D.C. TECHNOLOGIES, INC.

155 Bovet Road, Suite 410, San Mateo, CA 94402
Telephone: (415) 312-9022 FAX: (415) 312-9024

SPECIFICATIONS FOR

D.C. TECHNOLOGIES, INC. PFGA 7-84.4 SYSTEM

POLYFLEX FLAKE GLASS ARMOR APPLICATION

PROCESS FOR THE REPAIR AND LINING

OF ABOVE AND UNDER GROUND FUEL STEEL AND

COMPOSITE STORAGE TANKS

INTRODUCTION

This brochure explains in detail the specifications of **D.C. TECHNOLOGIES, INC. POLYFLEX FLAKE GLASS ARMOR** application process for interior repair and lining of above and under ground fuel steel and composite storage tanks. Specific subject areas include:

I. Theory of **POLYFLEX FLAKE GLASS ARMOR** application process.

II. Operational sequence of **POLYFLEX FLAKE GLASS ARMOR** application process.

III. Material Specifications For **POLYFLEX FLAKE GLASS ARMOR** (PFGA) 7-84.4 System.

I. <u>THEORY OF THE POLYFLEX FLAKE GLASS ARMOR APPLICATION PROCESS</u>.

To maintain long term service integrity of storage tank facilities for the immersion of liquids, the influence of chemical and physical conditions must be recognized and treated. The following are relevant chemical conditions in liquid storage tank maintenance which effect the chemical aspects of the tank.

1. Type of liquid being stored.
2. Service Conditions:
    a. Immersion or constant flow.
    b. Intermittent or spillage.
    c. Fumes only
3. The operating temperature range.
4. Material composition of the tank.
5. Chemicals externally affecting external tank material composition.

Physical conditions affecting the structural integrity of the tank as it relates to its function include the following:

1. Design criteria.
2. Flexibility in:
    a. Loading.
    b. Unloading.
    c. Operation.
    d. External shock.

3. Stress, strain loads created:

    a. In manufacturing.

    b. In installation.

    c. In use.

4. Impact corrosion.

In the field of above and under ground fuel storage tanks, problems caused by physical and chemical conditions manifest themselves in the form of product loss or water contamination of product. Better than 98% of all problems with steel fuel storage tanks originate from chemical reactions causing exterior and interior corrosion. Examples of these causes are; electrolysis, impact corrosion and sediment and water deposits at the bottoms of the tanks. The balance of steel tank problems are caused by physical reactions such as tank splits due to stress strain loads, which present themselves over time by leaks.

Composite tanks properly manufactured and installed are an ideal environment chemically and physically for fuel storage. The major reason to interior line a composite tank is to make it alcohol fuel compatible if it is not already, thereby relieving all possible chemical problems

All these chemical problems must be relieved in steel and composite tanks to achieve long-term service integrity of the underground storage.

D.C. TECHNOLOGIES, INC. POLYFLEX FLAKE GLASS ARMOR application process achieves this goal safely and adequately by repairing and chemically lining the entire interior and cathodically protecting the exterior of the underground tank with specialized methods and materials. The procedure for the **POLYFLEX FLAKE GLASS ARMOR** PFGA 7-84.4 SYSTEM includes the following phases:

1. ISOLATING THE TANK.
2. STRIPPING THE TANK OF ALL LIQUID.
3. PURGING THE TANK OF VAPORS.
4. CUTTING INTO THE TANK.
5. CLEANING AND PREPARING THE TANK
6. REPAIRING THE TANK.
7. SANDBLASTING THE TANK.
8. SECURING THE TANK.
9. CLEANING THE TANK FOR LINING OPERATIONS.
10. PRIMING THE SURFACES OF THE TANK.
11. LINING THE TANK.
12. INSPECTION OF THE LINING.
13. SEALING THE TANK.
14. CATHODIC PROTECTION.

II. OPERATIONAL SEQUENCE OF THE POLYFLEX FLAKE GLASS ARMOR APPLICATION PROCESS.

This section details the requirements, procedures and operating conditions of the **POLYFLEX FLAKE GLASS ARMOR** application process. All work is done in accordance with applicable local codes, plus Federal Occupational Safety & Health Administration Codes. Approval from local authorities is obtained prior to the commencement of work.

1. ISOLATING THE TANK FOR WORK.

Initially the tank is isolated to prevent the infiltration of petroleum product liquids or vapors.

2. STRIPPING THE TANK OF ALL LIQUID.

Secondarily the tank is emptied of all product. Some liquid residue usually remains due to; the inadequacy of a transfer pump to empty the tank, leaks that continually contaminate the interior of the tank and/or by the pitch of the tank trapping liquids at the bottom. This remaining portion of product is removed using an explosion-proof diaphragm air operated pump having the capability of pulling a 20 foot dry head. A small quantity of water is sometimes pumped into the underground tank to float any remaining gasoline from any low spots which exist in the tank.

3. **PURGING THE TANK OF FLAMMABLE VAPORS.**

To free the tank of gasoline vapor, fresh air is circulated through its fill opening and allowed to escape through its respective vent until the quality of the air within the tank is below the lower flammable limit (LFL) for gasoline vapor, which is 10% by volume. During this operation, all sources of ignition are removed from the vent area. The purging operation does not commence if the direction of the wind in respect to the vent opening can carry the escaping vapors to areas that could produce a hazardous condition. Ventilation of the tank is accomplished by use of an explosion-proof (EP) blower or air mover, which is capable of moving 750 cfm at 10 inches of water column. This type of apparatus prohibits any static electrical build-up. The EP blower or air mover is utilized throughout the entire **POLYFLEX FLAKE GLASS ARMOR** application process. Monitoring of the quality of vapor/air mixture escaping at the vent is done by a combustible gas indicator, such as the Mine Safety Appliance Explosive Meter, Model 5. The testing procedure is detailed in the manufacturer's instruction manual and includes the following steps:

1. TURNING ON THE APPARATUS.
2. CHECKING AND ADJUSTING VOLTAGE.
3. CALIBRATING.
4. SELECTING CORRECT RANGE (IF APPLICABLE).
5. PLACING OF PROBE.

6. MONITORING QUALITY.

7. CLEARING PROBE.

8. TURNING OFF APPARATUS.

Once a safe reading is achieved at the vent opening, readings at the fill opening are then taken.

These readings are taken at different levels inside the tank insuring against the existence of any explosive vapor pockets. After the tank is thoroughly purged of flammable vapors or any residue capable of producing flammable and all readings by the combustible gas indicator are maintained below the LFL, a safe working atmosphere within the tank is achieved.

4. CUTTING INTO THE TANK.

A typical underground fuel storage tank has no manway to enter its interior, therefore, one must cut into the tank in order to work within. In the **POLYFLEX FLAKE GLASS ARMOR** application process, one hole is first opened through the top of the tank and the combustible gas indicator probe is placed through this opening. The explosion qualities are again checked at different levels in the tank. Once it is assured the LFL is 10% or less is achieved throughout the tank the cutting opening of the tank is then completed.

The manway is cut approximately 24" x 24" in size by an air-operated hammer. During the entire opening operation, the EP blower or air mover continuously purges the tank. After the tank has been cut into, a workman with positive fresh air face mask equipment enters the tank to make further tests to assure that the tank vapors are below the proper LFL limits.

5. CLEANING AND PREPARING THE TANK.

Once a safe access to the tank's interior is procured, it is cleaned and prepared for sandblasting and lining operations. All sludge is removed by being shoveled into plastic containers which are bucketed out of the tank. The remaining moisture is gathered by a mineral absorbent and shoveled out in the same manner as the sludge. CAUTION: This sludge is considered hazardous waste and by State and Federal law it is mandatory that it be disposed of properly in approved three (3) ring drums with an EPA number identifier. NOTE: All hazardous waste removed from underground tanks always remains the service station owner's property as identified on the EPA paper work. For more clarification see notes in the contract quotation. During the cleaning operation, the workmen are supplied with fresh air through a face mask served by a continuous supply of positive air and wearing protective clothing. In addition, the EP blower or air mover is in continuous operation during the cleaning phase, replacing the air in the tank at a minimum of every two minutes. Once the tank is cleaned out, a thorough check is made to insure no liquid or fumes are re-entering the tank. Allinlets are secured, foot valves and submergible lines are removed, plugged, or covered tightly during sandblasting and lining operations.

6. REPAIRING THE TANK.

If liquid is seeping into the tank, this phase allows for the location, containment, and repair of these leaks. After locating the leak, the moisture is contained by the use of water plug material. This material cures water tight in the presence of liquid and is used to contain the moisture until the **POLYFLEX FLAKE GLASS ARMOR 157 MAXHESIVE** patching material is applied, bonded, and cured for permanent repair.

Once the moisture is contained, the surrounding substrate area is mechanically cleaned to white metal. After this area is dried and dusted, **POLYFLEX FLAKE GLASS ARMOR 157 MAXHESIVE** patching material is then applied to permanently repair the leak. This material is specially designed for this type of application, being of a trowel consistency. **POLYFLEX FLAKE GLASS ARMOR 157** specifications are detailed in Section III, Material Specifications.

The EP blower or air mover is in continuous operation during the repair phase.

7. SANDBLASTING THE TANK.

To insure proper bonding of the lining material for immersion service, it is mandatory to remove all rust, scale, and foreign material from the interior substrate. This is done by sandblasting to gray metal in accordance with Steel Structures Painting Council 5-63 or NACE Specifications #1 with a minimum of 150 cfm at 100 PSI continuous air supply.

The sandblasting specifications will provide between a 1 to 2 ml. profile penetration into the steel substrate. For composite tanks the profile penetration must be between 3 and 4 mils.

Not only is the entire interior of the tank sandblasted, but also the exterior area surrounding the tank opening and the sealing cover plate.

8. SECURING THE TANK.

After sandblasting, new leaks sometimes occur. If this takes place, they are treated in the same manner as outlined in Phase 6. Following the patch work, the surrounding area is reinspected and brought up to sandblasting specifications if needed.

The EP blower or air mover is in continuous operation during the securing phase.

9. CLEANING THE TANK FOR LINING OPERATIONS.

To insure proper bonding of the lining material to the steel substance, all dust, dirt and foreign particles resulting from sandblasting and/or work within the tank must be removed. This is accomplished by carefully cleaning the steel substrate by brushing, blowing off with oil and moisture free compressed air and/or vacuum cleaning.

10. PRIMING OF THE TANK SURFACES.

The primer is only needed if the first coat of lining material cannot be applied with five hours of sandblasting. The material used for the priming is **POLYFLEX FLAKE GLASS ARMOR 137** which is specifically designed as an undercoat primer for fuel storage tanks to be lined with **POLYFLEX FLAKE GLASS ARMOR 177.** The **POLYFLEX FLAKE GLASS ARMOR 137** is spray applied and is totally cured controlled for varying atmosphere conditions by a separate catalyst injection system. The function of the primer coat is to secure the sandblast cleaning from atmospheric visual and non-visual rusting so as to effectively secure the optimum bonding system for the **POLYFLEX FLAKE GLASS ARMOR 177** tank lining material. The EP blower or air mover is in continuous operation during the primary phase.

11. LINING THE TANK.

The Hi-Build lining operations proceed when the primer coat is properly cured. The material used for the Hi-Build lining is **POLYFLEX FLAKE GLASS ARMOR 177** lining material which is specifically designed as an interior lining for steel and composite above and under ground fuel storage tanks. **POLYFLEX FLAKE GLASS ARMOR 177** is spray applied and is totally cure controlled for varying atmosphere conditions by a separate catalyst injection system to a thickness of 125 mils. minimum. Quality control for applying the 125 minimum thickness for the tank lining operations is accomplished by applying alternately light and dark coats of the **POLYFLEX FLAKE GLASS ARMOR 177** tank lining material in a minimum of three (3) to four (4) spray applications. Since curing is totally controlled, successive applications can be applied covering light surfaces with a dark coat and the dark surfaces with a light coat maintaining the thickness standards.

The EP blower or air mover is in continuous operation during the Tank Lining of the tank.

12. INSPECTION OF THE LINING.

After proper cure and prior to sealing the tank, there is an inspection for thickness, and monolithic integrity. Thickness is checked with a Biometer thickness gauge, while the overall integrity of the cured properties is checked by a BARCOL hardness tester.

The EP blower or air mover is in continuous operation during the inspection phase.

13. SEALING THE TANK.

To seal the tank, an over-sized curved steel plate is bolted and sandwiched with **POLYFLEX FLAKE GLASS ARMOR 157** to the underground tank. The cover plate has a minimum of 2" total overlap around the tank opening parameter and is rolled to the contour of the underground tank.

14. CATHODIC PROTECTION.

To arrest any further exterior corrosion of the steel tank and/or steel piping, cathodic protection can be installed. Some local authorities require cathodic protection when any tank's interior is coated. The amount of steel to be protected and the resistivity of the soil surrounding the tank(s) determines the type of cathodic system to be installed - either Galvanic (self-current) or Rectifier (outside current). Both systems involve placing anodes in the ground around the tanks and/or pipes designed to protect them for up to 20 years. These anodes are electrically connected to the tank and create an electrical field which protects the outside surface of the underground steel storage tanks and/or piping.

III. MATERIAL SPECIFICATIONS

The essential features of the repair and lining with the **POLYFLEX FLAKE GLASS ARMOR (PFGA) 7-84.4 SYSTEM** are their cured chemical and physical properties of the materials used for above and under ground fuel storage tanks.

The properties of the **POLYFLEX FLAKE GLASS ARMOR 7-84.4 SYSTEM** relieve all the chemical conditions outlined in Section I for above and under ground tank(s) to insure long-term immersion service integrity. The **POLYFLEX FLAKE GLASS ARMOR 157** for repair work, **POLYFLEX FLAKE GLASS ARMOR 137** for priming operations and **POLYFLEX FLAKE GLASS ARMOR 177** for the Hi-Build lining work achieve this goal in concert with their respective hand lay-up and spray-on operations.

The chemical resistance of **POLYFLEX FLAKE GLASS ARMOR 137, 157** and **177** is excellent with aromatic fuels, salts and water. All these materials are flake reinforcement and make the cured material extremely tough and impermeable. Further, the materials are formulated from a blend of specially developed and tested resins and ingredients which effects a high yield of flexibility for the materials cured state, thus yielding a remarkably high resistance to the cracking below the permanent deformation point of steel with superior adhesion and excellent resistance to undercutting (which is lining separation from its substrate). This quality of flexibility in the **POLYFLEX FLAKE GLASS ARMOR SYSTEM** is in contrast to the properties that conventional cured coatings realize as being relatively "brittle" and thus subject to cracking and adhesion problems over time and throughout their curing process.

Over 25 years of experience of **D.C. TECHNOLOGIES.**, personnel in the field of above and under ground tank lining and chemical interior coating systems enables the **POLYFLEX FLAKE GLASS ARMOR 7-84.4 SYSTEM** to evolve with its construction of flake glass and specially formulated flexible resins to overcome all the inherent, undesirable qualities of a conventional lining system associated with shrinkage of curing and cracking in service.

PRODUCT DATA

POLYFLEX FLAKE GLASS ARMOR 137 PRIMER (PFGA - 137)

TYPE OF MATERIAL

POLYFLEX FLAKE GLASS ARMOR 137 is a thin flexible, medium reactivity, premium chemical resistent epoxy novolac-based vinyl resin reinforced with inert laminar flake particles. It is promoted for ambient temperature controlled curing and heat curing in cold temperatures.

MAJOR USE

Hand spray-up as an interior primer for the interior of above and under ground steel and composite storage tanks in use with constant immersion storage of aromatic fuels.

SPECIFICATIONS OF UNCURED POLYFLEX FLAKE GLASS ARMOR 137

Viscosity	700-1000 CPS
Weight per Gallon	10.3 Lbs.
Solids	100% by Volume

PROPERTIES OF CURED POLYFLEX FLAKE GLASS ARMOR 137

Hardness - BARCOL	20 minimum
Service Temperature Limit - West Continuous	130 Degrees F
Lining Thickness	2-4 Mils

CURING

POLYFLEX FLAKE GLASS ARMOR 137 requires catalyzation with MEK peroxide to effect curing. In temperatures below 35 Degrees F outside air temperature it is mandatory that the material be batch heated before and during application.

POT LIFE

The following table provides the approximate gel time at various temperatures and catalyst levels:

% MEK Peroxide	Gel Time at 50 F. Min	Gel Time at 77 F. Min	Gel Time at 90 F Min
1.0	15-20	7-12	2-5
0.5	25-50	15-35	7-12
0.25	50-70	35-55	25-20

STEEL SUBSTRATE PREPARATION

For sandblast to steel structures Painting Council SP-5-63.

PRODUCT DATA

POLYFLEX FLAKE GLASS ARMOR 157 MAXHESIVE (PFGA - 157)

TYPE OF MATERIAL

POLYFLEX FLAKE GLASS ARMOR 157 is a Hi-Build flexible thermosetting, premium chemical resistent epoxy novolac-based vinyl ester resin reinforced with inert laminar flake particles. It is promoted for ambient temperature controlled curing and heat curing in cold temperatures.

MAJOR USE

Hand lay-up for repair and sealing of above and under ground steel and composite tanks for aromatic fuel storage. Applied to seal up lap seams and leaks located within the tank.

SPECIFICATIONS FOR UNCURED POLYFLEX 157

Viscosity	Trowel Consistency
Weight per Gallon	13.2 lbs.
Solids	Volume Solids

PROPERTIES OF CURED POLYFLEX FLAKE GLASS ARMOR 157

Service Temperature Limit - Wet Continuous	140 Degrees F
Immersion Service	24 Hours
Thickness	0.5 to 2.0 inches

CURING

POLYFLEX FLAKE GLASS ARMOR 157 requires only catalyzation with MEK peroxide to effect curing. In temperatures below 35 Degrees F outside air temperature it is mandatory that the material be batch heated before application.

POT LIFE

The following table provides the approximate gel time at various temperatures and catalyst levels.

% MEK Peroxide	Gel Time at 50 F. Min	Gel Time at 77 F. Min	Gel Time at 90 F. Min
1.0	15-20	7-12	2-5
0.5	25-50	15-35	7-12
0.25	50-70	35-55	15-20

STEEL SUBSTRATE PREPARATION

For immersion service, sandbl[illegible]t to Steel Structures Painting Council SP-5-63.

PRODUCT DATA

POLYFLEX FLAKE GLASS ARMOR 177 TANK LINING MATERIAL (PFGA - 177)

TYPE OF MATERIAL

POLYFLEX FLAKE GLASS ARMOR 177 is a Hi-Build flexible thermosetting premium chemical resistent epoxy novolac-based vinyl resin reinforced with inert laminar flake particles. It is promoted for ambient temperature controlled curing and heat curing in cold temperatures.

MAJOR USE

Constant hand spray-up for interior lining of above and under ground steel and composite storage tanks in use with constant immersion storage of aromatic fuel.

SPECIFICATIONS FOR UNCURED POLYFLEX FLAKE GLASS ARMOR 177

Viscosity	3500-4000 CPS
Weight Per Gallon	12.8 - 12.9 lbs.
Solids	100% Volume Solids

PROPERTIES OF CURED POLYFLEX FLAKE GLASS ARMOR 177

Hardness - BARCOL	5-40
Tensile Strength	2700 PSI
Service Temperature Limit - Wet Continuous	130 Degrees F
Lining Thickness	125 Mils min.
Immersion Service	12 Hours

CURING

POLYFLEX FLAKE GLASS ARMOR 177 requires only catalyzation with MEK peroxide to effect curing. In temperatures below 35 Degrees F outside air temperature it is mandatory that the material be batch heated before application.

POT LIFE

The following table provides the approximate gel time at various temperatures and catalyst levels.

% MEK Peroxide	Gel Time at 50 F. Min	Gel Time at 77 F. Min	Gel Time at 90 F. Min
1.0	15-20	7-12	2-5
0.5	25-50	15-35	7-12
0.25	50-70	35-55	15-20

SUBSTRATE PREPARATION

Prior to application the substrate must be sandblasted to steel structures Painting Council SP-5-63 and then coated with **POLYFLEX FLAKE GLASS ARMOR PRIMER 137** if not completed with the sandblasting operations within five hours of the first coat of lining material.

D.C. TECHNOLOGIES, INC.

155 Bovet Road, Suite 410, San Mateo, California 94402
Telephone: (415) 312-9022 FAX: (415) 312-9024

CATHODIC PROTECTION SPECIFICATIONS

CECUT 37-87.5 SYSTEM

DESIGN & INSTALLATION OF CRITERIA FOR

CATHODIC PROTECTION OF UNDERGROUND STORAGE TANKS

SECTION 1: Design of Cathodic Protection Systems

I. INTRODUCTION

A. The purpose of this section is to recommend procedures for designing cathodic protection systems which will provide effective corrosion control and which will exhibit maximum reliability over the intended operating life of the systems.

B. In the design of a cathodic protection system, the Corrosion Engineer's responsibilities should include the following:

1. Recognition of hazardous conditions prevailing and the proposed installation site(s) and the selection and specification of materials and installation practices which will assure the safe installation and operation of the cathodic protection system.

2. Specification of materials and installation practices to conform with applicable codes, National Electrical Manufacturers Association (NEMA) Standards, and Recommended Practices of the National Association of Corrosion Engineers.

3. Selection and design of the cathodic protection system for optimum economy of installation, maintenance, and operation.

4. Selection and specification of materials and installation practices which will assure dependable operation throughout the intended operating life of the cathodic protection system.

5. Selection of a system to minimize excessive protective currents or earth potential gradients, which can cause detrimental effects on pipe, coating, or neighboring buried or submerged metallic structures.

II. MAJOR OBJECTIVES OF CATHODIC PROTECTION SYSTEM DESIGN

A. Deliver sufficient current to the structure to be protected and distribute this current so that the selected criterion(a) for cathodic protection is (are) efficiently attained.

B. Minimize the interference currents on neighboring underground structures.

C. Provide a design life of the anode system commensurate with the required life of the protected structure, or provide for periodic rehabilitation of the anode system.

D. Provide adequate allowance for anticipated changes in current requirements with time.

E. Placement of anodes where the possibility of disturbance or damage is minimal.

III. INFORMATION USEFUL FOR DESIGN

A. Piping system specifications and practices

1. Route maps and atlas sheets
2. Construction dates
3. Pipe, fittings, and other appurtenances
4. Coatings
5. Casings
6. Electrically insulating devices
7. Electrical bonds
8. Aerial, bridge, and underwater crossings

B. Piping system site conditions

1. Existing and proposed cathodic protection systems
2. Possible interference sources
3. Special environmental conditions
4. Neighboring buried metallic structures
5. Structure accessibility
6. Power availability
7. Feasibility of electrical isolation from foreign structures

C. Field survey, corrosion test data, and operating experience

1. Protective current requirements to meet applicable criteria
2. Electrical resistivity of the electrolyte
3. Electrical continuity
4. Electrical isolation
5. Coating integrity
6. Interference currents

D. Field survey work prior to actual application of cathodic protection is always required to establish current requirements, electrical resistivities of the electrolyte, and other design factors.

IV. TYPE OF CATHODIC PROTECTION SYSTEMS

A. Impressed current anode systems is the only approved method

1. Impressed current anodes can be materials such as graphite, high silicon cast iron, lead-silver alloy, platinum, or scrap steel. These anodes are installed in the soil or water either bare or in special backfill material. They are connected with an insulated conductor either singly or in groups to the positive terminal of a direct current source, such as a rectifier or generator. The protected structure is connected to the negative terminal of the direct current source.

V. FACTORS DETERMINING ANODE CURRENT OUTPUT, OPERATING LIFE, AND EFFICIENCY

A. Various anode materials have different rates of deterioration when discharging a given current density from the anode surface in a specific environment. Therefore, for a given current output, the anode life will depend on the anode material as well as the anode weight and the number of anodes in the cathodic protection system. Established anode performance data may be used to calculate the probable deterioration rate.

B. Data on the dimensions, depth, and configuration of the anodes and electrolyte resistivities may be used to calculate the resultant resistance-to-electrolyte of the anode system.

C. The number of impressed current anodes required can be reduced and their useful life lengthened by the use of special backfill around the anodes. The most common materials are coal coke, calcined petroleum coke, natural or manufactured graphite, and breeze.

D. In the design of an extensive distributed impressed current anode system, the voltage and current attenuation along the anode connecting wire should be considered. In such cases, the design objective is to optimize anode system length, anode spacing and size, and conductor size in order to achieve efficient corrosion control at the extremities of the protected structure.

E. Where it is anticipated that entrapment of gas generated by anodic reaction could impair the ability of the impressed current groundbed to deliver the required current, suitable provision should be made for venting the anodes. An increase in the number of anodes may reduce gas blockage.

F. Where it is anticipated that electro-osmotic effects could impair the ability of the impressed current groundbed to deliver the required current output, suitable provisions should be made to ensure adequate soil moisture around the anodes. Increasing the number of impressed current anodes may further reduce the electro-osmotic effect.

VII. DESIGN DRAWINGS AND SPECIFICATIONS

A. A suitable drawing will be prepared to designate the overall layout of the protected structure to be protected and the location of significant items of structure hardware, corrosion control test stations, electrical bonds, electrical insulators, and neighboring buried or submerged metallic structures.

B. The layout drawing should be prepared for each impressed current cathodic protection installation, showing the details and location of the components of the cathodic protection system with respect to the protected structure(s) and to major physical landmarks. These drawings should include right-of-way information.

C. Specifications should be prepared for all materials and installation practices which are to be incorporated in construction of the cathodic protection system.

SECTION 2: Installation of Cathodic Protection Systems

I. INTRODUCTION

A. The purpose of this section is to recommend procedures that will result in the installation of cathodic protection systems that achieve protection of the structure.

II. CONSTRUCTION SPECIFICATIONS

A. All construction work performed on cathodic protection systems should be done in accordance with construction drawings and specifications.

III. CONSTRUCTION SUPERVISION

A. All construction work performed on cathodic protection systems should be under the surveillance of trained and qualified personnel to verify that the installation is made in strict accord with the drawings and specifications. Exceptions may be made only with the consent of the Corrosion Engineer.

B. All deviations from construction specifications should be noted on as-built drawings.

IV. IMPRESSED CURRENT SYSTEM

A. Inspection and handling

1. The rectifier or other power source should be inspected for assurance that internal connections are mechanically secure and that no damage is apparent. Rating of the direct current power source should comply with construction specifications. Care should be exercised in handling and installing.

2. Impressed current anodes should be inspected for conformance to specifications, as to correct anode material and size, length of lead wire, and that cap is secure if used. Care should be exercised to avoid cracking or damaging anodes during handling and installation.

3. Lead wire should be carefully inspected to detect defects in insulation. Care should be taken to avoid damage to insulation on wire. Defects in the lead wire must be repaired or the anode must be rejected.

4. Anode backfill material should conform to specifications.

B. Installation provisions

1. Rectifier or other power source should be installed so that possibility of damage or vandalism is minimized.

2. Wiring to rectifiers shall comply with local and national electrical codes and requirements of utility supplying power. An external disconnect switch or circuit breaker on a-c wiring should be provided. Rectifier case shall be properly grounded.

3. Impressed current anodes can be buried vertically, horizontally, or in deep holes as indicated in construction specifications. Backfill material should be placed to assure that there are no voids around anodes. Care should be exercised during backfilling to avoid damage to the anode and wire.

4. The conductor (negative lead wire) to the protected structure should be connected as in VI Conductor connections to the rectifier must be mechanically secure and electrically conducive. Before the power source is energized, it must be verified that the negative conductor is connected to the structure to be protected and that the positive conductor is connected to the anodes. After the direct current power source has been energized by authorization of the Corrosion Engineer, suitable measurements should be made to verify that these connections are correct.

5. Underground splices on header cable (positive lead wire) to groundbed should be kept to a minimum. Connections between header cable and conductors from anodes should be mechanically secure and electrically conductive. All buried or submerged, wiring and connections must be sealed in metal conduit to prevent moisture penetration so that electrical isolation from the environment is assured.

V. CORROSION CONTROL TEST STATIONS, CONNECTIONS, AND BONDS

A. Installation provisions

1. Pipe and test lead wires should be clean, dry, and free of foreign materials at points of connection when the connections are made. Connections of test lead wires to the protected structure must be installed so they will remain mechanically secure and electrically conductive.

2. All test lead wire attachments and all bared test lead wires should be coated with an electrically insulating material. Where the protected structure is coated, the insulating material should be compatible with the pipe coating and wire insulation.

3. Conductors should be color coded or otherwise permanently identified. Wire should be installed with slack. Damage to insulation should be avoided, but repairs should be made if damage occurs. Test leads should not be exposed to excessive heat and sunlight. If test stations are flush with the ground, adequate conductor slack should be provided within the test station to facilitate test connections.

4. Conductor connections at bonds to other structures or across insulating joints should be mechanically secure, electrically conductive, and suitably coated. Bond connections should be accessible for testing.

VI. OTHER CONSIDERATIONS

A. Casing installations

1. Sufficient inspection should be made for assurance that no metallic contacts exist or are likely to develop between casing and the protected structure.

B. Insulating devices

1. Inspection and electrical measurements should assure that electrical isolation is adequate.

SECTION 3: Control of Interference Currents

I. INTRODUCTION

A. The purpose of this section is to recommend practices for the detection and control of interference currents. The mechanism and detrimental effects are described.

II. MECHANISM OF INTERFERENCE CURRENT CORROSION (STRAY CURRENT CORROSION)

A. Interference current corrosion on buried or submerged metallic structures differs from other causes of corrosion damage in that the direct current, which causes the corrosion, has a source foreign to the affected structure. Usually the interfering current is collected from the electrolyte by the affected structure from a direct current source not metallically bonded to the affected structure.

1. Detrimental effects on interference currents usually occur at locations where the currents are discharged from the affected structure to the electrolyte.

2. Amphoteric metal structures such as aluminum and lead may be subject to corrosion damage from a build-up of alkalinity at or near the metal surface collecting interference currents.

3. Coatings may become disbanded at the area where voltage gradients in the electrolyte force current onto the affected structure. This interference effect, of itself, is not considered damaging to non-amphoteric metals. However, as the coating becomes disbanded, more area of metal will be exposed. This can increase the demand for cathodic protection current and may create shielding problems.

B. The severity of corrosion (metal loss) resulting from interference currents depends on several factors:

1. Separation and routing of the interfering and affected structures and location of the interfering current source.

2. Magnitude and density of the current.

3. Quality of the coating, or absence of a coating on the structures involved.

4. Presence and location of mechanical joints have high electrical resistance.

C. Sources of interference currents

1. Constant current: These sources have essentially constant direct current output, such as cathodic protection rectifiers and thermo-electric generators.

2. Fluctuating current: These sources have a fluctuating direct current output such as direct current electrified railway systems, coal mine haulage systems and pumps, welding machines, direct current power systems, and telluric currents.

III. DETECTION OF INTERFERENCE CURRENTS

A. During corrosion control surveys, personnel should be alert for electrical or physical observations which could indicate interference from a neighboring source.

1. Structure-to-soil potential changes on the affected structure caused by the foreign direct current source.

2. Changes in line current magnitude or direction caused by the foreign direct current source.

3. Localized pitting in areas near to, or immediately adjacent to, a foreign structure.

4. Breakdown of protective coatings in a localized area near an anode bed or near any other source of stray direct current.

B. In areas where interference currents are suspected, appropriate tests should be conducted. Any one or combination of the following test methods can be employed.

1. Measurement of structure-to-soil potentials with recording or indicating instruments.

2. Measurement of current flowing on the structure with indicating or recording instruments.

3. Measurement of the variations in current output of the suspected source of interference current and correlation with measurements obtained.

IV. GENERAL METHODS FOR RESOLVING INTERFERENCE CORROSION PROBLEMS. (It should be understood that interference problems are individual ones).

A. Prevention of the pick-up or limitation of the flow of interfering current through a buried or submerged metallic structure.

B. Removal of the detrimental effects of interfering current from a buried metallic structure by means of a metallic conductor connected to the return (negative) side of the interfering current source.

C. Counteraction of the effect of interfering current by means of cathodic protection.

D. Removal or relocation of interfering current source.

V. SPECIFIC METHODS OF RESOLVING INTERFERENCE CORROSION PROBLEMS. (These methods may be used individually or in combination).

A. Design and installation of metallic bonds of proper resistance between the affected structures is a common technique of interference control. The metallic bond electrically conducts interference current from an affected structure to the interfering structure and/or current source.

1. Uni-directional control devices, such as diodes or reverse current switches, may be required in conjunction with metallic bonds if fluctuating currents are present. These devices prevent reversal of current flow.

2. A resistor may be necessary in the metallic bond circuit to control the flow of electrical current from the affected to the interfering structure. At the proper bond resistance, the discharge of interfering current from the structure to electrolyte is stopped.

3. If cathodic protection exists on the interfering structure, the attachment of metallic bonds can reduce the magnitude of protective voltage. Supplementary cathodic protection may then be required on the interfering structure to compensate for this effect.

4. A metallic bond may not perform properly in the case of a cathodically protected, bare, or poorly coated pipeline which is causing interference on a coated pipeline. A metallic bond may increase the current discharge. Coating the bare pipe or installing local galvanic anodes on the coated pipe may reduce the interference effects.

B. Cathodic protection current can be applied to the affected structure at those locations where the interfering current is being discharged. This discharge will usually occur at locations where the structures are in proximity. Anodes should be placed immediately adjacent to that portion of the affected structure that is discharging current.

1. The source of cathodic protection current may be galvanic or impressed current anodes.

2. The amount of cathodic protection current should be adjusted to restore either the original or protective potential level, whichever is less negative.

C. Adjustment of the current output from mutually interfering cathodic protection rectifiers may resolve interference problems.

D. Relocation of the groundbeds of cathodic protection rectifiers can reduce or eliminate the pick-up of interference current on nearby structures.

E. Re-routing of proposed pipelines may avoid sources of interference current.

F. Properly located insulating fittings in the affected structure may reduce or resolve interference problems.

G. Application of coating to strategic area(s) may reduce or resolve interference problems by decreasing the circuit conductance.

VI. METHODS TO INDICATE RESOLUTION OF INTERFERENCE

A. Restoration of the original structure-to-soil potentials of the affected structure to those values which existed prior to the interference.

B. Measurement of line currents on the affected structure to ensure that interference current is not being discharged to the electrolyte.

SECTION 4: Operation and Maintenance of Cathodic Protection Systems

I. INTRODUCTION

A. The purpose of this section is to designate procedures and practices for energizing and maintaining continuous effective and efficient operation of cathodic protection systems.

1. Electrical measurements and inspections are necessary to determine that protection has been established according to applicable criteria and that each part of the cathodic protection system is operating properly. Conditions which affect protection are subject to change with time. Corresponding changes are required in the cathodic protection system to maintain protection. Periodic measurements and inspection are necessary to detect changes in the cathodic protection system. Conditions may exist where operating experience indicates that surveys and inspections be made more frequently than recommended herein.

B. Care should be exercised in selecting the location, number, and type of electrical measurements used to determine the adequacy of cathodic protection.

II. A SURVEY SHOULD BE CONDUCTED AFTER EACH CATHODIC PROTECTION SYSTEM IS ENERGIZED TO DETERMINE IF IT SATISFIES APPLICABLE CRITERIA AND OPERATES EFFICIENTLY. THIS SURVEY SHOULD INCLUDE ONE OR MORE OF THE FOLLOWING TYPE MEASUREMENTS:

A. Pipe-to-soil potential.

B. Earth current.

C. Structure-to-structure potential.

D. Line current.

III. Periodic surveys to assure the continuity of cathodic protection are suggested as follows:

A. An annual survey should be conducted where cathodic protection of the entire piping system is the objective.

B. Surveys should be conducted at intervals of five years on structures where localized protection is the objective.

IV. INSPECTION AND TESTS OF CATHODIC PROTECTION FACILITIES SHOULD BE MADE TO ASSURE THEIR PROPER OPERATION AND MAINTENANCE AS FOLLOWS:

A. All sources of impressed current should be checked at intervals of two months. Evidence of proper functioning may be current output, normal power consumption, a signal indicating normal operation, or satisfactory electrical state of the protected structure.

B. All impressed current protective facilities should be inspected annually as part of a preventative maintenance program to minimize in-service failures. Inspections may include a check for electrical shorts, ground connections, meter accuracy, efficiency, and circuit resistance.

C. Reverse current switches, diodes, and interference bonds, whose failure would jeopardize structure protection, should be inspected for proper functioning at intervals of two months.

D. The effectiveness of insulating fittings, continuity bonds, and casing insulators should be evaluated during the periodic surveys. This may be accomplished by on-site inspection or by evaluating corrosion test data.

V. WHERE PIPE HAS BEEN UNCOVERED, IT SHOULD BE EXAMINED FOR THE EVIDENCE OF CORROSION AND, IF COATED, FOR CONDITION OF THE COATING.

VI. THE TEST EQUIPMENT USED FOR OBTAINING EACH ELECTRICAL VALUE SHOULD BE OF AN APPROPRIATE TYPE. INSTRUMENTS AND RELATED EQUIPMENT SHOULD BE MAINTAINED IN GOOD OPERATING CONDITION AND CHECKED ANNUALLY FOR ACCURACY.

VII. REMEDIAL MEASURES SHOULD BE TAKEN WHERE PERIODIC SURVEYS AND INSPECTIONS INDICATE THAT PROTECTION IS NO LONGER ADEQUATE ACCORDING TO APPLICABLE CRITERIA. THESE MEASURES MAY INCLUDE:

A. Repair, replace, or adjust components of cathodic protection systems.

B. Provide supplementary facilities where additional is necessary.

C. Bare structures can be thoroughly cleaned and properly coated if required to preserve cathodic protection.

D. Repair, replace, or adjust continuity and interference bonds.

E. Remove accidental metallic contacts.

F. Repair defective insulating devices.

G. Where shorted casings (metallic contact between casing and carrier pipe) cannot be repaired without removing the carrier pipe, the annular space can be filled with an inert material. Additional cathodic protection may be necessary to compensate for the shorted casing.