FEAP-UG-FM-94/12
July 1994

FEAP
FACILITIES ENGINEERING
APPLICATIONS PROGRAM

USER
GUIDE

Corrosion Control Acceptance Criteria for Impressed-Current-Type, Cathodic Protection Systems on Water Storage Tank Interiors

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Approved for Public Release; Distribution Is Unlimited.

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CORROSION CONTROL ACCEPTANCE CRITERIA FOR IMPRESSED-CURRENT-TYPE, CATHODIC PROTECTION SYSTEMS ON WATER STORAGE TANK INTERIORS

1 EXECUTIVE SUMMARY

Background

The Army currently operates and maintains more than 300 elevated water storage tanks, all of which require some form of corrosion control. Cathodic protection is a form of corrosion control used to prevent corrosion-induced leaks in steel structures exposed to water. Before accepting a cathodic protection (CP) system, the Directorate of Engineering and Housing/Directorate of Public Works (DEH/DPW) reviews the performance check data supplied by the engineering firm that installs the CP system. A performance check after installation is usually called for in the system's plans and specifications. Data recorded in the performance check may show problem areas not readily identified in the original design or construction phases. Even properly designed and specified CP systems cannot be expected to function properly unless the proper materials are delivered to the job site and subsequently installed according to the design and installation specifications. Unless adequate criteria are used in the performance check, the DEH/DPW may be forced to accept a CP system that may not provide sufficient cathodic protection to the steel structure.

The corrosion control acceptance criteria for impressed current type CP systems used on water storage tanks provides guidelines for the DEH/DPW cathodic protection installation inspectors whose responsibilities are to ensure that the materials and equipment specified are delivered to the job site and subsequently installed in accordance with the engineering drawings and specifications. The acceptance criteria for impressed current CP systems used on water tanks includes all components for the impressed current system, such as the rectifier, anodes, insulated conductors, and ancillary equipment. The acceptance criteria is composed of a checklist listing each component. The inspector checks "yes" or "no" to show whether the components comply with the job specifications. In some cases, the inspector measures and records physical dimensions or electrical output, and compares the measurements to standards shown in attached tables.

By using acceptance criteria, DEHs/DPWs can avoid the costs associated with premature failure of CP system components, due to improper materials selection or installation. If acceptance criteria are not followed, incorrect installation of a CP system component may necessitate the replacement of an entire CP system. Average cost for a typical water storage tank CP system is $15K. In addition, DEHs/DPWs can avoid the corrosion damage and high repair and replacement cost of the structure itself by using the impressed current CP acceptance criteria.

With the help of Dr. James Myers of JRM & Associates, USACERL developed and tested acceptance criteria for impressed current CP systems on a replacement CP system for gas lines at Fort Hood, TX, and on a CP system for an underground storage tank at Fort Lee, VA. The acceptance criteria developed from these studies were adapted for use with water storage tank systems.

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2 PRE-ACQUISITION

Description of the Technology

The corrosion control acceptance criteria for impressed current type CP systems used on elevated water storage tanks provides guidelines for the DEH/DPW cathodic protection installation inspectors whose responsibilities are to ensure that the materials and equipment specified are delivered to the job site and subsequently installed in accordance with the engineering drawings and specifications. The acceptance criteria for impressed current CP systems used on water tanks lists all components for the impressed current system, such as the rectifier, anodes, insulated conductors, and ancillary equipment. The CP acceptance criteria is composed of a checklist of each component. The inspector checks either "yes" or "no" to indicate whether the components comply with the job specifications. In some cases, the inspector will measure and record physical dimensions or electrical output, and compare those measurements to standards shown in attached tables.

Before installation, the DEH/DPW inspector must review the engineering drawings for the CP system, study the specifications for the components and materials to be used, and become familiar with the installation procedures identified in the engineering drawings and specifications.

For a CP system to function properly, the proper materials must be delivered to the job site. The components and materials needed for the CP system should be inspected. Section 1.3 of the Appendix to this guide contains the appropriate checklist on components and materials for the DEH/DPW or COE inspector to fill out. During the installation of the CP system, the inspector should fill out the checklist contained in Section 1.4 of the Appendix.

Once the CP system is installed and ready for operation, it is necessary to ensure that additional criteria are met. With regards to commissioning the CP system, it normally takes some time for polarization to take place on the structure surface. Generally, cathodic polarization is indicated by a change in the potential of a structure with respect to a reference electrode. After energizing the system, rectifier readings should be checked immediately and monthly thereafter, and structure-to-environment potential surveys should be made annually. Section 1.4, Nos. 20-25 of the Appendix contains questions for the inspector to fill out during commissioning of the CP system.

Life-Cycle Costs and Benefits

The use of acceptance criteria for impressed current CP systems used on water tanks will reduce the costs associated with the replacement of installed (usually submerged) CP system components that fail prematurally due to improper materials selection or installation. If acceptance criteria is not followed, this could lead to the replacement of an entire CP system due to incorrect installation of an anode or anode lead wire at an average cost (for a typical water storage tank) of $15K. In addition, the corrosion damage and high repair or replacement cost of the structure can be avoided when using the impressed current CP acceptance criteria.

3 ACQUISITION/PROCUREMENT

Potential Funding Sources

The "Acceptance Criteria for Impressed-Current-Type Cathodic Protection Systems Used To Mitigate Corrosion on Water-Storage Tank Interiors" is provided free of charge to Army installations.

Technology Components and Sources

The acceptance criteria for impressed current CP systems used on water tanks checklist can be filled out by any qualified COE or DEH/DPW inspector.

Procurement Documents

The most current version of Corps of Engineers Guide Specifications (CEGS) 16641, "Cathodic Protection System (Steel Water Tanks, 2/89)" and 16642, "Cathodic Protection System, (Impressed Current, 3/89)" should be followed when the CP system is being designed and installed. The CP system should follow the guidance contained in TM 5-811-7, *Electrical Design, Cathodic Protection*, and ETL 1110-9-10, "Cathodic Protection System Using Ceramic Anodes." A USACERL Draft Technical Report, *Cathodic Protection Acceptance Criteria: A Guide for Directorate of Engineering and Housing (DEH) Inspectors*, should be reviewed for a more in-depth look at CP systems and the needed emphasis for acceptance criteria.

Procurement Scheduling

Procurement scheduling should include training for one or more Army post DEH/DPW staff members to become qualified to complete the acceptance criteria checklist. DEH/DPW personnel can become qualified inspectors by attending the *Facilities Engineering Corrosion Course* taught at USACERL in April or May of each year. Although attendance of the corrosion course is not required of the inspectors, it is highly recommended. Other training sources are PROSPECT course No. 009, *Corrosion Control* and National Association of Corrosion Engineers (NACE) weeklong courses, *Cathodic Protection—An Introduction* and *Cathodic Protection—Theory and Data Interpretation.*

4 POST-ACQUISITION

Initial Implementation

The acceptance criteria inspections for impressed current CP systems used on water tanks need to be performed in three stages. First, the materials and supplies for the CP system should be inspected when they arrive. Second, an inspection should take place during the installation of the CP system. Third, a final inspection needs to be done immediately, and again 2 months after the system has been in operation.

Operation and Maintenance of the Technology

The acceptance criteria checklist for impressed current CP systems used on water tanks should be filled out by a qualified DEH/DPW inspector. There is no maintenance involved in this technology.

Service and Support Requirements

The acceptance criteria recommends that a qualified COE or DEH/DPW inspector fill out the checklist. The COE or DEH/DPW inspector needs to attend a *Facilities Engineering Corrosion Course* held at USACERL in the spring or early summer to become qualified. There is no tuition charge for the 1-week course for Department of Defense (DOD) personnel. Other training sources are listed in "Procurement Scheduling" (p 6).

Performance Monitoring

The performance of the acceptance criteria for impressed current CP systems used on water tanks can be measured by comparing results from the checklist with the actual performance of the CP system. A favorable performance would include a good correspondence between the evaluation and the system's performance, in other words, a properly working CP system with most of the criteria for acceptance met, or a malfunctioning CP system with few of the criteria for acceptance met.

APPENDIX: Acceptance Criteria for Impressed-Current-Type, Cathodic Protection Systems Used To Mitigate Corrosion on Water Storage Tank Interiors

This appendix contains the checklist that the DEH/DPW inspector is to use when an impressed current type CP system is to be installed on a water storage tank. Some questions may not be applicable for all impressed current type applications.

1.0 Introduction

The components and materials for an impressed-current type, CP system (e.g., the rectifier, anodes, insulated conductors, and ancillary equipment) used to mitigate corrosion on water-storage tank interiors and their installation must be properly specified and detailed on engineering drawings. Specified components and materials must also be delivered to the job site and installed in strict accordance with the specifications and engineering drawings. Otherwise, when it is commissioned, the CP system may not achieve its intended objective of mitigating corrosion.

This guide/checklist can help the inspector who is responsible for ensuring that the components and materials specified for an impressed-current-type, CP system for water tanks are delivered to the job sites. The guide/checklist further provides a convenient way to ensure and document that these components and materials are installed according to the specifications and engineering drawings.

1.2 General

Before installation, the inspector must review the engineering drawings for the CP system, study the specifications for the components and materials to be used, and become thoroughly familiar with the installation procedures identified in the specifications and engineering drawings.

1.3 Components/Materials Delivered to the Job Site

With regards to the components and materials delivered to the job site, the inspector should record answers to the following questions:

	YES	NO	N/A
1. Was a sufficient number of anodes of the type(s) specified delivered to the job site? Number of Anodes: ____________________ Anode Types: ____________________	___	___	___
2. Were the weights and/or dimensions of the anodes within ±10 percent of those specified or identified on the engineering drawings? In this regard, dimensional and weight data are summarized for anodes used inside water storage tanks in Tables A1 through A5.*	___	___	___

* All Tables and Figures are included at the end of this Appendix.

		YES	NO	N/A
3.	Based upon the certified chemical analysis reports furnished by the anode manufacturer or supplier, did the anodes satisfy the chemical composition requirements of the specifications and/or engineering drawings?	___	___	___
4.	If all of the anodes were to have the same insulated-conductor length (i.e., the length of the cable attached to each anode), what was this length on the anodes delivered to the job site? Cable Length: ______________________________			
5.	If the anodes were to have different cable lengths, what were these lengths on the anodes delivered to the job site? Cable Lengths: ______________________________			
6.	Were the anode-cable lengths at least as long as that required by the specifications and/or engineering drawings and not too long; i.e., so that the anodes do <u>not</u> touch the tank wall?	___	___	___
7.	Did any of the anode cables contain any splices?	___	___	___
8.	Did the copper conductors on the anode cables have the specified number of strands? Number of Strands: ______________________________	___	___	___
9.	Did the copper conductors on the anode cables have the size required by the specifications and/or engineering drawings? In this regard, information on conductor sizes is included in Table A6. Conductor Size(s): ______________________________	___	___	___
10.	Did the anode cables have the specified type(s) and thickness(es) of insulation? In this regard, information on insulation for cathodic protection cable is included in Table A7. Type(s) and Thickness(es): ______________________________	___	___	___
11.	What were the copper-conductor size(s), insulation thickness(es), and insulation type(s) for the header cable (i.e., the primary or main conductor to which each of the anode conductors was to be attached) on the CP system? Conductor Size(s): ______________________________ Insulation Type(s): ______________________________ Insulation Thickness(es): ______________________________			
12.	Did the header cable(s) satisfy the requirements of the specifications and/or engineering drawings?	___	___	___
13.	Did the insulation on the anode or header cables have any defects or nicks that extended below the outer surface more than 20 percent of the insulation thickness?	___	___	___
14.	Was the external sealing component(s) at the anode ends from which the connecting cables exited in accordance with the specifications and/or engineering drawings?	___	___	___

	YES	NO	N/A

15. How were the electrical connections between the anode cables and the header cable(s) to be made?

    Crimp Connector: ______________________

    Exothermic Weld: ______________________

    Other; Identify: ______________________

16. If the copper conductors on the anode cables were to be exothermically welded to the copper conductor(s) on the header cable(s), what was the weld-metal-part number and the mold-part number to be used?

    Weld-Metal-Part Number: ______________________

    Mold-Number: ______________________

17. If the copper conductors on the anode cables were to be attached to the copper conductor(s) on the header cable(s) using crimp-type connectors, who was the manufacturer and what was the manufacturer's catalog number for the crimp-type connector(s)?

    Manufacturer: ______________________

    Catalog Number: ______________________

18. Were the crimp-type connectors to be used in accordance with the manufacturer's recommendations for the conductor sizes involved? ___ ___ ___

19. Were the manufacturer's recommended devices and tools available at the job site for making electrical connections using crimp-type connectors? ___ ___ ___

20. Were the required number and type(s) of splice kits delivered to the job site for waterproofing the electrical connections (above the high-waterline in the tank) between the anode cables and the header cable(s)? ___ ___ ___

    Manufacturer of Splice Kit: ______________________

    Catalog Number of Splice Kit: ______________________

21. How was the copper conductor on the cable to the direct current power source to be connected to the cathodically protected structure?

    Exothermically Welded: ______________________

    Brazed: ______________________

    Other; Identify: ______________________

22. If the copper conductor on the cable to the direct current power source was to be exothermically welded to the cathodically protected structure, what was the mold-part number and the weld-metal-part number to be used?

    Weld-Metal-Part Number: ______________________

    Mold-Part Number: ______________________

	YES	NO	N/A
23. Was the weld-metal-part number and the mold-part number to be used in exothermically welding the copper conductor from the direct current power source to the cathodically protected structure in accordance with the manufacturer's recommendations?	___	___	___
24. If the anodes were to be supported from the roof of the tank, were the proper components for the supp o.t system (including any hand hole covers) delivered to the job sit	___	___	___
25. If the anodes were to be supported using a technique other than the roof-support concept, were the proper components for the support system delivered to the job site?	___	___	___
26. If access to the tank for the anode cables was to be made using a pressure-entrance fitting, was the proper device delivered to the job site?	___	___	___
27. If permanently-installed, reference electrodes were to be installed, was the required number of these delivered to the job site and did each of these have a potential within ±7 millivolts of a calibrated reference electrode of the same type?	___	___	___
28. Was the specified direct current power source delivered to the job site?	___	___	___

29. If the direct current power source delivered to the job site was a rectifier, who was the manufacturer and what was the manufacturer's model number?

Manufacturer: ______________________________

Model Number: ______________________________

	YES	NO	N/A
30. If the direct current power source delivered to the job site was a rectifier, did the model delivered satisfy the requirements of the specifications and/or engineering drawings? In general, the model number can be used to identify the characteristics of the rectifier (e.g., see Figure A1).	___	___	___
31. Was there any evidence of damage to the direct current power source or rectifier delivered to the job site?	___	___	___
32. Was the direct current power source or rectifier altered or modified at the job site?	___	___	___
33. Was adequate equipment available at the job site to successfully install the CP system?	___	___	___

1.4 Installation of the Components/Materials

With regards to the installation of an impressed-current type CP system for water storage tank interiors, the inspector should record answers to the following questions:

		YES	NO	N/A
1.	Was a corrosion engineer at the job site to supervise and inspect the installation of the CP system?	___	___	___
2.	What was the name of the corrosion engineer at the job site? Name: ______________________________	___	___	___
3.	Was the corrosion engineer a professional engineer and/or a National Association of Corrosion Engineers' "Corrosion Specialist" with suitable experience in corrosion control for the inside surfaces of water storage tanks?	___	___	___
4.	Did the corrosion engineer remain at the job site the time required to ensure that the CP system was installed, tested, and placed in service in accordance with the specifications and/or engineering drawings?	___	___	___
5.	Did the contractor submit a certified test report showing that the anode-to-cable connecting method had passed a 120-day laboratory test without failure at the place of connection wherein the anode(s) was subjected to maximum recommended current output while immersed in 3 percent sodium chloride solution?	___	___	___
6.	Excluding the riser, were the anodes installed within 6 in. of the locations identified on the engineering drawings with regards to the water storage tank bottom and wall?	___	___	___
7.	If a riser on the water-storage tank was to be cathodically protected, was the top and bottom of the anode or anode string within ±6 in. of that identified on the engineering drawings and was the anode or anode string centered within ±10 percent of the centerline of the riser?	___	___	___
8.	Was the support system for the anode(s) in accordance with the engineering drawings?	___	___	___
9.	Were the anodes connected to the header cable(s) using the proper components and the procedures identified in the engineering drawings?	___	___	___
10.	Was the negative cable to the rectifier or direct current power source electrically connected to the water storage tank in accordance with the engineering drawings?	___	___	___
11.	If installed, was the permanently-installed, reference electrode(s) positioned within 6 in. of the location(s) identified on the engineering drawings?	___	___	___
12.	If installed, was the "sensing window" for the permanently-installed, reference electrode(s) located between 0.25 and 0.5 in. away from the tank surface? (If it is impractical for the inspector to measure the distance of the reference electrode to tank wall, the IR face or off-potential readings must be taken.)	___	___	___

	YES	NO	N/A
13. Was the rectifier mounted in accordance with the engineering drawings?	___	___	___
14. Did the grounding system for the rectifier cabinet have a resistance-to-earth of not more than 25 ohms?	___	___	___
15. If the direct current power source was a rectifier, was a dedicated alternating-current supply provided?	___	___	___
16. Was the copper conductor(s) on the anode system connected to the positive output terminal on the direct current power source?	___	___	___
17. If installed, was the anode junction and/or anode (variable) resistor box installed in accordance with the engineering drawings?	___	___	___
18. If one was installed and with the tank filled with water, were any leaks observed at the site of the pressure-entrance fitting?	___	___	___

19. Was a structure-to-water potential survey conducted for the water-storage tank before the direct current power source was activated? If so, include these data as an attachment to this report, using the format:

Test Location	Structure-to-Water Potential, Volt vs. Copper-Copper Sulfate

20. Upon activation of the direct current power source, was an IR-error-free, structure-to-water potential survey conducted to ensure that the waterside surfaces of the tank were adequately protected without overprotection? In this regard, an IR-error-free potential of -0.85 volt referenced to copper-copper sulfate is considered to be adequate protection; a potential more negative than -1.2 volts is considered to be overprotection. Attach a copy of the structure-to-water potential survey to this report, using the format:

Test Location	Structure-to-Water Potential, Volt vs. Copper-Copper Sulfate

21. If a structure-to-water potential survey was conducted after activation of the direct current power source was activated and (possibly) adjusted, what was the output voltage and output current for the direct current power source? What was the current output to each of the anode circuits?

Output Voltage: ______________________________

Current Output(s): ______________________________

22. If a structure-to-water potential survey was conducted after final adjustment of the direct current power source, record the results on a separate sheet of paper and attach it to this report.

	YES	NO	N/A
Potential Survey Conducted? ______________________	___	___	___
Survey Results Attached? ______________________	___	___	___
23. Did the contractor provide the operating instructions, maintenance instructions, spare parts, training course, and performance test report(s) for the CP system required by the contract?	___	___	___

24. Record the dates that the inspector was inside the water storage tank for the purpose of inspection:

Dates: ____

25. Record the dates that the inspector was at the job site for inspection that did not require entrance into the tank.

Dates: ____

Table A1

Segmented, Solid Cylindrical, Mixed-Metal Oxide Activated Titanium Anodes for Impressed-Current-Type Cathodic Protection Systems

Anode Length (in.)	Anode Diameter (in.)
24*	0.138
48*	0.138
72*	0.138
96*	0.138
24**	0.138
48**	0.138
72**	0.138
96**	0.138

* Solid titanium substrate
** Copper/niobium/titanium substrate

Table A2

Tubular, Mixed-Metal Oxide Activated Titanium Anodes for Impressed-Current-Type Cathodic Protection Systems in Fresh Water

Diameter (in.)	Length (in.)
1.0	39.7
1.0	39.4
0.63	19.7
0.63	39.4

Table A3

Standard Solid Cylindrical, High-Silicon Chromium-Bearing Cast Iron Anodes for Impressed-Current-Type Cathodic Protection Systems

Anode Type	Diameter (in.)	Length (in.)	Weight (lb)	Surface Area (sq ft)
B	1.0	60	12	1.4
C	1.5	60	25	2.0
CD	1.5	60	26	2.0
CDD	1.5	60	26	2.0
D	2.0	60	44	2.6
M	2.0	60	60	2.8
J	3.0	36	80	2.5
E	3.0	60	110	4.0
SM	4.5	60	220	5.5

Table A4

Tubular, High-Silicon Chromium-Bearing Cast Iron Anodes for Impressed-Current-Type Cathodic Protection Systems*

Anode Type	Outside Dia. (in.)	Length (in.)	Wall Thickness (in.)	Weight (lb)	Surface Area (sq ft)
TA1	2.66	42	0.41	31	2.4
TA2	2.19	84	0.41	46	4
TA3	2.66	84	0.41	63	4.9
TA4	3.75	84	0.41	85	6.9
TA5	4.75	84	0.41	110	8.7
TA5A	4.75	84	0.69	175	8.7

* Center connections for tubular anodes eliminates loss due to "end effects" with solid cylindrical anodes.

Table A5

Special, High-Silicon Chromium-Bearing Cast Iron Anodes for Impressed-Current-Type Cathodic Protection Systems

Anode Type	Diameter (in.)	Length (in.)	Weight (lb)	Surface Area (sq ft)
FW	1.1	9	1.0	0.2
FC	1.5	9	4.0	0.3
G	2.0	9	5.0	0.4
B-30	1.0	30	7.0	0.7
C-30	1.5	30	12.5	1.0
CD-30	1.5	30	13.0	1.0
M-30	2.0	30	30.0	1.3

Table A6

Diameters for Concentric-Lay Stranded and Solid Standard Annealed Copper Conductors

Conductor Size, AWG/MCM	Diameter, Solid Conductor (in.)*	Diameter, Stranded Conductor (in)**
350**	-	0.681
350**	-	0.630
350**	-	0.575
4/0	0.460	0.528
3/0	0.4096	0.470
2/0	0.3648	0.418
0	0.3249	0.373
1	0.2893	0.332
2	0.2576	0.292
3	0.2294	0.260
4	0.2043	0.232
6	0.1620	0.184
8	0.1285	0.146
10	0.1019	0.116
12	0.0808	0.092
14	0.0641	0.073

* Without insulation
** Thousands of circular mils (MCM)

Table A7

Insulation Thickness for Stranded and Solid Copper Conductors

Insulation Type	Conductor Size (AWG/MCM)	Insulation Thickness (in.)
Thermoplastic waterproof (TW)	10-14	0.030
	8	0.045
	6-2	0.060
	1-4/0	0.080
	213-500*	0.095
High molecular wt. Polyethylene (HMWPE)	2-8	0.110
	1-4/0	0.125
	250*	0.155
Dual ECTFE** or PVF*** primary	-	0.020
HMWPE secondary	-	0.065

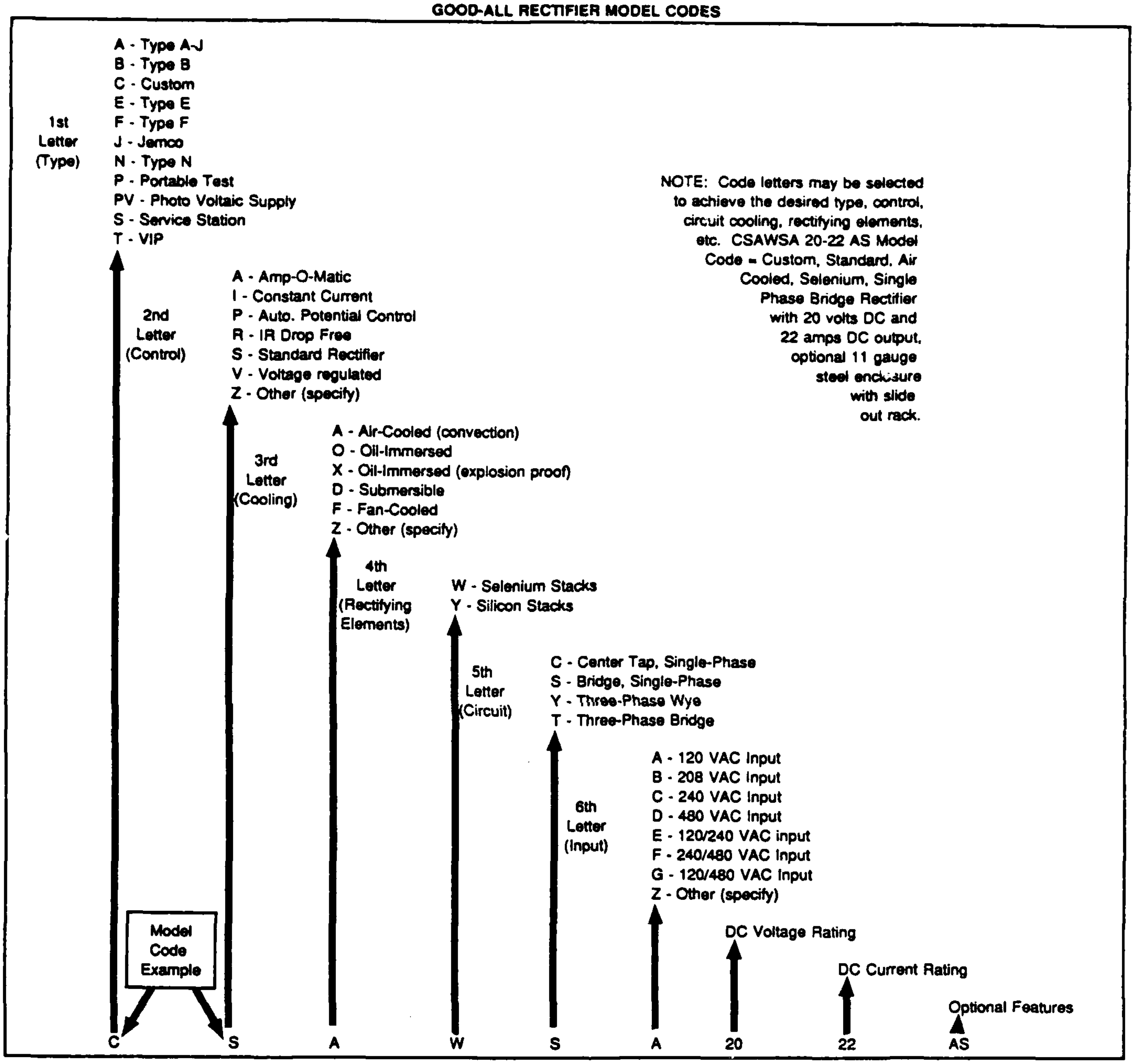
* Thousands of circular mils (MCM).
** Ethylene monochlorotrifluorethylene.
*** Polyvinylidene fluoride. Note: For dual insulation, the primary is the inner insulation; secondary is the outer insulation.

Table A8

Commonly-Used Shunts for Cathodic Protection Systems

Type	Resistance (Ohm)	Capacity (A)	Material
JB	0.01	8	Manganin strip
RS	0.01	6	Manganin wire
SO	0.001	50	Manganin wire
SS	0.001	25	Constantan strip

GOOD-ALL RECTIFIER MODEL CODES



OPTIONAL FEATURES

- A - Slide out rack for transformer & stack.
- C - Cross Arm Mounting.
- D - Legs—Air-cooled only—10" or specify.
- E - Continuous reading meters.
- F - Communication Interference filter.
- G - Efficiency filter.
- H - Other than standard number of DC Output steps (standard has 20 steps) (specify).
- J - Flashing signal light. (Continuous at normal current, flashing at undercurrent, out at loss of input.)
- K - Continuous signal light. (Out at loss of input, output or at undercurrent.)
- L - Lightning protection for AC input only.
- M - Lightning protection for DC output only.
- N - Lightning protection for both input and output.
- P - Special finishes.
- Q - Export Crating.
- R - Interrupter Circuit.
- S - Small arms proof (11 gauge front, side and back).
- T - Higher ambient temperatures (specify).
- V - Nonstandard access knockouts (specify).
- Y - Input frequency other than 60 cycle (specify).
- Z - Any other features (specify).

Figure A1: Optional Rectifier Features and the Good-All Electric, Inc. Model Code System for Determining the Characteristics of a Rectifier. (Similar Codes Have Been Established by Other Rectifier Manufacturers.) Reprinted with permission of Good-All Electric, Inc., 3725 Canal Drive, Fort Collins, CO 80524.

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