CP INTERFERENCE – THE ALTERNATE PERSPECTIVE
AUCSC, MORGANTOWN, 2012

Robin L. Pawson, P.Eng.
NACE CP4, Cathodic Protection Specialist
Cybex Corp. / Cybex U.S. Corp.

Introduction

The interference bond is now a commonplace cathodic protection system feature. It is designed to mitigate cathodic protection interference and allow the transfer of CP currents between pipelines. This circulation of current, from multiple sources, often precludes the possibility of recording true "polarized off" potentials at a time when higher degrees of accuracy are demanded. (e.g. Direct Assessment)

Why have the standard cathodic protection interference testing procedures remained basically unchanged for the past four decades? Did we get it right the first time? How do you explain all of the many inconsistencies and our selective approach to interference?

Let us question the accuracy of the testing procedures, the effects of reference electrode placement, the effects of voltage gradients, the erroneous interference test methods, the validity of the measured data, the inappropriate solutions often applied and some of the many cases which just do not fit the accepted norm.

The Statement And The Questions?

Interference bonds, either resistance or direct, have been commonly installed to mitigate CP interference for more than forty years. In that time period, there appears to have been minimal evidence of major problems with the historical approach and remedy to CP interference.

So, why now question the past and present techniques?

How do we explain:

- The inconsistency in the multitude of supposed interference cases that are totally ignored.
- The many cases of what would appear to be very serious CP interference which are not remediated, but cause no failure.
- The instances where, despite direct bonds, failure has occurred.
- The cases where interference bonds of up to 54 amps have to be installed to meet accepted CP interference mitigation requirements.

This paper addresses many aspects of present day practices, an analysis of actual field cases and questions the ways in which CP interference is detected, tested and remediated.

Note that, in this paper, all potentials are referred to the standard Copper/Copper sulfate reference electrode, unless stated otherwise.

The Pipe To Soil Potential

How much credence do we place in the displayed pipe to soil potential and do we really understand what the pipe to soil potential represents?

Prior to discussing CP interference, perhaps a quick consideration is required into what a pipe to soil potential represents. This understanding will be incorporated into other aspects under discussion, later in the paper.

The normal means of measuring a pipe to soil potential is to use a voltmeter connected to the pipeline and to a Copper/Copper Sulfate reference electrode, which is placed on the ground surface, over a bare cathodically protected pipeline. This is shown in *Figure 1*. A pipe to soil potential is displayed to the technician. But what does it really mean?

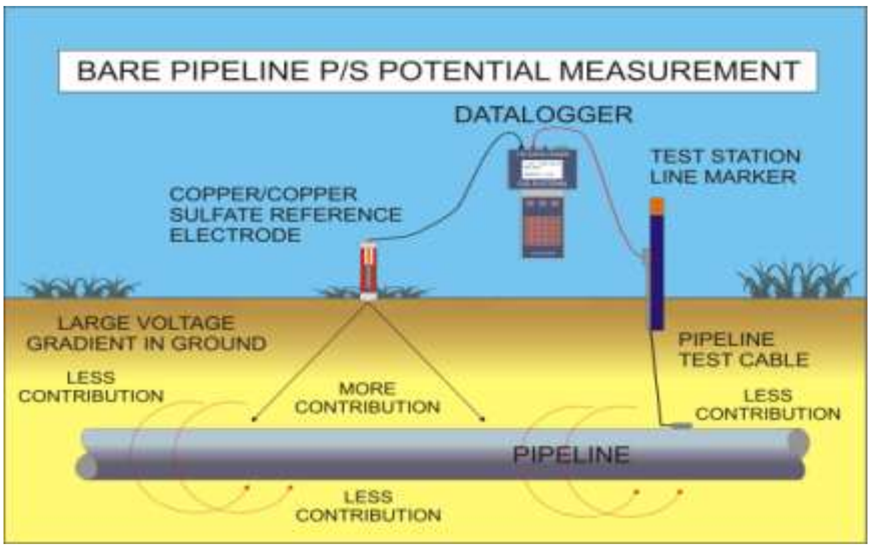


Fig 1

For a single cathodically protected bare pipeline, the displayed pipe to soil potential can include:

- The actual average pipe to soil potential of several lineal feet of pipeline. (the extent depending on the depth of cover, soil type and other factors)
- The voltage gradient in the ground due to cathodic protection current flow.

It may be expected that the potential contribution of areas on the bottom of the pipeline will be less than those on the upper surfaces, and the potential contribution of more distant locations will be less than those closer to the reference electrode. This is readily seen during C.I.S. and on underwater surveys of exposed pipelines.

With the cathodic protection current applied, there may also be a substantial voltage gradient in the ground, which is also included in the displayed potential.

Removal of the voltage gradient by rectifier interruption will still leave the reference electrode providing only an average pipe to soil potential.

It may be deduced from this reasoning that with a reference electrode on the ground surface, a measured "polarized off" potential of -850 millivolts will, in fact, include pipe to soil potentials less negative than -850 millivolts.

With a single coated cathodically protected pipeline, as shown in *Figure 2*, the reference electrode will generally "see" longer sections of pipeline and provide an average pipe to soil potential reflective of this length. The application of cathodic protection current provides further complications to the displayed data by including the voltage drop across the coating, and the voltage drop in the ground. (greater near holidays)

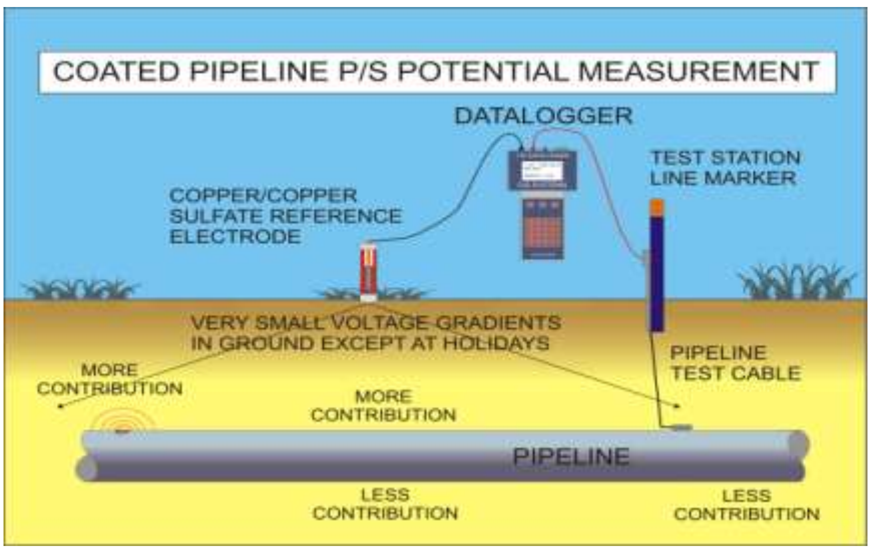


Fig 2

On a very well coated pipeline, the voltage drop in the ground will be very small compared to that across the coating. On poorly coated pipelines, the voltage drop in the ground may become a significant part of the displayed reading.

It is known, from C.I.S., that noticeable holidays and coating defects affect the displayed pipe to soil potential before and after the defect is passed. On very well coated pipelines, a coating defect may start to affect the displayed pipe to soil potential while the technician is still 40 feet away!

The Pipe To Soil Potential At Foreign Crossings

Now let us extend the same considerations to a crossing of two pipelines, as shown in *Fig 3*.

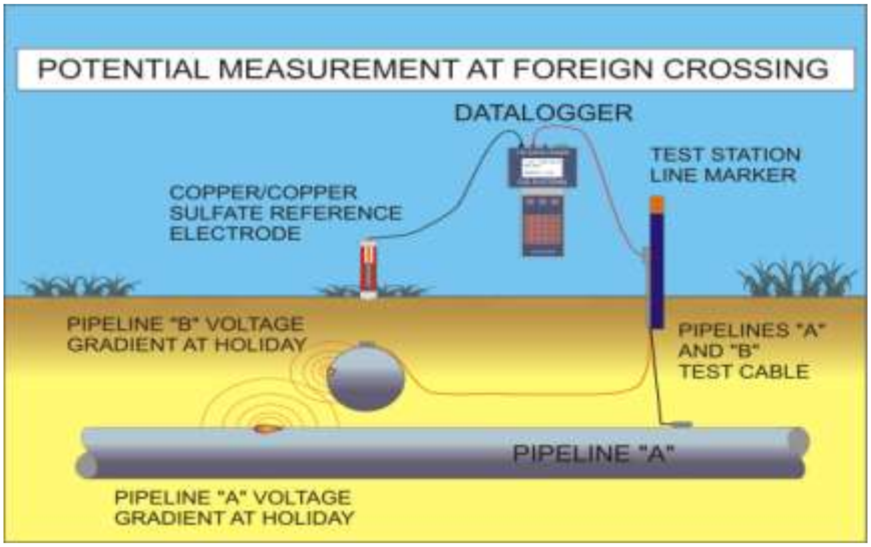


Fig 3

If both pipelines are under cathodic protection, there will be a variety of factors to consider. Bearing in mind that the reference electrode on the ground surface is not discreet, it may also include a voltage gradient affect from the foreign line.

In addition, the reference electrode, on the ground surface, will still only be providing an average pipe to soil potential

If the pipeline under test is over the foreign line, expecting that the reference electrode will reveal the pipe to soil potential of the underside of the pipe, at the crossing, is extremely hopeful.

By the same token, if the pipeline under test is the lower of the two lines at the crossing, the reference electrode is unlikely to aid in providing an accurate pipe to soil potential of the lower areas of the pipeline.

As well as the difficulty in evaluating what the pipe to soil represents, the effects caused by the foreign line should also be considered. These may include: the voltage gradient, in the ground, from the foreign pipeline cathodic protection system, the voltage gradient caused by the transfer of any interference current and the voltage gradient from any local cell actions. (at holidays in coated pipelines)

It should be apparent, by now, that the pipe to soil potential at a foreign line crossing may be a single reading, but it is a complex potential affected by many variables and cannot be solely used to determine the pipeline status at that location.

Permanent reference electrodes are often installed between the pipelines, at crossings, to provide a more accurate local pipe to soil potential in order to determine if interference is occurring.

However, it has been proven by recent field research that the permanent reference electrode, placed within inches of a pipeline, may reflect a pipe to soil potential based more on a defect 20 or 30 feet away than the pipe to soil at the crossing. Coatings at pipeline crossings are often enhanced to prevent current discharge or pick-up…..so what can the permanent reference electrode actually see?

On a bare pipeline, a permanent reference electrode installed a few inches from the pipeline, at one location, may not provide any real data on the pipe to soil potential even two or three feet away or at a different orientation.

The Common Statement

Probably the most common interference statement encountered is "you have to bring the foreign line back to the potential it was at before you applied cathodic protection to your line."

From our experience, the way that many people test for interference is to switch the "offending" rectifier on and off, and then note that with the "offending" rectifier on, their pipe to soil potentials are depressed. (less negative) The common conclusion is that this is adverse interference and remediation is required.

The question to ask is whether you can accurately record the pipe to soil potential of one pipeline, with the reference electrode on the ground surface, while the other pipelines' rectifier(s) are operating and foreign voltage gradients are present in the ground.

If, for example, the crossing of two bare pipelines is considered, the voltage gradient in the ground from the operation of only one of the CP systems will cause a totally inaccurate pipe to soil potential to be recorded on the other pipeline. As the reference electrode is placed on the ground surface, it has no option but to include any voltage gradients that fall within its' view. As discussed earlier, there can be substantial voltage gradients, in the ground, near a bare pipeline under CP.

Consequently, using this type of test for detecting interference, with the reference electrode on the ground surface, can produce erroneous results.

Testing for interference of a bare pipeline crossing a coated pipeline will also fall into the same category. If the pipe to soil potential of the coated pipeline is recorded with the reference electrode at the ground surface, the reading will include any voltage gradients, in the ground, caused by the bare pipeline CP system.

Again, erroneous data may be recorded.

And finally let us consider the case of two well coated pipelines at a crossing.

Well coated pipelines, distant from groundbeds, will normally have very small associated voltage drops in the surrounding ground.

In many instances, when the line rectifiers are distant, switching of the rectifiers on one pipeline may show only a small effect on the pipe to soil potential of the other pipeline.

However, there are cases where significant distortions of the pipe to soil potential are seen. One case may be when one of the pipelines has a rectifier and groundbed relatively close and the crossing falls inside the gradient field. A second case may be when one of the pipelines has coating defects near or at the crossing and the current densities in the areas of the holidays are sufficient to cause a noticeable voltage gradient in the ground.

The presence of, though not the full magnitude of, voltage gradients may be detected by using two calibrated reference electrodes and a voltmeter. If the two reference electrodes are placed on the ground surface, two to three feet apart, a voltage difference may be seen. Cycling of the local (or distant) rectifiers can be used to confirm the source.

The voltage gradient from groundbeds can be seen for long distances and the authors have noted foreign line CP system gradients up to ten miles away from their sources. This aspect is readily noticeable when other companies interrupt rectifiers for annual surveys and sometimes the actual company can be identified solely from the switching cycle!

Pipe type groundbeds, primarily used in the cathodic protection systems for bare pipelines, seem particularly prone to throwing current long distances.

Anomalous Interference Situations

Anomalous interference situations are those which are regularly seen, but consistently ignored.

Why are we so selective in the mitigation of interference? How is it that some structures and situations deserve our attention while many others are totally ignored?

Consider the following examples from interrupted C.I.S. (Note that these have occurred, in the authors' experience, hundreds, and in some cases several thousand times) The examples are generally based on interruption of a single pipeline CP system, with potentials recorded on structures in proximity.

Road Casing:	"On" potential -486 mV, "Off" potential -617 mV
Isolated Riser:	"On" potential -712 mV, "Off" potential -943 mV
Meterset Outlet:	"On" potential +244 mV, "Off" potential -540 mV
Tank Bottoms:	"On" potential -786 mV, "Off" potential -960 mV
Well Take-Offs:	"On" potential -497 mV, "Off" potential -600 mV
Foreign Pipeline:	"On" potential -658 mV, "Off" potential -858 mV

All of the above types of "supposed" interference have been consistently noted for many years and yet no action is taken. Strangely enough, there would appear to be very few, if any, failures. Yet, in each case, the structure to soil potential of these structures seems to be adversely affected by operation of the nearby pipeline CP system?

During the course of many years of C.I.S. (Over 14,000 miles), potential tests have been undertaken at hundreds of crossing test stations. In many cases, the “foreign” pipeline pipe to soil potentials show “interference”, even with resistance bonds installed. Very few people seem to care to correct these potential problems. Or are they really problems?

What about the cases where resistance bonds are installed at the crossing of a cathodically protected coated pipeline with an unprotected bare pipeline. Switching of the coated line rectifier(s) shows a small change in the apparent pipe to soil potential of the bare pipeline, so interference is declared and a resistance bond is installed to protect the bare pipeline from adverse interference?

After a bond has been installed, does the “offending” company increase the local rectifier output to compensate for the current lost by their own pipeline? Does this then affect the validity of the test results and the resistance bond that has just been installed?

If the output of the local rectifier of the “offending party” is not increased, would it be prudent to undertake a C.I.S. on local areas on the pipeline, in case the loss of current through the bond has caused a significant loss in protection?

Interference bonds regularly carrying from 5 to 54 amps are encountered when a bare pipeline cathodic protection system is in proximity to, or crosses, another pipeline. Is it really possible that bonds of this magnitude are required to correct an interference problem? Or is it the result of trying to follow the common guideline: “you have to bring the foreign line back to the potential it was at before you applied cathodic protection to your line.”

There are many cases where despite the bond and many amps of current, it is impossible to “bring the foreign pipeline back to the potential it was at previously.” Is this the proof that our testing is flawed?

What is the explanation for the excavations at pipeline crossings where repeated C.I.S. has shown severe “interference” and yet physical inspection of the pipeline shows no adverse affects? Is the potential change criterion really applicable when investigating CP interference?

The Interference Bond – Good For All Occasions

When a CP interference situation is suspected or deemed a possibility, the parties involved would generally meet at the site, undertake a mutually agreed testing procedure and often install a resistance bond to alleviate the apparent interference problem. The resistance bond is probably crafted with a calculated and tested length of nichrome wire and a shunt in series.

Note that when such testing is undertaken, it would be under the particular set of pipeline, cathodic protection and climatic conditions prevailing at that time.

Once installed, the bond may be diligently read at the prescribed time intervals, but generally will not be adjusted in future years.

Many changes can occur over the following months and years. The local rectifier outputs may be increased or decreased, new rectifiers may be added or older rectifiers removed, sections of pipelines may be recoated or suffer coating degradation, other bonds may be installed with pipelines at other locations, or it may rain for forty days or be dry for six months.

Do the parties re-test the interference situation and adjust the bond resistance, even once to accommodate any of these changes?

Strangely enough, the answer is generally no.

And yet for some inexplicable reason, the resistance bond continues to effectively function to mitigate interference for many years, despite these changing conditions. Doesn't this fact cast doubt on the whole veracity of this type of testing and solution? Did we really need the bond in the first place? Has our only accomplishment been to assist in the circulation of current and afford protection to a foreign pipeline? Were our procedures inappropriate for the testing for interference?

And finally, the case of the interference bond that was not good for all occasions. The crossing of two bare pipelines, one under cathodic protection and one not, resulted in the failure of the unprotected pipeline at the crossing, despite the pipelines being bonded together through a test station.

Unfortunately, the crossing occurred in the middle of a farm field and the bonding test station had been located at the side of the field, where the chance of damage would be minimal. The cause of this failure is believed to have been due to the size of the bond wires (AWG #8/7 str.) which had a total length of approximately 500 feet. The bond resistance, though still small, was thought to have been too high, and enough current was discharged at the crossing, by the unprotected pipeline, that a failure occurred. A permanent reference electrode did exist at the crossing area, but did not indicate the forthcoming problem.

In this case, even a direct bond can have too high a resistance to mitigate real interference.

The Costs Of Bonds

The cost of the interference bond will include:

- The cost of personnel for the initial testing.
- The cost of personnel and materials for the installation of the solution.
- The cost of "lost" amps.
- The cost of regular monitoring.
- The ongoing extra power costs.
- The extra cost of rectifier interruption for C.I.S.

The cost of personnel and materials for testing and installation of the bond would normally be split between the parties involved, but still represents a cost in terms of time and materials.

The cost of “lost” amps can be extremely high. If a figure of $1000 per amp of installed cathodic protection current is used, a bond carrying 5 amps will cost one of the companies $5,000 plus the ongoing increased rectifier power cost. (if applicable) If the bond is installed after initial operation of the CP system, there may not be this amount of spare capacity available and still afford protection to the pipeline. An increase in the size of the local groundbed and rectifier may be required.

Regular monitoring costs could involve personnel once a year, or in the case of a critical bond, every 60 days. One of the companies involved will bear this cost. If the company has a hundred bonds, this monitoring cost can be very high.

Undertaking C.I.S. with the view of recording accurate “polarized off” potentials is certainly becoming more difficult in some areas. While bonds may carry current in one direction while the rectifiers are “on, current may flow in the reverse direction when the rectifiers are briefly “off” during interruption.

Consequently, it is often necessary, to not only interrupt the rectifiers on the line to be surveyed, but also the local rectifiers on foreign lines to which bonds have been installed. In the cases where several pipelines have been interconnected via bonds, the time and cost required to locate and interrupt all of the affecting rectifiers can be considerable.

The -850mV Problem

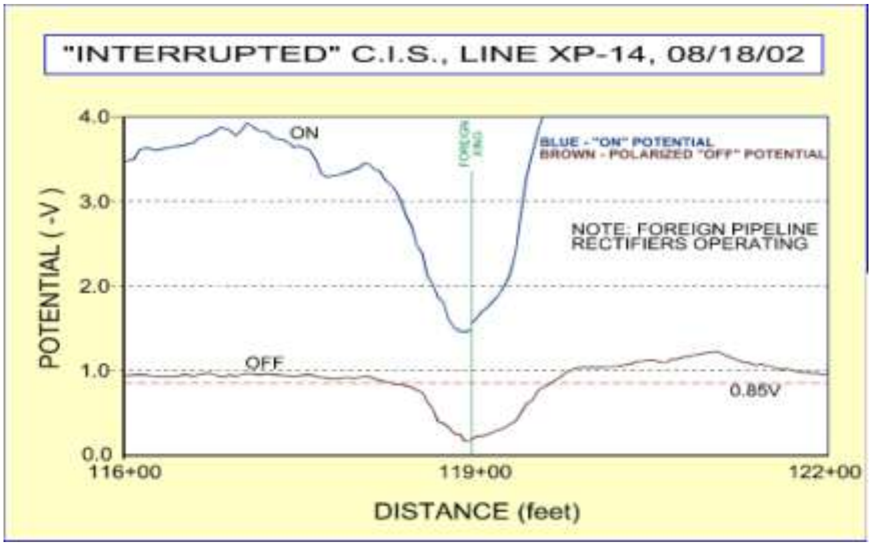
A typical scenario would be: “When your cathodic protection system is operating, my “polarized off” pipe to soil potential at the crossing is -237 millivolts.” This obviously doesn’t meet the -850 criterion and will not satisfy the appropriate regulatory body.” This is a problem.

The answer probably lies in the fact that this pipe to soil potential is recorded while the CP system on the other pipeline is still operating and the reference electrode was placed on the ground surface. Consequently, there are voltage gradients still present and the -237 millivolt reading is really an “apparent” pipe to soil potential and not a true value.
However, the need to provide an easy solution and gain the necessary -850 millivolts often results in the installation of magnesium anodes at the crossing. These are installed to provide a low resistance path for any interference currents that may wish to migrate from one line to the other and, just as importantly, to provide a pipe to soil potential that meets the requirement of inspection.

Following the same thought processes, you cannot disconnect the Magnesium anodes to record an “off” potential because the “interference” will affect the data. The pipe to soil potential that is often recorded is therefore one with the anodes connected. But the potentials look better!

Potential Profiles At Crossings

Close interval surveys through pipeline crossing areas can produce interesting potential profiles. The potential profile shown in *Graph 4* is that for a well coated pipeline crossing a second well coated pipeline. The pipe to soil potentials become less negative as the crossing area is approached with a recorded least negative “off” potential of – 147 millivolts.

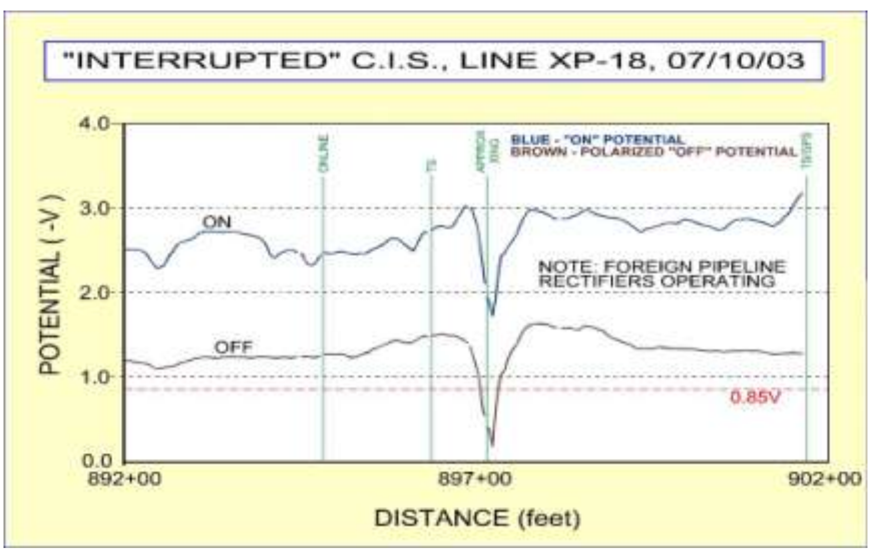


Graph 4

There is no bond, at or near the crossing, and the situation has existed for more than 12 years!

The two closest foreign line rectifiers were four and five miles away from this crossing. When one of these was switched off, the potential of -147 millivolts immediately changed to -368 millivolts and stayed at this value. Interestingly, if part of the source of “interference” had been removed, some polarization would have been expected. No re-polarization was seen.

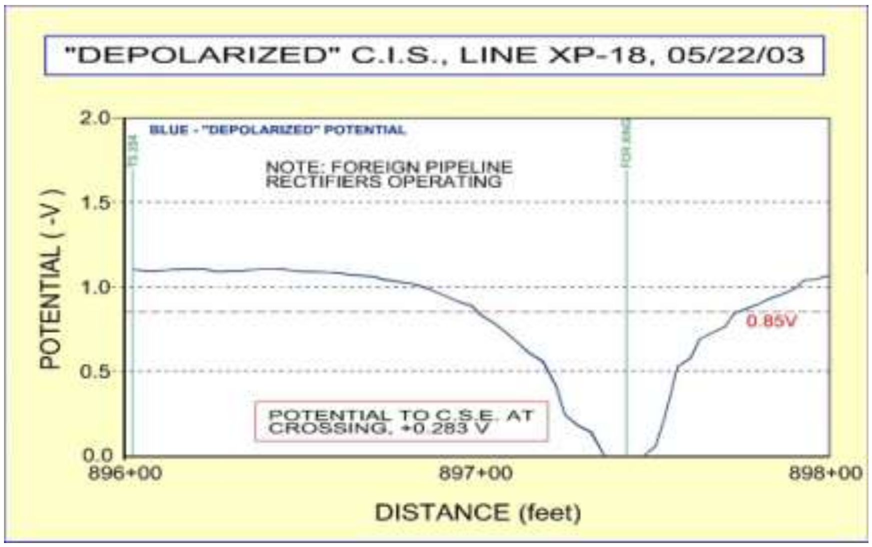
Graph 5 shows the C.I.S. on a well coated pipeline crossing a protected bare pipeline.



Graph 5

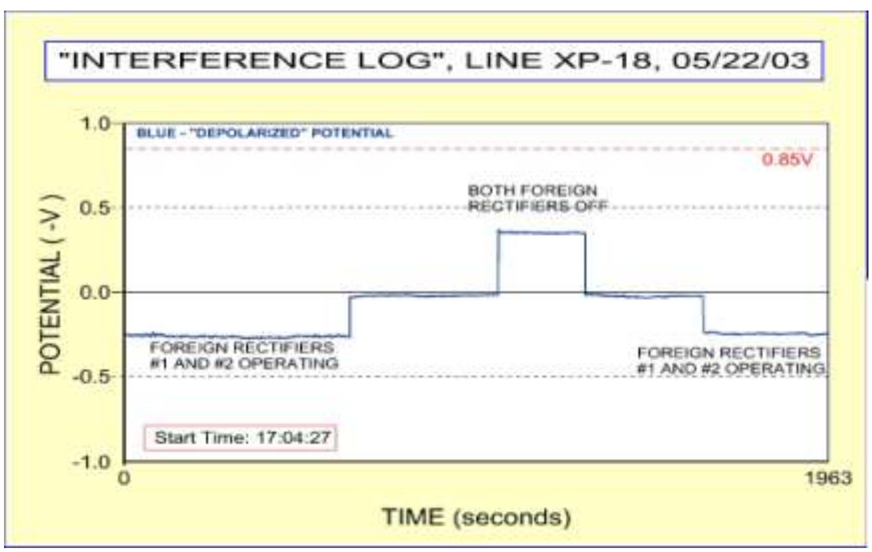
The profile becomes far less negative at the crossing area, with an "off" potential of – 177 millivolts. This value would normally arouse serious interest and concern, particularly as the pipeline is well coated and the -177 millivolt is an average, intimating that there would be potentials even less negative than this value.

Of even more interest is the fact that this situation has existed for approximately ten years without any remediation or known problem.



Graph 6

Approximately six weeks later, a depolarized survey was undertaken through this same crossing. The graph in *Graph 6* shows the C.I.S. profile through this crossing. The least negative depolarized potential recorded was +283 millivolts.



Graph 7

It was then decided to undertake some further testing. A computerized datalogger was located at the crossing and set to record the pipe to soil potential versus time.

The two closest bare pipeline rectifiers were approximately half a mile each side of the crossing, each with an output in the 40 amp range. These rectifiers were turned off for approximately twenty minutes and then back on in sequence. The results are shown in *Graph 7*. The immediate change when each rectifier is switched off is readily apparent.

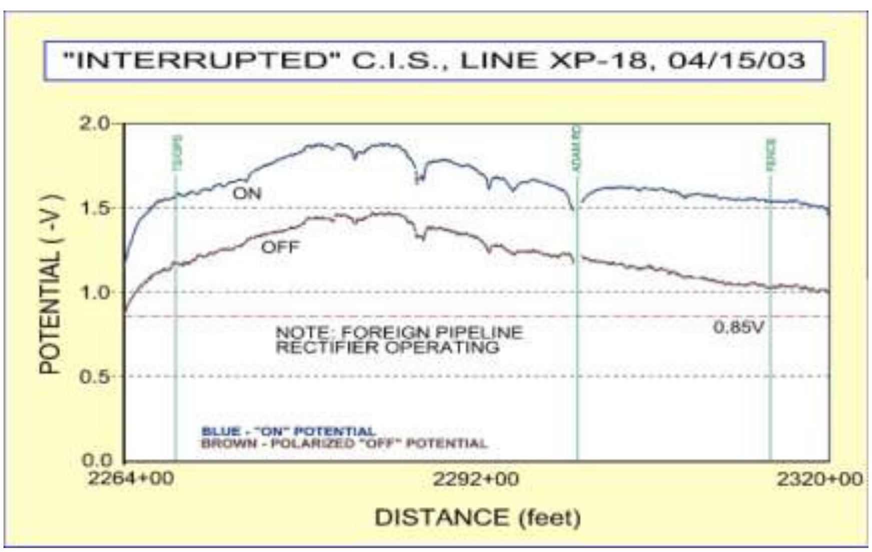
Shouldn't we expect some sign of re-polarization of the line, as would be expected if interference was taking place. Is the effect seen simply the removal of the foreign voltage gradient? When the two rectifiers were switched back on, there was no evidence of depolarization, as might be expected if interference was taking place.

As the bare pipeline had rectifiers at approximately one mile separations, it could be implied that if the next two were also switched off, the coated pipeline potential may have immediately shown a normal pipe to soil value.

When the source of interference is removed, what should we see? The immediate removal of the foreign voltage gradient effect is understood, but if interference was taking place, shouldn't we see some signs of re-polarization on the affected pipeline when the source of interference is removed? (Or depolarization when the source of interference is activated)

Potential Profiles Parallel To A Foreign Groundbed

The pipe to soil potentials on a pipeline may also be affected by proximity to a foreign groundbed, even when there is no actual crossing of the pipelines.



Graph 8

This is seen in *Graph 8*, where a coated pipeline approaches within two thousand feet of a foreign groundbed. The C.I.S. plots are interesting because both the "on" and "off" pipe to soil potentials change by the approximately the same magnitude as the survey proceeds. This would intimate that whatever influence is affecting the "on" potential is also equally affecting the "off" potential, and is therefore a factor outside of the pipeline system being tested.

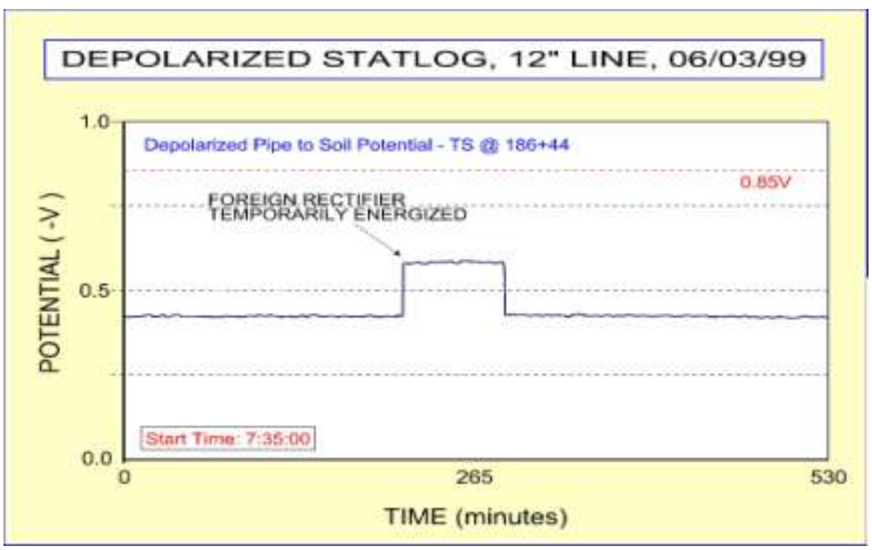
We often hear the phrase "area of current pick-up", because the pipe to soil potentials would appear to be more negative than expected. Remember that if there is current pick-up, there must be current discharge somewhere.

There were no areas of current discharge located on this pipeline and the simple explanation may be that the coated pipeline merely passed through the edge of the voltage gradient of a foreign groundbed. Just because a structure passes through a voltage gradient does not mean that interference will take place.

Alternate Methods For Interference Detection

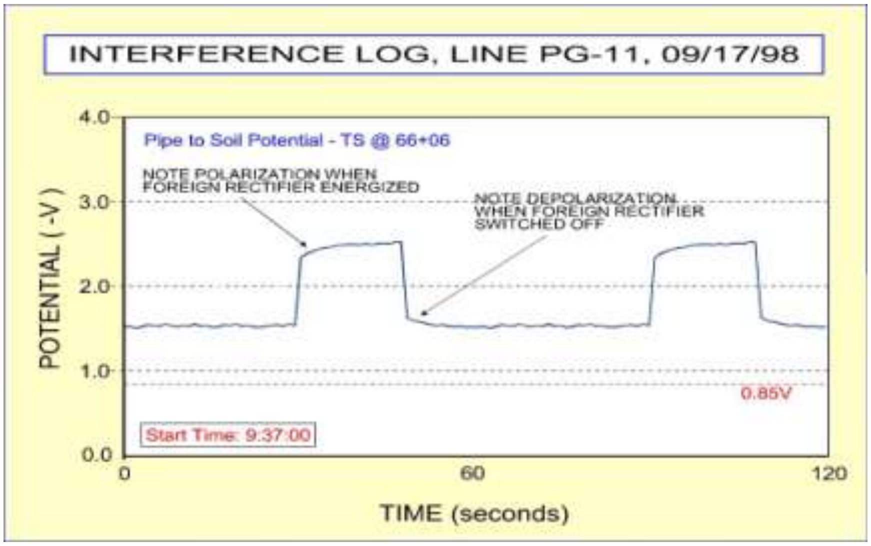
Because foreign voltage gradients in the ground can distort measured pipe to soil potentials and may not be a direct indicator of interference, perhaps a different approach can be investigated.

The graph in *Graph 9* is a stationary log of the depolarized pipe to soil potential, on a bare pipeline, at the same location for approximately nine hours.



Graph 9

This log was recorded while a close interval depolarized survey was being undertaken. As can be seen, the depolarized pipe to soil potential changed by approximately 150 millivolts for a period of almost eighty minutes. The cause was located the following day and found to be the temporary energization of a small rectifier on an isolated coated pipeline approximately a third of a mile away. No polarization of the bare pipeline can be seen in this graph, despite the potential change, only the effect of a foreign voltage gradient.



Graph 10

Graph 10 shows pipe to soil potentials versus time when a foreign rectifier is cycled.

In this case, not only is there a voltage gradient effect, but depolarization of the pipeline can be seen and adverse interference is proven.

Should interference testing use polarization and depolarization effects as the test? This is one aspect that the authors will be investigating further.

One qualifying point to remember in all of the discussions is that the reference electrode is not discreet, it is still on the ground surface and it is still only providing an average pipe to soil potential.

One other method of interference has been briefly investigated. This involves measuring the IR drop in the pipeline, in the vicinity of the crossing, while the foreign rectifier(s) are being interrupted. It would be expected that if the pipeline under study is picking up and/or discharging current, the changing current flow in the pipeline could be recorded. While this may be true on a mega scale, very small current flow (several milliamps) is extremely difficult to detect. On the good news side, special equipment is now available to measure very low current flows (down to 1 milliamp) and this may provide a new perspective on interference testing.

Conclusion

The legacy of our actions over the last forty years is a system of pipelines often interconnected through a variety of resistance or direct bonds, and carrying cathodic protection current from numerous sources over many miles of pipelines.

It would appear that the safest course of action is to provide a bond of some description, whether needed or not. And, indeed, it would be a rare case when the normal interference testing would not show that a bond is required.

The question to ask is: “do we really understand how to test for interference phenomena?”

It would appear that in many cases we have abrogated our real need for knowledge on this subject and replaced it with expediency.

The misapplication of interference testing and resolution has resulted in the extra costs borne by those supposedly causing the interference problem(s). These costs not only include the cost of replacement “amps”, but also extra power costs, the costs of continual monitoring and maintenance and the extra costs of more complicated C.I.S.

Undertaking the accurate measurement of “polarized off” potentials on a designated pipeline has become increasingly difficult, often involving the interruption of numerous rectifiers on multiple pipelines.

A concerted effort is required within the industry to modernize our technical knowledge through detailed scientific field research, and to propose the practical testing that would be required to effectively deal with the problem of CP interference.

Future Investigations

It is already planned to continue the field research at foreign line crossings on selected pipelines over the next several years. This work will include field data collection and the use of aqueous environments for testing. The relationships between polarization and interference will be investigated as well as the effects of reference electrode placement at pipeline crossings.

One field technique not discussed is DCVG. The application of DCVG for detection of even small coating holidays may have serious application for the evaluation of pipeline crossings and interference phenomena.