tabular form." INCO

RELIABILITY AND CORROSION. R. D. Barer. Naval Engineers Journal April 1966 p 321-331 refs

The article discusses the importance of design for corrosion protection. Examples are discussed which illustrate the corrosion hazards that appear between design office and field execution. Coatings and cathodic protection are discussed as means of increasing reliability.

REPORT ON PIPELINE PRACTICE BY AN ASCE DIVISION TASK FORCE. J. W. Pierce. Civil Engineering Aug. 1963 p 34-37

"A study of practices throughout the pipeline industry was made by a task force of the Committee on Pipeline Planning of ASCE's Pipeline Div. The object was to review the practices of water, oil, gas, and product pipeline companies with respect to their use of coatings and means of controlling pipeline corrosion. Steel, cast iron, concrete and asbestos pipes uncoated or coated with asphalt, coal tar, somastic, tape and concrete were pipelines covered in the survey. About half of the 178 firms are actively seeking better means to control corrosion. Cathodic protection and use of thin-wall pipe are included in the discussion." INCO

A REVIEW OF CATHODIC PROTECTION THEORY AND PRACTICE FOR NEWCOMERS AND OLDTIMERS ALIKE. L. P. Sudrabin. Materials Protection May 1963 p 8-12, 14-16

"Proper application of cathodic protection requires an understanding of complexities which involve concepts of the electrochemist, metallurgist, electrical engineer and others. Geometry often is an important consideration in its application. Successively considered are concentration polarization, IR drop, characteristics of a pit; cathodic, anodic and mixed control; significance of potentials, electrical characteristics of cathodic protection, importance of anode location, significance of change in slope; polarization of Al, Pb, stainless steels; fatigue and cavitation corrosion, instrumentation and anodes." NACE

A REVIEW OF CORROSION AND CATHODIC-PROTECTION PRINCIPLES FROM AN ELECTROCHEMICAL POINT-OF-VIEW. G. A. Marsh. Journal of Petroleum Technology Sept. 1962 p 967-972

"Objective of paper is to discuss theory or principles of cathodic protection as they might be applied internally in a water-injection system. Nature of aqueous corrosion of steel is reviewed and relationship between corrosion and cathodic protection is discussed. Key role of cathodic reaction in corrosion process is emphasized. Electrochemical point-of-view is used throughout. Contribution of bacteria to corrosion process, impressed current vs. sacrificial anode systems, and use of corrosometer probes as aids in cathodic protection are among topics covered." INCO

THE ROLE OF CURRENT DISTRIBUTION IN CATHODIC PROTECTION. R. E. Meredith. Materials Protection Feb. 1963 p 39-42, 44

"Using principles applicable to superposition of electrical fields, current distribution is evaluated for several multiple electrode situations and design criteria are established for cathodically protecting otherwise unprotected surfaces." NACE

SECOND CORROSION SURVEY OF STEEL SHEET PILING. C. V. Brouillette et. al. U.S. Naval Civil Engineering Lab., Port Hueneme, Calif. TR R 467 AD-637 044 Aug. 1966 18 p

"In-service steel sheet piling was investigated in 1959 at eight naval stations. In 1965 the piling at five of these stations was investigated again to gather further information on the corrosion rates of steel sheet piling at waterfront locations. The value of applying maintenance coatings from the mean low-water mark to the top of the piling and of using cathodic protection was reaffirmed by this second survey." Author

SOLUTION POTENTIALS AND THEIR INTERPRETATION IN PIPELINE CATHODIC PROTECTION. PART 2 Corrosion Technology Aug. 1963 p 206-209

"It is often difficult to decide whether a value is a cathodic or an anodic potential, and the method of identification is described in some detail in this concluding article. In another section the author deals with interference to cathodic protection systems caused by stray currents and provides some very interesting practical data regarding problems he has investigated. Other subjects covered include a detailed description of the ground wire method of taking potential measurements, and the use of solution potential measurements for plotting the direction of stray currents." Author

SPALLED CONCRETE TRACED TO CONDUIT. Engineering News-Record 12 March 1964 p 28-29

"As a result of concrete cracking in the new Washington, D. C. stadium and in several other concrete structures in the Washington area, the Public Buildings Service, the U.S. Army Corps of Engineers and the D. C. Building Department have banned use of Al conduit in concrete... Cause of corrosion is galvanic action set up by contact between reinforcing steel and Al conduit. Expansion of corrosive compound, on the conduit can crack or spall concrete. There is a difference of opinion as to whether $CaCl_2$ or other salt is required to sustain the corrosive action. Major Al companies oppose code prohibitions of concrete-embedded Al conduit claiming that Al conduit has served well in the vast majority of cases." INCO

SPREAD AND COATINGS. C. L. Wilson. Anti-Corrosion Methods and Materials Dec. 1967 p 6-8

"The idea of current concentration on 100 percent efficiency coatings on the cathode at the closest point to the anode is investigated. The simple case of a point anode and a flat plate is considered. For pipelines, the groundbed is treated as a point source anode and a mathematical expression is derived. Results of computations for various sizes of coating sleeves suggest that this technique of a patch of special coating opposite an anode is far more effective on pipelines than on plates. A table lists the length of coating sleeve with the corresponding percentage increase in spread." GA

STOPPING SHIP HULL CORROSION. Australasian Corrosion Engineering Aug. 1965 p 39

"Advanced protection system using lead anodes containing platinum inserts has been installed in modified American tanker, S. S. Angelo Petri, and is expected to pay for itself within two years through elimination of corrosion repair costs. Completely solid-state, automatic control system maintains hull and fittings at potential at which no corrosion can occur." LDA

STRESS-CORROSION BEHAVIOR OF 12 PERCENT NICKEL MARAGING-STEEL WELDMENTS. A. W. Loginow. United States Steel Corp., Monroeville, Pa. Applied Research Lab. Rept. S 23309 AD-616 982 31 Dec. 1964 18 p

"Stress-corrosion cracking was observed in specimens exposed in the three seawater environments in 6 to 17 days; no significant difference in cracking time was observed among the environments. The absence of base-metal cracking (away from welds) in some specimens exposed for 170 days is regarded as evidence that the base metal may be resistant to cracking in marine environments. It also appears that carbon steel can prevent cracking by cathodically protecting 12Ni-5Cr-3Mo weldments." Author

STRUCTURAL ALLOYS FOR HYDROFOIL CRAFT. D. C. Vreeland. Naval Ship Research and Development Center, Annapolis, Md. AD-820 277 Aug. 1967 19 p

Titanium and 17-4 PH stainless steel were considered for construction of struts and foils for an experimental Navy hydrofoil craft. If design constraints preclude the use of titanium because of its lower yield strength, then 17-4 PH stainless steel overaged at 1050 F or higher would be recommended. Cathodic protection would be needed for the latter material in foil systems that are to be continuously immersed.

STUDY OF CONTACT CORROSION IN LABORATORY AND NATURAL ATMOSPHERIC CONDITIONS. I. L. Rozenfelid, T. I. Pavlutskaya and L. M. Lapides. Air Force Systems Command, Wright-Patterson AFB, Ohio Foreign Technology Div. FTD-MT-63-124 N64-28169 AD-602 562 14 Feb. 1964 31 p

"Survey is presented of electrode-corrosion investigation. General conclusion from all experimental material, both in laboratory and in natural conditions, consists in fact that influence of contact on speed of metal corrosion in atmospheric conditions is significant. Explained by concentration of corrosion, due to small range of contact, directly at borders of metals in contact. Speed of contact corrosion, in turn, depends greatly on composition of atmosphere. Susceptibility of various alloys and metals to contact corrosion and methods of determining contact corrosion are discussed." STAR

A STUDY OF VARIOUS INHIBITORS FOR PREVENTION OF GALVANIC CORROSION. Final Report W. H. Deaver, CCL-175 N65-18674 AD-610 136 4 Jan. 1965 9 p ref

This report evaluates various types of corrosion inhibitors and metallic salts to determine their ability to prevent or retard galvanic corrosion of magnesium-steel assemblies.

A SURVEY OF DEVELOPMENTS IN CORROSION PROTECTION. Corrosion Prevention and Control. Nov. 1962 p 31-34, 36, 38, 40

"Survey of techniques used for Al, stainless steel, Cu and brass surface preparation and treatment including shot blasting, etching, pickling, plating, cleaning, degreasing, anodizing and cathodic protection processes. Review of protective coating materials, such as ceramics, resins and plastics; application and coating methods." RML

A SURVEY OF REQUIREMENTS AND COSTS FOR CATHODIC PROTECTION ON 22,000 MILES OF COATED PIPELINE. F. W. Hewes. Materials Protection Sept. 1966 p 41-46

"Presents an accumulation of data on cathodic protection requirements and costs for 400 separate pipelines involving a total of 22,395 miles. Average current requirements were found to be 9.4 microamps per sq. ft. and average cathodic protection installation costs 1.36 cents per lineal ft. An analysis is made of the significance of findings on buried pipeline protection economics." NACE

TESTING OF COAL TAR COATINGS. PART 5. CATHODIC PROTECTION IN SEA WATER. W. F. Fair, Jr. amd R. B. Teel. Materials Protection Aug. 1963 p 66-70

"Information is given on tests of steel panels coated with hot and cold applied coal tar systems, both sand-filled and not, exposed in sea water and subjected to negative potentials ranging from -1.0 to 1.45 volt negative to a calomel half cell. Tests to 70 months showed the effect of voltages of this magnitude, well above those required for adequate cathodic protection in sea water." NACE

TESTS TO FIVE YEARS INDICATE ALUMINUM ALLOY PIPE GIVES ECONOMICAL SERVICE. J. F. Whiting and T. E. Wright. Materials Protection Dec. 1962 p 36-38, 40, 42, 45, 46

"Performance of Al pipe in Canadian oil fields and in other kinds of service handling a variety of fresh waters shows that this material can be used with confidence... When necessary, in soil of low resistivity, cathodic protection of both bare and coated pipe is economically feasible. Data on burial times to 11 years in the U.S., Canada and Great Britain indicate pitting rates are not excessive and that rates diminish with time." NACE

A THIN-PLATE BATTERY. SUPPLEMENT TO QUARTERLY REPORT. MAY 15 - AUGUST 15, 1963. R. T. Foley, J. Smit and H. H. Titus. Melpar, Inc., Falls Church, Va. AD-412 865 1963 29 p

"Fabrication and fixture testing of 28-volt series battery packs are described. These units were tested in the new multi-cell test fixture described in the twelfth quarterly report. Different modes of activation and details of fabrication were evaluated in terms of voltage output, pressure rise, and temperature rise. These tests included a fractional factorial series of experiments, comprising five battery variables at two levels. An investigation of the effect on the Mg-stainless steel couple of ammonia solutions was also initiated during this quarter. This study was undertaken to determine the extent to which galvanic corrosion contributed to the pressure and temperature rises within the battery." TAB

THIRTY YEARS OF PROOF: CORROSION CONTROL PAYS OFF. R. K. Talley. Materials Protection Feb. 1966 p 35-36

"Explains basic corrosion theory, and cathodic protection. Discusses costs and effectiveness of corrosion control programs. Cites economics of cathodic protection program used by the Colorado Interstate Gas Co." NACE

THREE STEPS TO ARREST BODY AND MOLDING CORROSION. Paper No. 668 F J. B. Hill, W. G. Renshaw and T. R. Harkins. SAE Journal July 1963 p 34-35

"Crevice corrosion and galvanic corrosion behind trim parts attached to automobile bodies can be arrested by taking 3 simple steps singly or in combination: (1) use insulating clips to attach trim to body; (2) avoid paint damage by careful assembly; and (3) use Zn plating on stainless steel moldings. Zn plate deposited electrolytically on stainless steel coils at mills provides a sacrificial corrosion to protect C steel in a cathodic protection system." INCO

TRENDS IN THE CATHODIC PROTECTION OF VESSELS. P. V. Palmer. Corrosion Technology Feb. 1964 p 17-21

"It is reasonable to deduce that at least 95% of all applications of cathodic protection to hulls are achieved by use of galvanic anodes. Some 80% are probably based on Zn or Al alloys. Platinized Ti anodes represent only a minority of the total impressed current anodes fitted to ships. Until the causes of failures of platinized anodes are made clear and limits of performance are established, users will hesitate to accept them without reservations... Cathodic protection of dry-cargo ships and oil-tanker compartments and cathodic protection with Al and Al alloy anodes are discussed." INCO

TRIALS OF PAINT SYSTEMS ON STEEL UNDER CATHODIC PROTECTION. J. H. de Vlieger and J. L. T. Brakkee. International Shipbuilding Progress June 1962 p 10-18

"Paint and cathodic protection are regarded as complementary means of combating corrosion. Ships' hulls were painted with zinc-rich paint or coated with sprayed zinc and were protected with zinc anodes." ZDA

UNIQUE CATHODIC PROTECTION SYSTEM FOR DEEP SEA MOOR. L. J. Wandron and M. H. Peterson. Materials Protection Aug. 1965 p 63-69

"Describes design, assembly, and installation of Mg anode cathodic protection system on 3-point moor laid in 5400 ft of water in Tongue of Ocean of Bahama Islands in May, 1962. Because of lack of engineering data and experience in cathodically protecting large wire rope installations, existing cathodic protection designs could not be used. Basic, theoretical and practical considerations for cathodically protecting moor are discussed. Also, recommendations are given for protecting future installations of this type." NACE

UNUSUAL CASE OF CATHODIC PROTECTION INTERFERENCE. R. L. Cawlfield. Materials Protection Jan. 1966 p 37-38

"Discusses unusual case history of pipeline cathodic protection interference from rectifier used to protect well near pipeline. Problem was solved by use of junk pipe installed near pipeline." NACE

USE OF ANODIC PASSIVATION FOR CORROSION MITIGATION OF IRON AND ALLOY STEELS. D. A. Shock, J. D. Sudbury and O. L. Riggs, Jr. In: First International Congress on Metallic Corrosion, London 10-15 April 1961 Butterworths 1962 refs p 363-367 (Ref/TA462/161)

Reports and laboratory investigation into the basic nature of passivity. Pilot and plant tests showed that the circuity developed could be applied to acid storage tanks. Further study indicated that the passivation system could be applied to steels in a wide range of corrosive environments.

USE OF DEPLETED URANIUM FOR CATHODIC PROTECTION. F. W. Hoertel. U. S. Dept. of Interior, Bureau of Mines, Washington, D. C. Rept. of Investigations No. 6285 1963 13 p

"An investigation of the use of depleted uranium as a sacrificial anode for the cathodic protection of submerged and underground structures of Fe, steel, and Cu was made. Uranium-metal couples were tested in a simulated marine environments and under simulated boiler service conditions. Similar couples were tested in samples of Missouri soils to simulate underground service." RML

USE OF ORGANIC COATINGS IN TANKERS. T. J. Lengyel and G. A. Wilson. Official Digest Oct. 1964 p 1113-1132

"Three methods of corrosion control are used in tanker ships. Cathodic protection and water and/or oil soluble inhibitors are covered very generally. Organic coating is covered in much greater detail and is compared to other methods with regard to corrosion protection, maintenance requirements, cargo contamination, installation and maintenance costs, and effect on ships capacity." RML

WATER AND METALS. E. E. McSweeney. Office Digest June 1965 p 670-682

"The role of corrosion preventive coatings is discussed from the viewpoint of the electrochemical mechanism of corrosion. Subjects discussed include the permeation of organic films by water, cathodic protection, anodic passivation, cleaning of metallic surfaces and the selection of pigments and solvents." RML

WEATHERED STEEL - A NEW CONCEPT IN CORROSION CONTROL. J. J. Carey. Engineering Journal Nov. 1964 p 23-28

"Discussion covers mechanism of corrosion, methods of protecting steel surface by painting, electrochemical and cathodic protection, corrosion studies in U. S. and Canada, superiority of low alloy steels, effect of environment on steels, design recommendations to minimize trouble and concept of weathered steel and applications." INCO

WELL CASING AS AN ELECTROCHEMICAL NETWORK IN CATHODIC PROTECTION DESIGN. M. A. Riordan and R. P. Sterk. Materials Protection July 1963 p 57-64, 66, 68

"Describes field investigation of well casings as electrochemical networks. Character of well casing network and associated remote electrode response is discussed. Network is analyzed as long line resistance network and as a polarized network. Concludes that a knowledge of electrochemical characteristics of well casings can be adequately investigated by practical means and that the feasibility, current requirements, and effectiveness of cathodic protection can be determined. A conventional E-log I curve as a straight line on rectangular coordinates is not satisfactory in determining current requirements." NACE

WHAT CAUSES BONDING BREAKS IN CATHODICALLY PROTECTED PIPE COATINGS. L. M. Applegate. Power April 1967 p 72-74

"To explain how disbonding occurs, some coatings on steel were subjected to protective potentials as much as 30 times that required for cathodic protection. The tests show an impermeable coating adhering to steel without voids or channels to admit water by capillary action cannot be disbonded by 15-v differences of potential between metal and surrounding electrolyte also that excessive protective potential is harmless on an impervious coating." GA

WHAT FIELD PERSONNEL SHOULD KNOW ABOUT RECTIFIERS. Materials Protection April 1965 p 75-82

"Describes selection, installation, operation, inspection of cathodic protection rectifiers so field personnel can understand functions of rectifier components. Schematic diagrams show basic circuits of rectifiers. Discusses basic differences between single phase and three phase rectifiers and provide method for determining proper application of each. Also, shows basic differences between selenium and silicon rectifiers. Suggest points to check during periodical inspections and outlines steps in trouble shooting for rectifier failures." NACE

WHAT WE DO AND DON'T KNOW ABOUT CORROSION. F. L. LaQue. Materials in Design Engineering Jan. 1963 p 99

"Checklist on electrochemical theory, stress corrosion, pitting impingement attack, cavitation erosion, cathodic protection and atmospheric corrosion." RML

WHERE AND WHEN TO USE COPPER ALLOYS. A. W. Tracy. Chemical Engineering Progress Sept. 1963 p 78-83

"Mechanical and physical properties of some Cu alloys, including Cu-Ni (10 and 30 Ni). Cu-Ni, 30%-7152, Cu-Ni, 30%-707, and Ni silver (65-18), are tabulated. General corrosion resistance, dezincification corrosion, types of pitting, stress-corrosion cracking (Ni silvers have intermediate resistance and Cu-Nickels high resistance), corrosion-fatigue, galvanic corrosion, use of Cu alloys, particularly the Cu-Nickels (10 and 30 Ni), in power station condensers, process cooling, petroleum refining, salt and sugar and pulp and paper and environmental effects are covered in the discussion." INCO

ZINC ANODES PROTECT WATER MAIN. Consulting Engineer Jan. 1965 p 80

"The relief water main in Washington, D. C. is to be protected by nearly two miles of new lightweight, high performance, zinc cathodic protection line anodes. It is believed they will give superior protection with considerable economic advantage over other methods. The anticipated maintenance-free life is 50 years. Zinc anodes are installed, in 500 ft segments, on both sides of main and strapped to it with nylon to prevent shifting when trench is backfilled. Zn reference electrodes are installed along the line and pipe to soil potentials are readily obtained at junction boxes." ZDA

ZINC-RICH PAINTS. Paint and Varnish Production April 1964 p 35-41

"Attention is drawn to the important role played by zinc-rich paints in the field of protection against corrosion and the mechanism by which such coatings protect ferrous surfaces is discussed. The general chemistry of corrosion is summarized and the principles of cathodic protection are given. A survey is made of the investigations carried out on the protective action of zinc-rich paints. The results indicate that cathodic activity of the coatings is soon eliminated by the formation of basic zinc compounds, and that the chemical process is the major source of protection obtained with the zinc dust paints." ZDA