This paper places emphasis on the Dallas Area Rapid Transit, (DART), Light Rail System, which operates on a DC voltage traction power system utilizing a high rail-to-earth resistance return path. This system operates at approximately 800 volts direct current (DC) with substation spacing of up to two miles. If the rail system is not properly insulated from earth, stray current from the traction system can cause damage to underground metallic facilities owned by the transit system as well as facilities owned by others. Stray current corrosion is caused by direct current from a source external to the underground metallic structure. DART, like most modern transit systems, incorporates corrosion control measures to insure that the DC traction return current travels along the running rails and does not stray onto surrounding metallic structures and cause excessive stray current corrosion. The maintenance-of-way maintainers play an important part in the prevention of stray current corrosion. This paper will provide the maintenance-of-way personnel with a better understanding on how the different systems interact together and what role they can play in the prevention of stray currents. Other routine corrosion control methods will be presented to assist the maintenance-of-way personnel in understanding corrosion control techniques.

Keywords: D.C Transit System, negative return, stray current, high resistance system, and impedance bond.
INTRODUCTION:

This paper is designed for railroad maintenance-of-way personnel engaged in repair and routine preventive maintenance of the running rail, switch machines and ballast on a direct current (DC) operated system as it relates to corrosion control. Personnel attending the presentation or reading this paper need not have a background in electronics and chemistry. It would be helpful for personnel to understand the difference between voltage, current and resistance.

DEFINITIONS:

To provide a better understanding of direct current operated transit systems and corrosion control the following definitions and analogies are presented:

1. **VOLT**: The VOLT is the basic unit of electrical pressure, which forces an electrical current (electrons), to flow through an electrical circuit. Voltage can be used to indicate electrical pressure in general. The comparable term in a water system would be water pressure expressed as **pounds per square inch (p.s.i.)**.

2. **AMPERE**: The ampere (often abbreviated to amp) is the basic unit of electrical current flow. This current is caused to flow through an electrical circuit by electrical pressure (or voltage). The comparable term in a water system to express the rate of water flow could be, for example, **gallon per hour**.

3. **OHM**: The OHM is the basic unit for resistance to the flow of electrical current. With a fixed driving voltage applied to an electrical circuit, the amount of current flowing through the circuit decreases as the circuit resistance increases. Conversely, the current flow increases as the circuit resistance decreases (a short circuit has virtually no resistance). The comparable term in a water system to express resistance is the water valve, as the handle is turned clockwise the water flow becomes less, as the handle is turned counter-clockwise the water flow increases.

4. **INSULATOR**: An insulator or insulating material will have a very high resistance to the flow of electrical current and is used to confine or control the flow of current in electrical circuits. Examples are wire insulators or cable jackets of rubber, neoprene, plastic or similar insulating materials. Some good examples of insulators on the light rail tracks are the insulating pads located underneath the
wood and concrete tie fasteners and direct fixation pads, the insulating sleeve and strips used to mount the impedance bonds, and the insulators used in the switch machine rods.

5. ANODE: An anode is that metallic part of a corrosion cell from which direct current flows into the surrounding electrically conducting electrolyte. The anode metal is consumed (corroded) by this action.

6. CATHODE: A cathode is that metallic part of a corrosion cell to which direct current flows from the surrounding electrolyte.

7. ELECTROLYTE: A chemical substance, the moist soil or a liquid solution, that is adjacent to and in contact with a buried or submerged metallic structure and that contains ions that migrate in an electric field.

8. LEAKAGE CURRENTS: Direct current that follows a path other than along the intended traction power circuit.

9. IONIC CONDUCTION OF ELECTRICITY: The current flow that takes place through the electrically conducting electrolyte. Example: When electricity flows through water.

10. METALLIC CONDUCTION OF ELECTRICITY: The reciprocal of resistance; the ease with which current flows through a circuit. Example: The current flow in a copper wire.

11. IMPRESSED CURRENT SYSTEM: Direct current supplied by a device using a power source external to the electrode system used for cathodic protection.

12. BONDING: The process of establishing electrical continuity through the use of a metallic conductor.

13. ELECTRICAL CONTINUITY: The property of a structure, rebar, cable and other metallic objects to allow conduction of electrical currents by way of a continuous metallic pathway.

14. GALVANIC CORROSION: The corrosion resulting from a corrosion cell is an electro-chemical reaction - Rust.

15. IMPEDANCE BOND: Connections across an impedance device provide electrical continuity for the direct current (DC) traction power while producing a barrier to the alternating current (AC) train control signals.

16. CATHODIC PROTECTION: This is a widely used and effective method of corrosion control. It can be used to control corrosion on bare underground structures. It is commonly used as a supplement to
coatings on underground structures. For pipelines carrying hazardous materials, for example, the use of coatings and cathodic protection is required by Federal Regulations on all new construction. On existing facilities in this category, coated or bare, cathodic protection in corroding areas is similarly required by regulations.

17. RAIL-TO-GROUND TESTS: This is a test that is conducted by the use of a low voltage direct current (DC) source to impress a current between a section of isolated track and a low resistance ground at which time a simultaneous measurement of the change in track-to-ground potential (voltage) is obtained. The power source usually consists of a 12-volt car battery. The resistance-to-ground of the track section in ohms is calculated from the change in track-to-ground potential (voltage) per ampere of test current. This resistance value is then transformed to a comparative figure for the track section in ohms per 1000 feet. This is used to gauge the effective isolation of the section of track.

18. INDUCED VOLTAGE: Alternating current (AC) voltage induced into the light rail's running rail, handrails, metal grates, metal buildings, and other metal objects installed on the earth caused by transformer action of an overhead high voltage transmission line.

OBJECTIVES

Persons reading this paper should attain a better understanding of how a DC voltage transit system operates and the components that are involved. Listed below are some objectives that will be gained by reading this paper:

1. Be able to recognize the primary reason for the prevention of stray current.

2. Be able to trace the current paths from the substation to the overhead electrification, through the train, and return path back to the substation.

3. Know the definition of stray current.

4. Be familiar with the methods of stray current prevention.

STRAY CURRENT CORROSION

Stray current corrosion is caused by an earth path of direct current (DC) from a source external to an underground metallic structure. NOTE: On a direct current (DC) operated transit system, the sources are the rectifier substations, overhead catenary, trains and running rails. Examples of underground metallic structures are the rebar in the platforms, piers, bridge decks, tunnel lining bolts, or any other buried metal
objects belonging to the transit or structures owned by others. Stray currents can be picked up by these structures and travel some distances, and then discharge into the surrounding environment in order to complete the circuit and return to the external source. When stray current discharge occurs, an anodic condition exists and in some cases very severe corrosion occurs on the underground structure.

DIFFERENCE BETWEEN STRAY CURRENT CORROSION AND GALVANIC CORROSION

Stray current corrosion is generated by an external source, the driving current and potentials from an external DC source (example the light rail trains) which promoted current discharge into the surrounding areas and possibly stray current to flow. In severe cases, the stray current on the structures can be hundreds of amperes. In galvanic corrosion (rusting), corrosion cell driving potentials are generated from the system and are quite small (typically less than a volt) and corrosion currents tend to likewise be small.

SEVERITY OF STRAY CURRENT CORROSION

If stray current is allowed to flow and then discharge from an underground structure into the environment, the rate of corrosion attack can be extremely rapid. Structure failure, under these conditions can occur within a short period of time. This is entirely logical where, for example, hundreds of amperes are discharged. In accordance with the electrochemical equivalent of the metals consumption rates of iron is approximately 20.12 pounds of iron will be consumed per ampere year. If several ampere are flowing on an iron structure, a significant amount of metal will be consumed as corrosion products.

TYPES OF STRAY CURRENT CORROSION

There are two general types of stray current, dynamic and static.

1. DYNAMIC STRAY CURRENT: Dynamic stray current are those which are subject to variations with time (example: trains moving from one location to another). Sources of dynamic stray current can cause changes in current pickup and discharge areas on a structure and can cause reversal of current flow on a structure in some instances. This behavior results in changes in the location of anodic and cathodic areas.

2. STATIC STRAY CURRENTS: Static stray currents are those which are from a steady state external direct current voltage source which results in fixed anodic and cathodic areas on an affected structure with a relatively constant amount of current flow in the structure.
SOURCES OF STRAY CURRENT CORROSION

1. MAN-MADE SOURCES: Man-made sources of stray current include (but are not limited to) the following:
   a. DC Powered transit systems.
   b. DC powered mining operations.
   c. DC welding operations.
   d. High voltage-direct current electric power transmission system.
   e. Cathodic protection systems.

NOTE: Of the sources listed, all are dynamic sources except cathodic protections systems.

2. NATURAL SOURCES: A natural source of stray current is what is know as “telluric” or earth currents of magnetic origin. These are direct currents, of a variable nature, in the earth's crust, which are a result of variations in the earth's magnetic field. These variations in the magnetic field are in turn caused by variations in solar activity.

TRACTION POWER SYSTEM

Most light rail transit systems are similar in their construction and use a high resistance system. The DART Light Rail Transit (LRT) System is electrified by an overhead catenary arrangement and consists of underground, at grade and elevated sections. The system is double-track operation except in the yard and shop areas, where multi-track operations is required. The transit vehicles receive the electrical traction power from an overhead contact system by means of a pantograph. The overhead contact system is energized at 800 volts direct current (VDC) from numerous traction power substations located along the route. The running rails of each track are used for the return circuit of the traction power system. The substations are connected to the 13.2KVAC, 60 HZ, three phase distribution network of the local power utility system and include all necessary equipment required to convert the primary AC supply voltage to approximately 800VDC. In order to fully appreciate the dynamics of stray current, MOW personnel should clearly understand the electrical circuits involved in producing stray currents. The intended current paths of the substations are from the positive of the DC circuits, along the catenary wires, down the train's pantagragh, through the motors of the trains, past the rotational metal train wheels via the ground brushes, along the negative return running rail, and back to the negative circuit of the DC powered
substation. The electrons that deviate from this route through earth's paths and other metal structure paths are called stray currents. An effective corrosion control program requires that the negative return running rails have a high rail-to-ground resistance, which requires that the running rails be installed with special fasteners. This also means that all additional components that may come in contact with the return rail be insulated or isolated from ground. Examples of this are track switch machines, trip stops, bumping posts, return cables, ballast, and any other device that may be attached or close to the running rail. By maintaining an effective corrosion control program and MOW sound maintenance procedures the traction power circuits are assured of having a low resistance return path and a high rail-to-earth resistance, which is free of stray currents.

**SIGNAL SYSTEM**

Signal System Equipment is installed in numerous buildings along the right-of-way on the DART System. The signal system is comprised of double rail 100 Hz track circuits. These track circuits divide the line into signal blocks, which are separated by insulated joints. Located at these insulated joints are impedance bonds which are designed so that the DC traction power return circuits travel in almost equal amounts in each rail, and offer a low impedance path to a DC return circuit but a high impedance to the 100 Hz signal.

**HELPFUL MAINTENANCE HINTS FOR MAINTENANCE-OF-WAY MAINTAINERS**

1. Maintain a one-inch clearance from the bottom of the rail to the top of the ballast.
2. Keep metal objects from touching the ballast and the rail, switch machine rods, or any other device that is installed on the running rail. Sometimes soda cans, wire and metal objects can come in contact with the running rail.
3. Look for burnt or damaged insulators that are installed between the running rail and switch machines. This could cause low resistance connections between the running rail and the ballast. The result could be stray current leakage into the ground and possible interference if a foreign metallic structure is buried in the vicinity of the rails.
4. Look for connections to impedance bonds where the cable connections and the case lips do not come in contact with each other.
5. Remember that ionic conduction of electricity can pass through concrete, ballast and earth. These items are classified as an electrolyte.
6. By maintaining a high rail-to-earth resistance very little stray current will occur as a result of the operation of a DC electrically powered transit system.

7. One of the most difficult problems to solve in maintaining a high rail-to-earth resistance on a DC electrically powered transit system is to electrically insulate the trackwork from the surrounding paving on grade crossing materials through highway and pedestrians grade crossings. Keep these areas clean and free of accumulated debris and dirt. By keeping these areas clean, a high rail-to-earth resistance is maintained, thus preventing stray currents from entering the earth and causing accelerated corrosion.

**SUMMARY**

In conclusion, the maintenance-of-way maintainer can play a very important part in the prevention of damaging stray currents. With an effective monitoring and preventive maintenance program, any transit system could maintain a safe and effective mass transit operating system.

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**FIGURES:**

1. Insulated Rail Fastening System for Concrete Ties
2. Insulated Rail Fastening System for Timber Ties
3. Insulated Direct Fixitation System
4. Traction Power System