An age old problem

Ted Huck, MATCOR, USA, discusses the installation and application of linear anodes for rehabilitating ageing pipelines.

Ageing pipelines with deteriorating coating systems can present a significant challenge for pipeline operators. Recently, Energy Transfer Partners, a Texas based pipeline company, was faced with the prospect of having to recoat significant sections of a critical service pipeline. The coal tar epoxy coating system had degraded to the point where cathodic protection could no longer be achieved and the existing pipeline coating systems near the ground bed were being over polarised and stressed, so money was appropriated to recoat the worst sections. For one 5 km segment of the pipeline, the company had budgeted US$ 1.8 million for recoating. The pipeline operator was looking for a more economical solution.

MATCOR engineers recommended a cost saving alternative based on installing a mixed metal oxide linear impressed current anode system parallel to the pipeline along the entire length of the right-of-way. For the pipeline operator, the proposed solution sounded too good to be true. At an installed cost of US$ 5/m, the application, if successful, would save over US$ 1.5 million for the 5 km segment, compared to the estimated cost of recoating that particular segment of pipeline.

First layer of defense

Pipeline operators often use a combination of coatings and cathodic protection to mitigate corrosion risks in accordance with international standards and local regulations. Coatings provide the first layer of defense as they isolate the metallic pipeline from its environment. Coating manufacturers continue to develop and improve the range of coatings that is commercially available.

Early coating systems were simple mixtures of crude pitches and solvents and later these bitumastic/asphaltic coatings evolved into engineered coal tar enamel coatings that were used well into the 1960s. Over time, advanced multi-layer polyethylene, polypropylene and fusion bonded epoxy coatings systems for new construction pipeline projects have replaced coal tar enamel to provide longer life and higher coating. In many new construction projects, the high coating effectiveness can result in greatly reduced cathodic protection current requirements, allowing ground beds to be spaced many kilometers apart, while still providing thorough cathodic protection distribution.

Cathodic protection

The second layer of corrosion defense for pipelines is the application of cathodic protection to supplement the coating system, providing protective current to holidays in the coating system. Typically, discreet anode ground beds are located over the length of the pipeline to distribute current uniformly to all the bare holidays in the pipeline coating system. One of the critical issues for any pipeline coating system as it ages is to determine whether or not it fails in a shielding or non-shielding mode.

Failure in non-shielding mode

Coatings that fail in a non-shielding mode do not prevent the flow of protective current to the pipe surface. This is typical of coal tar enamel and bitumastic/asphaltic coating systems. For these non-shielding coatings, upgrading the cathodic protection system to overcome the deficiencies of an ageing coating system is a viable strategy. Other coating systems that shield current from flowing to the pipe, such as tape coatings and polyethylene wraps, severely limit the

Figure 1. Coal tar enamel coating disbonded from pipeline. This sample was located close to the system rectifier.

Figure 2. MATCOR SPL™-FBR linear anode installation using a trench unit.

Figure 3. Linear anode supplied on a reel can be easily installed in the field.

options available to mitigate the effects of ageing pipeline coatings and may force the owner/operator to consider a costly recoating project.

For pipeline operators, it is very important to recognise the coating system(s) that have been used on the pipeline. Often, pipelines contain multiple vintages and types of coatings, depending on the age and repair history of the pipeline.

Pipeline operators, in accordance with international standards and local regulations, frequently test the effectiveness of cathodic protection using over the line survey techniques. With the advent of formalised pipeline integrity programmes around the world, additional tools are utilised to closely monitor both the cathodic protection and the coating system quality.

These techniques help operators to identify ageing pipeline systems with deteriorating coating systems. Characteristically, these systems suffer from poor current distribution, typified by areas of low potentials and exceedingly high levels of applied current density. The challenge for pipeline operators with ageing coatings showing deterioration is to control current distribution to achieve the prescribed polarisation levels consistent with international standards for adequate cathodic protection.

The first warning signs occur when current distribution is diminished such that between rectifier/ground bed locations, potentials fall below criteria. The typical response to this problem is to increase the overall output of the

Figure 4. Linear anode installation complete with warning marker tape immediately prior to backfill.

individual ground bed anodes. This generally does not alleviate the current distribution problem. Instead, the localised current around the groundbed increases significantly while continuing to drop off as you move away from the groundbed location. High localised potentials can actually stress the coating and cause further coating disbondment. The higher output current increases the ground bed's consumption rate, reducing operating life while raising operating costs appreciably. All this occurs without meeting cathodic protection criteria.

Operators eventually realise that ramping up the current output from the existing cathodic protection system fails to resolve the problem (and in many cases further accelerates the coating system failures,) the next solution is to increase the frequency of ground beds.

Adding ground beds and reducing the current output across the system may provide some relief, however, this is often insufficient, as it is sometimes not economically feasible to provide a sufficient quantity of ground beds to effectively distribute current. In some extreme cases, pipeline potentials can drop off precipitously when only a hundred meters from the ground bed location.

Failure in shielding mode

For pipeline systems utilising shielding type coatings such as tape wrap systems, recoat may be the only option. Recoating costs typically run US$ 40 - 45/m in open right of way areas and can be significantly more expensive in congested urban locations (these figures are applicable to the US and may vary significantly.) Recoating projects are both costly, and QA/QC intensive. The success of a recoat project is heavily dependent on the quality of the field recoat process. There are many variables that can adversely affect a field recoat project, including surface preparation, humidity, substrate temperature, mixing procedures for the field applied coating, pot life, coating inspection program, etc. Recoat is also a very invasive procedure requiring complete excavation of the pipeline.

Under the right circumstances, an economically attractive alternative to recoating is to utilise a linear anode configuration. The continuous anode replaces discreet systems with a system of continuous anodes running parallel to the entire segment of pipeline, thus assuring that current distributes as needed across the whole installation. This option is only viable when the coating system is non-shielding - this would include asphaltic and epoxy type coating systems. The application of a linear anode system typically costs around

US$ 5/m in open right of way (again these are general price guidelines and can vary significantly).

When implementing a linear anode system, it is critical that a corrosion engineering firm with proven expertise is involved in the linear anode system design. The linear anode system design must take into proper consideration the critical issue of voltage drop and its affect on DC current attenuation. Excessive system voltage drops can have a significant impact on DC power distribution to the linear anode system. Rectifier location, header cable sizing and segment lengths must be co-ordinated with site power availability considerations. While rectifiers located no further than 1 - 2 km apart are ideal, practical considerations including availability of AC power, right of way issues and other factors can force this to be extended, further complicating the system design and affecting the installed cost.

While voltage drop considerations often drive the design, one of the benefits of a linear anode system is that the power consumption is relatively low. Ground bed resistance, as determined by Dwight's Equation, is significantly affected by anode length and this results in very low groundbed resistance values for linear anode systems relative to conventional ground beds. This makes the linear anode system much more suitable for low wattage power sources such as solar arrays and thermo-electric generators (TEGs) than conventional ground beds, whose wattage could be two or more times that of a linear anode system to achieve the same current discharge.

Case study

For Energy Transfer's application, individual anode segments of approximately 150 m length were connected to a parallel header cable and zoned into approximately 600 m long operating circuits. The project included designing the power feeds, minimising DC current attenuation and finding AC power points for the rectifiers. Over the 5 km pipeline segment, AC power feeds were readily available at two locations. An additional rectifier location required a buried AC power feed of approximately 1 km in length to supply AC to a rectifier. The final system design utilised three rectifier locations roughly spaced evenly across the 5 km segment.

The project installation was closely managed by Energy Transfer's personnel. The anode was located in parallel to the pipeline approximately 3 m off the pipeline centreline and at a depth of approximately 1 m. The anode installation was completed in two weeks, including three excavations of the pipe to connect system grounds and install test station leads. The project lost one day to weather, as the remnants of Hurricane Rita passed through the area providing some much need rain and not so much needed excitement for the Houston based installation crew whose families evacuated Houston. The actual installation area was several hundreds of kilometers inland from the Gulf of Mexico.

Conclusion

The system has been operating for almost two years and has been deemed a complete success. Indeed, the system is performing better than expected providing current attenuation beyond the length of the installation based on over the line indirect inspection testing. An ILI run is being scheduled to validate the over the line survey results and further installations are planned to address similar segments along the same pipeline and for other pipelines in the operator's systems.