A GLOBAL CP PROBLEM

Ted Huck, Matcor, USA, discusses attenuation deficit disorder and pipeline rehabilitation.

Around the world, the pipeline industry is seeing a growing number of 'attenuation deficit disorder' outbreaks along older pipelines. This is not a disease or medical condition afflicting pipeline personnel, but is a reference to a growing global problem with pipeline cathodic protection (CP) systems, which are affected by older coatings that are failing. Attenuation is the technical term to describe the reduction in the strength of a signal transmission over long distances. In the context of CP, this refers to how far current will be able to effectively travel from a CP anode location to protect the length of the pipeline. When CP current cannot attenuate, it becomes very difficult to effectively supply CP along the length of the pipeline and, for too many older pipelines with ageing coating systems, the existing CP systems simply cannot distribute current (attenuate) effectively over the length of the pipeline. They suffer from attenuation deficit disorder.

Coal tar enamel, bitumastic and asphalt coatings

Every good disorder has an underlying cause. For pipelines suffering from attenuation deficit disorder, the underlying culprit is the coating. Coatings play an integral role in the pipeline industry, providing the first line of defence against corrosion. When exposed to the environment, steel will react with moisture and oxygen to form iron oxide (commonly referred to as rust). This electrochemical reaction occurs naturally as steel is not a stable, naturally occurring material – it is a material that has to be manufactured in an energy intensive process. Given the opportunity to release that energy back into the environment and revert to a more natural state (iron oxide), steel will inevitably corrode. Coatings are used to protect buried piping by creating a barrier between the environment and the steel pipe.

For more than 80 years, coal tar enamel, bitumastic and asphaltic enamel coatings (CTE type) dominated the pipeline coating market and were popular until well into the 1970s. Millions of kilometres of steel pipelines have been installed worldwide with CTE type coatings. However, today, more efficient, better performing coatings systems, such as fusion bonded epoxies (FBE) and cross-linked polyethylene (XLPE), have largely displaced CTE type coatings. While CTE type coatings have proven to be extremely durable, the majority of the very large installed base of CTE type coated pipelines around the world are reaching or passing the expected design service life of the coating.

What about CP?

CP is used, and in most locations/applications mandated for all steel oil and gas pipelines, to prevent corrosion from occurring in those very few areas where the coating system is not effectively providing a barrier between the pipeline and the environment. Even with today's very high quality coating systems, there remain some minor defects in the pipeline's coating system after the pipeline has been installed. CP supplements the coating system by sending electrical current from a source (anode) through the environment (the ground) to the pipe surface. The effect of current being applied to the steel surface is to change the environment such that the corrosion reaction cannot proceed. The corrosion reaction is the process of steel giving up electrons to the environment (in chemistry this is called an oxidation reduction reaction). When sufficient CP current is applied onto the outer steel surface, the steel is prevented from being able to give up electrons to the environment, effectively stopping the corrosion reaction from occurring.

CP systems are designed to distribute sufficient current along the entire length of the pipeline. This assures that any areas where the coating is not properly isolating the pipeline from the environment have adequate CP current to arrest the corrosion reaction. Fortunately, with well-coated pipelines, a single current source is capable of distributing current several tens of kilometres in each direction. The distance that current can effectively travel from a single source in each direction – the CP system's attenuation – depends heavily on the quality of the pipeline coating system. The better the coating system, the fewer areas for current to flow to the pipeline, meaning the current being discharged from a single location will be able to distribute further along the pipeline, thereby optimising current attenuation.

With coatings providing the primary layer of protection by isolating the pipeline from the environment and CP sending protective current to the few areas being missed by the coating system, pipelines are protected from the adverse effects of external corrosion and can be expected to provide safe and efficient transportation of liquids and gases.

Figure 1. Asphaltic enamel coating failure.

Figure 2. Recoating operation along the open right-of-way (ROW).

CTE starts showing its age

Pipeline operators worldwide are grappling with what to do as their 1950s once state-of-the-art coatings systems start to fail. With millions of kilometres of CTE type coated pipelines installed worldwide, this is an ever-increasing problem. A variety of factors can affect the service life of these coatings and, in many cases, pipelines that were installed over 50 years ago continue to find their CTE type coatings in good shape. However, these coatings are at, or past, their expected service life and failures are inevitable. When CTE coating ages and starts to fail, it generally does so in a non-shielding mode, with large chunks of the coating dissociating with the underlying steel pipeline.

As the CTE type coating fails, this has two important impacts on the CP system.

- The amount of current required to properly protect the pipeline goes up significantly as more and more of the steel is exposed to the environment. If the coating goes from 98% coating efficiency to 80% coating efficiency after 40 years of service, the current requirements for that pipeline increase to 20 times that which was required when the pipeline coating was new.
- The current attenuation diminishes significantly. In many cases, current simply cannot distribute much more than several 100 m from the current source. So, when the system was originally designed for current distribution to be tens of kilometres in each direction, now current hardly distributes at all – this is the attenuation deficit disorder problem.

While the current requirements are increasing and the distribution is diminishing, the typical response is to increase the quantity of CP stations and to ramp up the CP system output as much as possible at each of the existing CP stations, in order to try and push current further out in each direction. Unfortunately, this often results in localised areas of excessive current around the CP station (in the CP jargon, this is known as over-polarisation). This excessive current in a localised area results in accelerating the coating failures through a process known as cathodic disbondment.

Recoating the pipeline

At some point in the process of adding more CP stations and increasing the current output to levels that further degrade the coating, it becomes apparent to the pipeline operator that more drastic measures are required. The old coating system simply cannot perform the primary role of isolating the pipeline from the environment to any reasonable level of effectiveness, and the CP system designed to provide a secondary role of protecting a few coating defects cannot protect an ever-increasing number of large defects. The pipeline operator has two choices at this point – replace the coating on the pipeline with a new coating system, or install a much more comprehensive linear anode CP system that is designed to be the primary defence against corrosion.

Replacing the coating system, or recoating, is an invasive process that requires the pipeline to be fully excavated along the entire length so that a new coating can be field applied. The access issues can be significant and invariably there will be areas that are just not easily excavated, and will likely have to be skipped and addressed separately.

Assuring a successful field recoat requires significant QA/QC as several variables can affect coating quality, including proper removal of the old coating, sandblasting and surface preparation of the

Figure 3. Cable plow installation of linear anode to the side of the pipeline along the ROW.

steel pipeline, proper mixing and storing of the coating, careful consideration of coating pot life during the installation process, controlling the substrate temperature during the coating process, proper control of the humidity, temperature and curing time, and careful backfilling to avoid damaging the new coating. Recoating is both costly and time consuming with costs easily exceeding US$1000/m in some locations and large recoat projects can take years to complete.

Rehabilitating the CP system

Under the right circumstances, an attractive alternative to the recoat approach is to consider the use of linear anodes as a rehabilitation strategy. Unlike conventional CP stations that are spread out from each other and are designed to distribute current over some distance, linear anodes are long length anodes that are run parallel to the pipeline being protected and discharge current directly to the adjacent pipeline. The current output for the continuous anode is very low, however, the distribution of current is assured because the anode runs the entire length of the pipe section being protected. This option is only viable when the pipeline coating fails in a non-shielding mode such as CTE type coatings.

The advantages of the linear anode rehabilitation approach are that it is a much less intrusive installation and does not require the pipeline to be fully exposed along its entire length. The linear anode can be installed using a variety of methods including cable plow, backhoe/trenching and – in congested areas where soil disturbances need to be avoided – the linear anode can be installed using horizontal directional drilling (HDD). The cost of linear anode installation is significantly less than the cost of recoating a pipeline – with typical costs being no more than 20% of the cost of recoating (and in some cases much less) and the installation takes a fraction of the time of a recoat project.

When implementing a linear anode system, it is critical that an experienced corrosion engineering firm with proven expertise in designing linear anode systems be engaged, as proper consideration must be given to the critical issue of voltage drop and DC power distribution.

Conclusion

Pipeline operators will continue to face the attenuation deficit disorder caused by older CTE type coatings. When remedying this problem, operators should give consideration to the use of linear anodes as an alternative to recoating, especially for areas where recoating is not practical or extremely cost prohibitive.