Keeping Stray-Current Corrosion At Bay

Pipelines and Light Rail Transit: A Delicate Balance

by **Glenn H. Willson, P.E. V&A Consulting Engineers, Inc.**

In many American cities, especially those with widely dispersed, fast-growing populations, light rail transit (LRT) has become an increasingly popular transportation alternative, offering a way to relieve congestion, prepare for future growth, and in some cases, spur downtown revitalization.

Twenty U.S. municipalities, including Boston, Philadelphia, Baltimore, Washington DC, San Jose (California), Minneapolis, Denver, Dallas, Houston, Portland (Oregon), Sacramento and Los Angeles, have put new LRT systems into operation since 1960. Another 37 cities have LRT systems planned or in the works, according to the American Public Transportation Association (APTA). For pipeline operators in those areas, this means new operational and safety concerns, including the risk of stray-current corrosion.

Most LRT systems resemble the streetcars of a century ago, with lightweight passenger units operating singly or in short, usually two-car, trains on fixed rails in a right-of-way that may be partly or entirely shared with other traffic. Most are powered electrically. Substations with DC (direct-current) rectifiers supply electricity to the train through an overhead cable via a trolley or a pantograph. DC power is preferred for rail transit because of its superior torque characteristics. The overhead cable is connected to the positive side of the rectifier. The rails on which the train travels serve as the negative (return) conductors connected to the negative side of the rectifier.

The DC current will use any conductive medium to return to the substation. This means the entire LRT system, including trackwork, power system and other equipment, including train yards, shops, etc., can potentially send stray electric currents, sometimes called "leakage currents"— i.e., unwanted, non-designed currents — into the surrounding soil and onto nearby buried structures. Stray-current corrosion occurs at the point where the current leaves the pipeline, carrying iron ions that became positively charged when they lose one or more electrons.

The damage is unseen but the effect can be major. A 1-ampere current discharging continuously from a steel pipeline will remove approximately 20 pounds of steel in a year. Since many LRTs are located in crowded utility corridors and in city streets with gas and oil pipelines and other underground utilities and structures, uncontrolled stray current can cause extensive damage to rail and concrete reinforcing steel, cables, and pipelines. By one estimate, stray-current corrosion damage in the U.S. may total over $500 billion annually.

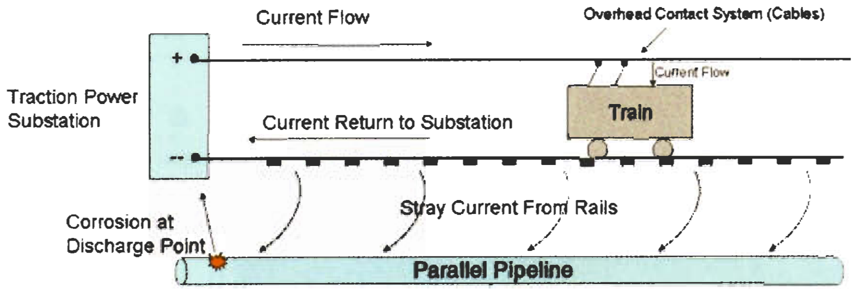

Figure 1: Schematic of stray current emanating from a typical LRT system

This kind of thing delights LRT opponents, who like to play up the danger that "ravaging corrosion" from light-rail systems will attack utility lines, roadways, bridges, and water-supply systems and generally, as one critic put it, "electrocute the infrastructure."

Fortunately stray-current corrosion has been very well studied since the 1890s. Well-proven, cost-effective techniques for predicting, testing, mitigating and/or preventing stray current are readily available. The challenge is to be aware of the potential hazards early on, and plan and act accordingly.

What Should You Do?

In the first half of the 20th century, many parts of the country were served by an extensive inter-urban streetcar network. But DC-powered surface transit essentially disappeared after World War II, so stray-current corrosion is an unfamiliar issue today even for most corrosion departments. It is essential for operations managers to be sure their staff becomes familiar with the issues involved and that the company's board and supervisors understand them as well.

As in so many other areas, good communication turns out to be the key. When Minneapolis's 12-mile Hiawatha light-rail system was being planned, for example, stray current control was coordinated by a committee whose membership was drawn from utility companies, industry and the military, as well as the owner, Metro Transit. The system produced only minimal stray current when it went into service in 2004, with no adverse impact on the gas piping.

Early in the design phase, the LRT engineers will typically conduct a detailed survey of the right-of-way and identify all systems that need to be relocated or lowered. Typically, facilities that pass close under the rails will be specified for relocation. The depth under the rails that pipelines will have to be moved can vary from four to 10 feet, depending on several parameters.

Historically, DC transit equipment was carefully grounded to minimize the shock hazard. More recently, with the advent of advanced power system equipment (e.g., high-speed breakers and solid-state overvoltage protection equipment), continuous welded and cross-bonded rails, improved insulating materials and the powerful computer simulation and design programs mentioned earlier, it has become possible to design "floating" (ungrounded) LRT systems that are electrically isolated from the soil, thereby reducing stray current risk.

Most new LRT systems installed today are ungrounded "floating" systems, leading some observers to conclude that stray-current corrosion is essentially a thing of the past. In the long run, they are probably right. For now, though, pipeline owners need to test, test, test to ensure there are no stray-current impacts to their system.

The pipeline team should know the locations and lengths of all crossings as well as train yard and shop facilities, which can present additional (and often different) stray-current issues.

Ideally, the rail designers will contact the utility owner and share this kind of information. Usually the pipeline operator will have the opportunity to attend meetings and otherwise get educated on the subject. If the rail designer is not forthcoming with this information, you may need to take the initiative instead.

Items to be particularly aware of include:

- ☐ Type of trackwork. Traditional tie-and-ballast tracks and direct-fixation (where rail is bolted to concrete surface of slab) are best in terms of minimizing stray current. This is due to the fact that higher rail-to-earth resistanc-

Tie and ballast insulating fastene

es can be achieved with these types of trackwork. Embedded tracks (as at level crossings), are more likely to produce stray current. Unbonded connections across mechanical joints or a high resistance path of the return current along the rails can increase stray current.

- Locations of traction power substations. Substations can be one of the most common sources of stray current. Some of the worst cases of stray current are caused by excessive distance between substations or between high-voltage substations and passenger stations.
- Other problems areas. These tend to be passenger stations, upgrade trackwork, underwater tunnels, crossovers, and other places where the train slows and then accelerates.

Most transit operators have taken several steps to ensure that stray current has been addressed in the design and construction of their LRT systems and to control stray current at the source. Protective measures may include:

- Permanent reference electrodes under the tracks where utility pipelines cross underneath LRT system tracks;
- Insulating flanges with four-wire test stations on either end of a metallic utility pipeline crossing the LRT system alignment;
- Four-wire test stations on electrically continuous piping parallel to trackwork;
- Permanent reference electrodes placed along tunnels, in passenger and power station areas, beside major piles, and adjacent to bridge structures; and
- Installation of electrically continuous wire fabric mesh underneath embedded or direct-fixation trackwork.

Two basic types of tests should be conducted on any LRT system to determine the magnitude of stray current present. Rail-to-earth resistance tests measure the resistance between the rail sections and earth (high resistance reduces stray current) and electrical substation voltage tests measure the resistance between substation negative connection and the substation bus.

Recent advances in technology and materials such as neoprene and cross-linked polyethylene have also given LRT designers much more effective ways to mitigate stray current. These include higher-resistance rail insulating fasteners and "rail boot" electrical isolation systems for embedded trackwork. Railroad ties made of recycled plastic-fiberglass composite (nonconductive, non-hygroscopic) may help reduce stray current.

Other improvements include using computer simulations to yield data through which stray current can be reduced and optimal locations for electrical substations and passenger stations can be found.

Test, Test, Test

To prepare a gas distribution pipeline facility for the construction of a light rail transit system, pipeline operators need to be familiar with the baseline pipe-to-soil potentials of their pipelines. The main factors affecting likelihood of and vulnerability to stray current are:

- Rail-to-earth resistance;
- Soil resistivity;
- Orientation/geometry of piping to the trackwork;
- Quality of pipe coating;
- Soil resistivity (which is influenced by soil type, moisture, and chloride content) and permeability); and
- Certain location-specific issues (e.g., the problem is greater at underwater tunnels, crossovers, and other places where the train slows and then accelerates).

Cathodic protection test stations can be destroyed or paved over during construction projects. Public utility owners should locate their test stations prior to construction in the area where their cathodic protection systems are located.

Transition from direct fixation to embedded trackwork

Despite all precautions, a certain amount of stray current is inevitable. To protect buried pipelines, V&A urges operators to make sure that an adequate and properly designed testing program is conducted to determine the presence and magnitude of stray current on buried utilities and structures.

Pipeline potential tests measure the voltage between the pipeline and a copper/copper sulfate reference electrode in the vicinity of the trackwork area. Data should be collected before and after the train is operational in order to compare the results. This is best done with recorders. The pre-construction testing allows the piping operator to establish a baseline, i.e., levels at the location prior to energization of the LRT system.

Field testing of the pipeline's existing CP system confirms that the existing cathodic protection system is functioning properly and that the new LRT system is not adversely influencing the pipelines. Some fluctuations of the pipeline pipe-to-soil potentials are normal during the operation of the LRT. Corrosion of the pipeline will be mitigated as long as the pipe-to-soil potentials are maintained at protected levels.

Pipelines that are electrically continuous and parallel to the trackwork are more subject to stray current than shorter pipes that are neither electrically continuous nor parallel to the trackwork. Longer pipelines provide more opportunity to pick up stray current. Look at the pipeline alignment. If more than 1,000 feet of electrically continuous pipe is parallel the LRT alignment, within 10-20 feet of the trackwork, stray current impacts should be evaluated. These values will vary depending on the factors discussed above.

Look at areas where pipeline crosses trackwork. Isolate your pipe (install insulating joints) on each side of the crossing and install cathodic protection on the section under the rails. The installation of insulation flanges may be costly if no flanges exist. A nearby valve may be used to install the insulating flange kit. The installation of a neoprene mat between the piping and trackwork can also mitigate stray current.

After the LRT system becomes operational, a corrosion specialist should set up potential recorders to monitor the effects of the LRT on the pipeline potentials. The recorders should be run for at least a day (or better, 48 hours) at several locations. The stray current expert can recommend locations for testing (areas of possible stray current) after reviewing soil data, proximity of piping to the rail, rail-to-earth resistance data and type of trackwork.

When a new LRT system starts up, good inspection and testing practices are likely to get the attention they deserve, and the chance of a major pipeline failure is probably at an all-time low. The challenge for the rail operator is to maintain the high level of maintenance, testing and inspection on a long-term, year-after-year basis. Without it, corrosion failures may start to occur within surprisingly few years. ***P&GJ***

Author: Glenn H. Willson, P.E., is Manager of Engineering Services at V&A Consulting Engineers, Inc. He heads the firm's corrosion consulting assignment for several LRT Systems across the U.S.