

Stray Current Mitigation For Water Mains In Portland's Transit Mall

by Aaron Eder, P.E. ■ Kennedy/Jenks Consultants

From its modest beginnings in the early 1870s when horse-drawn rail cars plied First Avenue, light rail in Portland, OR, flourished, then declined and has since enjoyed a resurgence. By 2030, planners forecast a million new residents in the Portland metropolitan area. The Portland Mall Light Rail project is a key component in the planning effort connecting Clackamas County, one of the region's fastest-growing areas, with Portland State University (PSU), the number one destination in its transit system. However, light rail systems such as Portland's impose unique impacts on utilities within the light rail corridor. This fast-tracked project mitigates those impacts while reducing the duration and cost of construction and minimizing the impacts to downtown businesses.

Background

When the Portland Mall was completed in 1978, it received immediate international attention as a model for transit and downtown redevelopment. The Portland Mall revealed a prototype for redeveloping a downtown area using a transit project as the catalyst. Today the Portland Mall – commonly referred to as the Transit Mall – serves many purposes. It fronts office buildings and retail businesses. It is a transit facility with the highest concentration of bus service in the city, and it is an important public space comprising 17 total blocks in downtown.

After more than 25 years of service, time has taken its toll on the Transit Mall. The most noticeable problem is that it looks worn out. The bricks and granite pavers are cracked in many places and the benches and other furnishings need repair or replacement. But there are also other problems. Several businesses have found that the Transit Mall is a poor front door for their businesses. Some have even closed their entrances fronting on Fifth and Sixth Avenues.

The Tri-County Metropolitan Transportation District of Oregon (TriMet) was established in 1969 after the previous transit provider, Rose City Transit, failed to generate ridership while meeting federal air quality standards and went bankrupt. TriMet quickly absorbed many of the outlying suburban bus services over the next few years. TriMet also began preparing for rapid transit solutions, opening the Portland Transit

Mall to buses in 1975 and studying light rail.

In September 1986, the Eastside Metropolitan Area Express (MAX) line opened for revenue service, spanning 15 miles from Gresham to downtown Portland. One of the first light rail systems in America, Eastside MAX helped set the standard for the future of American light rail design. It also marked a critical point in Portland's history, as the region abandoned automobile-focused urban design to become a civic leader in land use and transportation.

In 1998, the Westside MAX line, TriMet's first extension of its light rail network, opened for revenue service, spanning 18 miles from the fast-growing high-tech corridor in Hillsboro to downtown Portland. One of the largest public works projects in Oregon's history, it included twin tunnels, each tunnel 21 feet in diameter and spanning three miles through Portland's West Hills area.

Portland Mall revitalization

The city of Portland has joined with TriMet to undertake the Portland Mall Revitalization Project, a key element in the planning effort connecting Clackamas County, one of the area's fastest-growing areas, with PSU, the primary destination in TriMet's transit system. Because planners forecast a million new residents in the region by 2030, this extension of the region's light rail system is a key element in the long-range regional transportation plan. The extension will position the region for future growth of high-capacity light rail to the southeast and southwest portions of the metro area.

The goal of the Portland Mall Revitalization Project is to add light rail service to the Mall and to use this opportunity to revitalize the Mall so that it better serves its multiple functions. This project and the Interstate 205 light rail project are jointly considered to be part of the "South" portion of the North-South light rail concept. Without the Portland Mall segment, the light rail system will not be able to expand due to limited capacity on the existing cross mall system.



Fig 1: Shoring can prove to be challenging in streets that are congested with other utilities. Photo courtesy of Portland Water Bureau.

Unique impacts to utilities

Light Rail Transit (LRT) system operations impose two unique impacts to utilities within the LRT corridor. The first and most obvious impact is that, unlike cars or buses, light rail trains cannot be detoured around obstructions in the road when, for instance, a water line breaks. Utilities that lie beneath the tracks must be either relocated or improved to minimize the possibility of breaks and mitigate the need to tear up the road and shut down LRT operations during routine or emergency utility maintenance. Due to safety constraints, construction crews are restricted from working too closely to moving trains or the high-voltage catenary power lines installed overhead. Furthermore, excavation beneath or bordering the track is restricted due to the potential for undermining the track, as well as reducing the load on the existing utility.

Construction parallel to rail systems can be more challenging than crossing under the track because these excavations warrant trench safety systems such as shoring to support the trench and protect crews. In streets that are congested with other utilities, such as Portland's Transit Mall, shoring can prove to be a challenging task in itself (see Figure 1). An additional challenge of excavations parallel to rail systems is the physical limitations of the heavy machinery used to install and maintain utilities. Construction machinery generally spans the excavation, which may infringe upon the rail system right-of-way and impede train movement.

The second, and less obvious, impact of a new light rail system is stray current corrosion. Light rail trains are powered by electricity. Electrical current travels in a circuit from the power station to the train via the

overhead wires above the tracks, through the train's electric engine, and back to the power station via the rail and ground. Because the soil serves as a parallel conductor to the track, a portion of the current will return to the power station through the ground. The current returning through the ground is known as a "stray current," due to the fact that it follows a path other than that intended. Electric current in the ground will use the most conductive medium to return to the power station. Iron and steel water pipes are often good conductors. However, when the current leaves the pipe, it takes electrons with it and corrodes the pipe.

Why metallic pipes corrode

The basic fundamental cause of corrosion can be explained in terms of energy. It is more natural for a metal to exist in the form of a compound, since compounds such as oxides contain less energy than metals and are therefore much more stable. When metallic pipes are made, iron is separated from its associated oxygen in a blast furnace. This produces a large amount of

energy in the form of heat. As long as they remain metallic, steel and iron pipes retain this energy, bound up within itself, with a natural tendency to corrode back to the ore from which it was derived. It is this energy that drives the corrosion process.

In order for corrosion to occur there must be a complete electrical circuit including an anode and a cathode. The anode is the location where the current leaves the metal, and the cathode is the location that receives the flow of current. In the case of electric light rail systems, the current goes out from the substation along the overhead wire until it reaches the train, passing through the motors and theoretically returning along the rails to the substation. In reality, the majority of the current does return along the rails to the substation.

However, if a reasonably low-resistance parallel path exists, whereby the current may follow pipelines and cables to return to the negative ground of the substation, a portion of the current will take this route. In these cases, the current follows a parallel metallic path, such as a water main. Portions of water mains can be electrically continuous due to typical construction

methods such as leaded joints on cast iron pipes and mechanically restrained joints on ductile iron pipes. When the current jumps from the rails to the water main, the rail serves as the anode and the water main serves as the cathode. In these cases, the water main is protected, because electrons are not being removed from the pipe. When the current leaves the water main to enter the lead cable, the water main serves as the anode and the cable serves as the cathode. In these cases, electrons leave the pipe with the current, and the pipe corrodes.

Solution

The previous example was simple, but in the complex environment of a metropolitan district, the path of stray currents can be difficult to follow. To reiterate this important point, anodes corrode; cathodes do not. To prevent pipeline corrosion, it is only necessary to make it sufficiently cathodic. If a current is passed from the earth to a pipeline, the incoming currents will nullify any outgoing currents from the anodes of local corrosion cells. Further, if the pipe receives current over its entire area, it

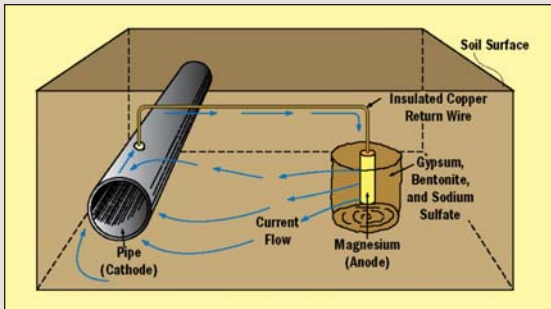


Fig 2: The electrical circuit is complete when the current flows from the pipe (cathode) to the magnesium (anode). (Figure taken from AWWA M27.)

will be immune from corrosion. A current through the earth can be easily produced by galvanic action from the energy of corrosion of a magnesium anode. In this case, a piece of magnesium is connected to the pipe with wire and buried, away from the pipe. Because magnesium is much more active than the iron or steel in the pipe, a considerable voltage is established between the magnesium and the pipe. Current will flow from the magnesium (anode), through the earth, to the pipe (cathode). The electrical circuit is completed when the current flows from the pipe to the anode through the wire (see Figure 2).

Today, the vast majority of buried pipelines are coated with some kind of organic

coating. Corrosion can be prevented completely by either maintaining a perfect coating or impressing a protective cathodic current density on a bare line. Maintaining a perfect coating is impossible, as a perfect coating does not exist.

Impressing a protective cathodic current density is too costly due to the high current demand. Somewhere between these two extremes lies the economic optimal combination of a good coating supplemented by cathodic protection to protect the inevitable imperfections in the coating.

Water Bureau approach

On previous light rail projects, the Portland Water Bureau (Bureau) developed a 10-foot separation criterion between the track and water mains, which combined the requirements for access, corrosion control and direct construction conflicts. The requirement for a 10-foot clearance provides access for operation and repair and corrosion

control, all of which are components of risk assessment. With this "Electric Rail Design Criteria" (ERDC), all water mains within 10 feet of the proposed track slab were to be relocated. Further, all mains crossing under the track were to be steel-encased ductile iron (DI) pipe with the casing extending 10 feet from each side of the track slab. In streets that are congested with other utilities, such as Portland's Transit Mall, there is simply not enough unoccupied space to construct a new pipeline 10 feet away from the track or extend a steel casing 10 feet beyond the track slab. In these cases, the design criteria are supplemented by secondary insulation of the track slab and/or an upgrade of pipeline materials and construction.

TriMet's design criteria for corrosion control takes active measures to prevent stray currents in the first place. The embedded track design sets a resistance standard of 500 ohms per thousand feet of track. Di-electric rail boots and di-electric geomembrane under the track slab meet this standard. Di-electric rail boots are essentially rubber spacers, placed between the rail and surrounding track slab, which allow dynamic movement of the rail and provide

electrical isolation. Di-electric geomembranes are essentially impermeable membranes that are resistant to the transfer of electrical currents. Problems occur only if the rail boot is punctured. To help track this, Tri-Met monitors "real time" returns at the substation ground mat. The presence of a stray current outside a set range triggers an automatic response, and the leak can be located and repaired.

Cathodic protection of the pipe is cost-based. As such, these di-electric features allowed some existing water mains located within 10 feet of the track slab to remain, depending on their age and condition. However, water mains parallel to the track and located within 5 feet of the track slab were relocated outside of this corridor to eliminate the need to shut down LRT operations during routine or emergency utility maintenance. All told, over 12,000 feet of 12-inch water mains will be relocated.

The Bureau allows an additional measure to reduce the construction schedule and cost of the water main relocations. Distribution main crossings can be replaced with concrete-encased high density polyethylene (HDPE) pipe (see Figure 3). The Bureau identified four large-diameter critical sup-

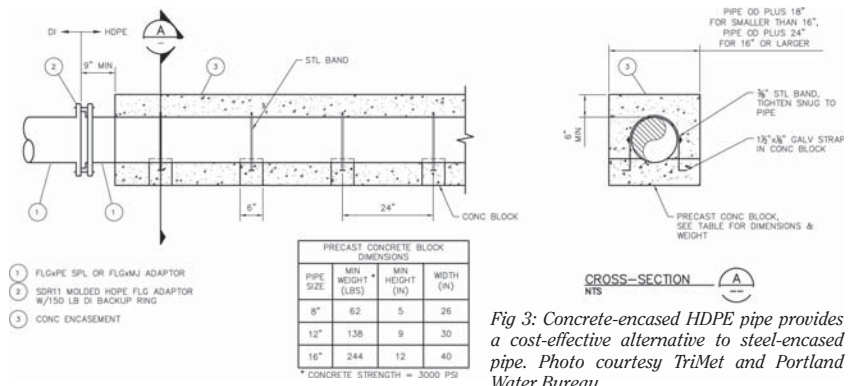


Fig 3: Concrete-encased HDPE pipe provides a cost-effective alternative to steel-encased pipe. Photo courtesy TriMet and Portland Water Bureau.



Fig 4: Steel-encased ductile iron pipes will be installed at four critical supply main crossings. Photo courtesy TriMet and Portland Water Bureau.

ply main crossings that are crucial to the water supply in the downtown area. These four crossings will be replaced with steel-encased DI pipe (see Figure 4).

Existing service lines and hydrant runs crossing under the track slab will be replaced with PVC-encased DI or copper, depending on the existing pipe size.



To mitigate the impacts from stray electric currents, 30-pound magnesium anodes will be placed every 100 feet along the pipeline. In addition, insulating joints, consisting of two flanged pipe ends with a di-electric gasket in between, will be placed every 500 feet along the pipeline, as well as at each end of the steel-encased critical supply mains. These insulating joints prevent stray currents from traveling too far along the pipeline. Test stations will be located at these locations to monitor corrosion. A continuous electric circuit will be created between corrosion test stations by installing bonding wires across each pipe joint (see Figure 5). As an additional measure, all ductile iron pipe will be wrapped with 8-mil poly-



Fig 5 (left): Bonding wires installed across each pipe joint creates a continuous electric circuit between corrosion test stations. Photo courtesy Portland Water Bureau. Fig 6 (right): Polyethylene encasement provides additional protection from corrosion. Photo courtesy Portland Water Bureau.

ethylene encasement (see Figure 6).

Maintaining business and pedestrian access was critical to the success of the project. TriMet has been working closely with its contractors to speed the pace of construction and ensure that customers always have access to businesses. To ensure that construction impacts are minimized, crews will be working in three to five-block work zones for up to eight weeks, and then moving to the next work zone.

Summary

This innovative engineering project will provide a water system that will not impact LRT operations during routine or emergency utility maintenance. Further, the project will provide cathodic protection from stray electric currents that are common with LRT projects. Measures will be taken to re-

duce the duration and cost of construction while minimizing the impacts to downtown businesses and their respective customers.

About the author: Aaron Eder is a project manager and civil engineer for Kennedy/Jenks Consultants in Portland, OR, one of the West Coast's leading water and wastewater treatment and design firms. He is a licensed professional civil engineer in Oregon and Washington. Eder received his bachelor's degree in civil engineering from the University of Washington in 1995 and his master's degree in civil engineering from Portland State University in 2005. He was instrumental in Kennedy/Jenks recently being awarded several on-call contracts with the Portland Water Bureau and City of Beaverton. He is currently serving as the project manager and project engineer for this project, which is currently under construction.

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