Chapter 7
Corrosion Control

7-1. Corrosive Environment of Lock Gates

Lock gates are located in river water which is a submerged corrosive environment. Corrosion causes different degrees of structural and metallic deterioration of the gates. This affects operation and repair of the gates. Adequate coating (painting) and cathodic protection with protective potential achieving minus 850 millivolts "instant off" over 90 percent of each gate leaf face will extend the life of a lock gate leaf well over 100 years. (See Plates B-75 through B-78.)

7-2. Corrosion and Corrosion Control

a. Most of the time, the locks initially perform their function in spite of frequent use, floating impact, floods, and corrosion. The lock gates (usually miter type) are vital to the locking function and require periodic maintenance in such areas as the quoin and miter blocks, diagonals, lower areas of the gate, loss of gate plumb, and loss of seals. This is caused by flooding, waterborne impact, frequent use of equipment (under pressure and high velocity), loss of protective paint, and corrosion. These problems are usually resolved with expenditures or lock replacement. Since the gates are key operating elements, failure of their function causes disruption of river traffic. Repairs and/or replacement are very expensive. Because of this loss of service and high cost of dewatering, gate repair, and painting, it is becoming more important to ensure that cathodic protection is providing protective potentials.

b. Corrosion causes the lock gates and valve gates to deteriorate, and consequently preventative maintenance is required. Many times when corrosion causes the need for maintenance it is not attributed to the corrosion process.

c. A significant number of the maintenance problems can be delayed, and even prevented, with effective coating and cathodic protection. It can be established that lock gates can be protected from the devastating effects of corrosion with proper coating and cathodic protection. While it is true that this does not place the lock gates in a perpetual state of corrosion prevention, and while it will not undo earlier deterioration due to corrosion, it is a fact that a properly maintained and adjusted cathodic protection system will decrease the need for many lock repairs and prevent the expensive lock facility from becoming obsolete by deterioration. The initial expense of installing cathodic protection and the expense of regular maintenance of the systems can easily be shown to provide a very high cost-benefit ratio.

7-3. Painting Structures

a. The primary corrosion control system for lock gates is painting. The paint protects some areas of the lock gate components. This provides some degree of corrosion protection. When paint is scratched and cut with waterborne impact, metal surfaces or holidays are exposed to the corrosive electrolyte. The base surface areas become anodes and will corrode in a concentrated area. This affects the limit states of strength and serviceability of the steel in the gates. The corroded area is manifest in operation and maintenance of lock gates.

b. The following approaches should be used to improve the painting system and ensure its durability:

(1) Determine that the surfaces to be painted have rounded edges and corners, and smooth joints.

(2) Avoid waterborne impact.

(3) Install cathodic protection to protect the exposed areas of the steel.

c. Environmental concerns have caused some restrictions on metal preparation and application of quality paints used in the past which are also presently being used when possible. The environmental concerns have resulted in poorer quality of paint on the market.

(1) Recently, a study at the Construction Engineering Research Laboratory (CERL), Champaign, Illinois, was made on a large number of different paints on the market. The paints studied represented most current approaches to painting and some new, highly touted paints that met environmental concerns.

(2) Most of these paints failed in the laboratory tests. Only a small number of the best were selected for field tests. In field tests (in water environment and submerged), these paints did not perform well when compared to paints presently being used (vinyl). Future environmental concerns will further restrict or eliminate the use of presently applied paints. Only in certain areas of several states are those restrictions in effect at this time. This, of course, emphasizes the importance of cathodic protection and painting where needed.

(3) With the advent of poorer quality paint, the proper installation and maintenance of cathodic protection will become much more critical. The paint quality for submerged metals is becoming a serious problem because of environmental controls of cleaning and painting metal. Corroded metal structures could cause unsafe and wasteful operation of facilities. Periodic inspections help to identify potential unsafe conditions, deteriorating conditions, and equipment not working. Cathodic protection equipment should be working. Periodic inspection reports on civil works structures should include the most recent dated electrolyte potential survey, condition of cathodic protection system, and plans for cathodic protection system repair and modification if required.

(4) Future emphasis on limiting dewatering of locks is another factor that increases the importance of operational cathodic protection.

7-4. Type of Cathodic Protection

a. Impressed current. Cathodic protection for lock gates should be provided utilizing Guide Specification CW-16643. Cathodic protection should be impressed current and should have good impact protection to protect the anodes from waterborne impact.

b. New techniques. Guide Specification CW-16643 provides new techniques for impact protection and for achieving operational cathodic protection systems, and addresses methods of providing protection against ice and debris, steps to increase quality construction, and training on design, installation, operation, and maintenance of cathodic protection systems.

c. Cathodic-protection testing, evaluation, and restoration. All testing, evaluation, restoration, or new installation should be supervised by a professional engineer registered in corrosion engineering, or an individual who has satisfied the requirements for accreditation as a corrosion technologist or specialist by the National Association of Corrosion Engineers (NACE). Installation of the cathodic protection systems should also be witnessed by appropriate Government representatives qualified in cathodic protection.

d. Restoration of cathodic-protection systems. Existing inoperable cathodic-protection systems at many navigation structures can be restored. This approach is less expensive than installing complete new cathodic protection systems and, therefore, should be considered first. When graphite anode strings are exhausted, they should be replaced with cast iron anode strings. In many cases anode strings can be replaced and cathodic-protection systems repaired without dewatering.

e. Complete replacement of cathodic-protection systems. Guide Specification CW-16643 should be followed when designing and installing new cathodic-protection systems or when complete replacement of cathodic-protection systems at navigation structures is found to be necessary.

7-5. Cathodic-Protection Operation

An impressed current cathodic-protection system should be provided for each gate leaf. Each system consists of a rectifier supplying protective voltages to anodes which will distribute uniform protective voltages through the river water to the submerged gate structure. Cathodic-protection should be installed on those portions of the gates submerged at normal pool levels. The faces of the gates are protected to upper pool stages, except that the downstream face of the lower gates shall be protected to the lower pool. Meters are provided as part of the rectifier for monitoring of the cathodic-protection systems. Surveillance of the rectifier output (voltage and current) is required to ensure that the rectifier unit operates on a continuous basis at the desired output levels. Voltage and current indications with the lock chambers filled provide surveillance of the rectifier and cathodic-protection operation. The cathodic-protection systems will encounter flooding and floating debris and will require impact protection to prevent damage to the cables providing voltage to the anodes.

7-6. Anode Concepts

One of two basic concepts for providing cathodic protection should be used. Method one uses cast iron button anodes on the skin plate and string type (sausage) anodes in the compartment areas. The sausage anodes and cables are protected from impact by installing them in perforated plastic pipes and in areas subject to ice and debris by installing channel and angle iron in front of each anode string. The button anode cables are protected from impact with conduit. The cast iron button anodes are more durable and can withstand impact. The second method uses cast iron button anodes in all areas.

7-7. Flooding and Emergency Maintenance

The rectifiers are portable (normally with wheels) so that during flooding conditions they may be removed and safeguarded from water or storm damage.

7-8. Cathodic-Protection Tests, Adjustments and Reports

a. Tests, adjustments, and data collection. Tests should be performed and data tabulated showing structure to reference cell potentials at a number of different points. Test data should include rectifier voltages and currents. There is no prescribed time interval for testing new systems, but as a general rule measurements should be made monthly until steady state conditions are obtained, and at about 6-month intervals thereafter for the first year or two; and thereafter at least at yearly intervals, depending on the judgment of the corrosion engineer responsible for the tests. Based upon the measurements taken, the current and voltage of the rectifier should be adjusted as required to produce a minimum of minus 850 millivolts "instant off" potential between the structure being tested and the reference cell. This potential should be obtained over 90 percent of each face of each gate leaf. This must be achieved without the "instant off" potential exceeding 1,200 millivolts. Acceptance criteria of the cathodic-protection systems are defined in the National Association of Corrosion Engineers Publication NACE RP-01-69-92.

b. Reports. Reports in a format similar to that illustrated in NACE RP-01-69-92 (see Table 7-1) of a miter gate showing the measurements made and data obtained, should be prepared and evaluated.

7-9. Measurement of Existing Cathodic-Protection Systems

The performance of existing systems should be measured annually and appropriate actions taken.

a. One structure to electrolyte potential survey (using reference cell) should be performed annually. Any system found to not be operating in accordance with established criteria should be optimized (adjusted).

b. Any cathodic protection system found to be in need of repair should be repaired.

c. A report showing the condition of the cathodic protection systems, and/or plans to repair the systems, should be submitted each year.

7-10. Cathodic Protection for Miter and Quoin Blocks

One of the most expensive maintenance problems that occurs on lock gates is corrosion of the miter and quoin blocks. This can be prevented with impressed current anode strings in the vicinity of the miter and quoin blocks. Guide Specification CW-16643 provides drawings showing anode locations I-1 anode string 2S1 and 1S1 that can provide voltage sufficient to protect the miter and quoin blocks. All areas of the miter block and push-pull rods should be painted. The area where the blocks seal against each other does not have to be painted.

Table 7-1
Steel to Reference Cell Potentials

Rectifier No. 1
UPPER GATE - LAND LEAF - UPSTREAM SIDE
(Impressed Current Installation)
REPORTS CONTROL SYMBOL ENGW-E-7
DATE OF TEST: 1 Oct. 1991

Pre-Protection				Current On			Current Off (Instant Off)		
Depth Below Water Surface	Quoin End	Middle	Miter End	Quoin End	Middle	Miter End	Quoin END	Middle	Miter End
0'-6"	-0.500	-0.505	-0.495	-1.050	-1.000	-1.055	-0.655	-0.700	-0.650**
2'	-0.500	-0.500	-0.500	-1.040	-1.030	-1.035	-0.700	-0.735	-0.705
4'	-0.500	-0.500	-0.500	-1.050	-1.085	-1.050	-0.825	-0.755	-0.815
6'	-0.500	-0.495	-0.495	-1.050	-1.100	-1.055	-0.855	-0.765	-0.850
8'	-0.495	-0.490	-0.490	-1.050	-1.085	-1.050	-0.865	-0.770	-0.850
10'	-0.490	-0.480	-0.485	-1.080	-1.110	-1.070	-0.880	-0.880	-0.850*
12'	-0.490	-0.480	-0.480	-1.070	-1.080	-1.060	-0.885	-0.880	-0.880
14'	-0.480	-0.479	-0.470	-1.070	-1.070	-1.065	-0.880	-0.885	-0.980
16'	-0.470	-0.464	-0.460	-1.000	-1.020	-1.030	-0.885	-0.890	-0.980
18'	-0.465	-0.455	-0.450	-1.000	-0.979	-1.050	-0.880	-0.885	-0.985
20'	-0.460	-0.445	-0.440	-0.950	-0.930	-1.000	-0.870	-0.875	-0.1075

Rectifier voltage = 2.10 volts
Rectifier current = 0.50 amps
Coarse tap position = L
Fine tap position = 2
Meter used 5 meg ohms/volt 2 volt scale
Half-cell 0'-3" or less from lock steel
Resistance of circuit: E = IR
2.10 = .5R
R = 2.10/.5 = 4 ohms

* Acceptable reading
** Unacceptable reading

NOTE: Include as many 2' increments as necessary to cover submerged depth of gate.