

## **Corrosion Rate Monitoring in Pipeline Casings**

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### **ABSTRACT**

Pipeline casings are widely used at locations where a pipeline crosses beneath railroad tracks, highways, and other areas where external pressure and stress can impact pipeline integrity, or areas where rehabilitation or replacement of the pipeline could significantly disrupt other systems. The casing is intended to protect the pipeline but recent recommendations from the Pipeline and Hazardous Materials Safety Administration (PHMSA)<sup>(1)</sup> and NACE International<sup>(2)</sup> indicate that in many instances casings provide little if any benefit. Conversely the casing can also create an environment that can trap water in the area surrounding the pipeline. The water and water vapor inside the casing can lead to atmospheric and galvanic corrosion issues. Additionally the presence of water can cause electrolytic shorting between the pipeline and the casing that could affect the level of cathodic protection on the carrier pipe.

A variety of water displacing substances are used to prevent water and water vapor related problems inside pipeline casings. Many are wax-based, or petrolatum-based agents that may provide an effective barrier between the pipe and potentially corrosive elements. These substances fill the casing and typically become semisolid. The material is subject to degrade over time. It is difficult to measure or monitor on an on-going basis the effectiveness of these barrier agents due to the difficulty of detecting voids that can develop inside areas of the casing. Additionally, as the fill material settles, areas of the casing can be exposed to galvanic corrosion agents. In recent years an increasing number of “vapor phase corrosion inhibitor” substances have been developed for use as displacement

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agents for casing applications. A unique characteristic of this type of inhibitor is the ability to protect the pipeline at the liquid phase, liquid to gas phase, and gas phase within the interstitial area without filling the entire casing. This allows the operator to monitor the corrosion rate inside the casing environment with electrical resistance (ER) probes.

This paper is a case study on the use of corrosion rate monitoring probes to determine the rate of material loss inside the pipeline casing where a vapor phase corrosion inhibitor substance is used. The probe can be suspended in the protective vapor and provide continual measurements of probe material loss. The data can be transmitted using remote monitor technology and accessed by the technician from any web-enabled device. The availability of this data allows the technician to track and trend the rate of corrosion, develop predictive analysis using near real-time data, and proactively address any acceleration of the corrosion rate inside the casing that could be due to inadequate moisture displacement.

This study focuses on combining elements of several evolving technologies to enhance pipeline integrity in casing installations. The vapor phase corrosion inhibitor provides very effective displacement, and the combination of the ER probe and a web-based remote monitor system provides accurate, near real-time performance data.

Keywords:

pipeline casing, vapor phase corrosion inhibitor, ER probe, remote monitor system

## INTRODUCTION

Enclosing pipelines in a larger diameter protective casing at locations where the pipeline crosses beneath highways and railroad tracks has been standard practice since the earliest days of the petroleum pipeline industry. Early crude oil pipelines were typically small diameter (up to 8 inches), composed of wrought iron or bare steel with the segments joined using threaded collars. Leaks due to external and internal corrosion were common. Due to the propensity for pipelines to leak, casings were used initially at railroad crossings in order to provide a means of removing and replacing corroded pipe without excavating a railroad right of way, as well as to protect the right of way from washout as a result of a leak occurring under the rails. It was also thought the casing would provide a degree of relief from the load transferred from the train thereby reducing the risk of damage to the carrier pipe. As pipelines and roadways became more prevalent these factors were considered in the inclusion of casings at many road crossings as well<sup>1</sup>.

Pipe manufacturing materials and technology have changed substantially from the early days of the petroleum industry. Pipeline construction has significantly changed as well. Pipe joints are welded rather than traded, coatings and cathodic protection reduce external corrosion, and corrosion inhibitors reduce internal corrosion. Technology has also significantly changed the methods of evaluating pipeline integrity and monitoring pipelines for corrosion, leaks, and other issues that impact pipeline integrity. Pipeline casings are increasingly viewed as a liability rather than an asset in regards to evaluating and maintaining pipeline integrity. Casings make the process of assessing coating integrity using common methods less effective, requiring use of costlier, more complicated assessment methods<sup>2</sup>. Casings are subject to leaks in the casing wall as well as at the casing end seals. The filling inside the casing designed to displace electrolytes can leak out or settle after installation producing voids where water, mud, and other electrolytic substances can gather, potentially creating an electrolytic short between the carrier pipe and the casing. In recent years NACE and PHMSA have offered reassessments regarding the value of using casings at highway and railroad crossings<sup>3</sup>. At a workshop held in July of 2008, PHMSA identified three basic long term issues regarding casings: 1) the need to stop installing casings unless recommended as a result of engineering analysis; 2) the need to

develop consensus for removing existing casings whenever possible; and 3) the need to develop and update industry standards and best practices for inspecting, maintaining, and repairing existing casings.

### FIELD STUDY

This paper focuses on the need to update best practices for maintaining existing casing sites that either cannot or should not be removed<sup>4</sup>. The study demonstrates a method for continually monitoring the corrosion rate inside the casing annulus, as well as monitoring the pipe to soil potential of both the casing and carrier pipe. Acquiring this data on a continual basis provides immediate indication of an acceleration of the corrosion rate inside the annulus or a shorting of the casing to the carrier pipe. The sites used in this study were excavated and resealed at both ends of the casing. The annulus was filled with a gel based vapor-phase corrosion inhibitor (VpCI). The ER corrosion probe was suspended in the vapor protected upper portion of the casing. The corrosion rate as measured by the resistance change in the probe was periodically transmitted to a web-enabled database, along with the potential measurements of the casing and the carrier pipe. The major concerns within a casing are undetected leakage points in the casing or seals that allow a corrosive environment to develop inside the casing, and the potential of a casing to carrier pipe electrical short. Through combining the technologies of the VpCI, ER corrosion rate probe, and remote monitoring, the operator is provided with the necessary data to ensure the environment at the casing is optimum for corrosion prevention and to recognize any abrupt change in operating conditions.

The carrier pipe at this site was a 30 inch (762 mm) coated steel pipeline transporting crude oil. The casing at the site was approximately 38 inches (965 mm) in diameter and located approximately five feet (1.2 m) beneath a two-lane highway. The sites selected for this study were evaluated for casing and carrier pipe integrity. The first steps were to excavate the pipe and casing in order to replace the boot with new sealant compound and secure wrapping in order to completely seal the casing ends (Figures 1 - 4).



**Figure 1: Cleaning the casing and pipe**



**Figure 2: Sealing compound is installed between carrier pipe and casing.**



**Figure 3: Adhesive wrapping applied over seal. Figure 4: Hardening overwrap applied.**

Following rehabilitation of the casing seal, leads were attached to the casing and to the carrier pipe, and a reference cell was installed adjacent to the pipe in order to measure pipe to soil potentials on the unprotected casing and the protected carrier pipe (Figure 5 and Figure 6).



**Figure 5: Welding leads to the casing.**



**Figure 6: Installing the reference cell.**

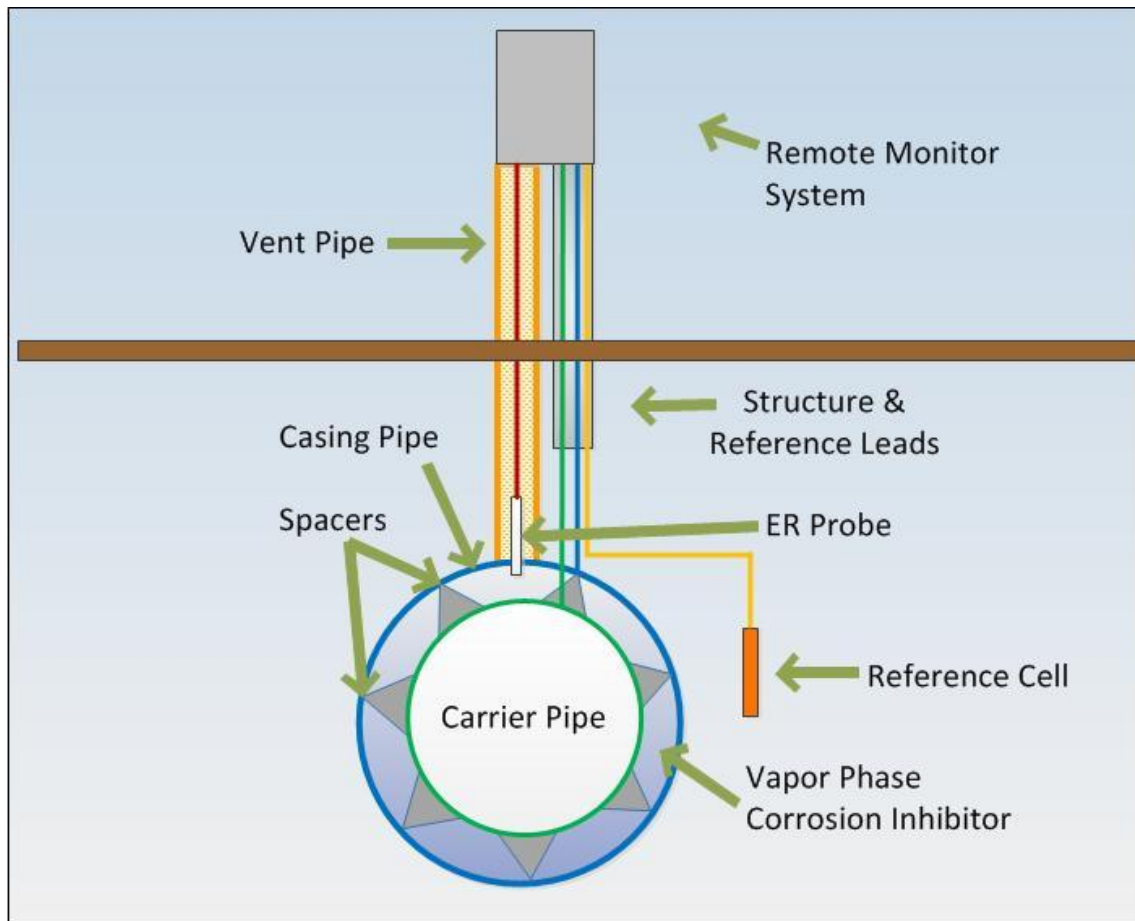
The excavation was refilled and the ER probe and monitor system were installed. The ER probe was suspended in the upper portion of the casing, above the carrier pipe. The ER probe leads, casing structure lead, carrier pipe lead, and reference cell lead were all connected to the terminals at the remote monitor. The monitor unit was located atop the vent pipe and the vent pipe was sealed with a cord-grip insert allowing the lead cables to pass through to the monitor connection terminals while maintaining the vapor phase atmosphere in the annular space (Figure 7).





**Figure 7: Photo of monitor equipment installed.**

Following the completion of the casing seal rehabilitation, and the installation of the monitoring equipment, the annular space inside the casing was partially filled with an atomized liquid VpCI product. The corrosion inhibitor molecules in this solution can mix with and migrate through water, soil, and vapor space inside the casing. If the casing is well-sealed, the corrosion inhibitor does not need to fill the entire annular space in order to remain effective. This characteristic allows the use of the ER probe in the unfilled upper portion of the annular space in order to determine the corrosion rate in the annular space on a continual basis (Figure 8).



**Figure 8 – Diagram of completed project site**

Following the application of the corrosion inhibitor into the casing, the “fill vent pipe” was fitted with a pressure release/vacuum breaker valve in order to maintain the vapor phase environment throughout the annular space.

If leaks in the casing develop, the corrosion rate reported by the probe will significantly change, thereby alerting the operator to a potential corrosive environment inside the casing. Steps can be taken, from refilling the casing with additional inhibitor to complete rehabilitation of the casing if necessary, to remedy the issue. The corrosion rate measured by the probe is transmitted to the remote monitor web interface. On the website the raw data (resistance value) measured at the probe is converted into a “mils per year” corrosion rate. This data is stored on the website and can be displayed graphically showing a corrosion rate trend (Figure 9). Changes in that trend line can be evaluated periodically for significance.



**Figure 9 – Graphical display of corrosion rate in mils per year from test site (screen shot).**

The monitor system was also recording structure to soil potential readings for the casing and the carrier pipe at the same intervals as the corrosion rate data. These measurements were transmitted to the web interface as well. The voltage potential measurements provide information regarding the level of protection on the carrier pipe and can also indicate a casing to carrier pipe short condition as shown in the screen shots below (Figures 10 and 11). The “normal” potential on the casing was in the -720mV range until 9/5/12. The “normal” potential on the carrier pipe was in the range of -1250mV until 9/5/12. The potential measurements for both the casing and carrier pipes shifted to -890mV when it reported on 9/5. This event is consistent with the carrier pipe shorting to the unprotected casing, and the casing in turn becoming a ground for the cathodic protection current.



**Figure 10 – Casing potential measurements (note “event” on 9/5/12).**



**Figure 11 – Carrier pipe potential measurements (note “event” on 9/5/12)**

## RESULTS

None of the technologies employed at these sites are new, but the combination of the technologies as a new approach to dealing with a difficult cathodic protection challenge is an innovation. Vapor phase corrosion inhibitors have been in use for some time, as have ER corrosion probes and remote monitoring systems. The manufacturer of the corrosion inhibitor used in this study recommended using a corrosion probe to periodically evaluate the corrosion rate was within acceptable levels<sup>5</sup>. Another concern at cased crossings is a case to carrier pipe short. Additionally, it seems logical to evaluate potential measurements at the cased site not only to ensure adequate protection on the carrier pipe, but to detect short conditions as well. The next logical step was to combine all three of these technologies in order to provide the operator with reliable, real-time data. The effectiveness of the inhibitor, as measured by corrosion rate, is continually reported at a rate that provides an almost immediate trend line. This measurement also provides a good indication regarding the integrity of the casing and seals, as significant leaks would be reflected in the corrosion rate measurements. The inclusion of the potential measurements on the casing and the carrier pipe provide the operator with critical data verifying a proper level of cathodic protection is maintained on the carrier pipe. As seen by the occurrence on 9/5/12 these measurements can also indicate a short between the casing and the pipe. Additionally, all of the parameters monitored through the web interface can trigger alarm notifications to the user in the event that a user-defined significant change in values occurs.

## CONCLUSIONS

The long term issues identified in the PHMSA workshop in 2008 regarding casings were: stop installing pipeline casings unless there is a demonstrated need; remove existing casings whenever possible; and develop and update standards and best practices for inspecting, maintaining, and repairing existing casings. There are numerous casings currently in use that will not be removed that will need to be safely maintained for years to come. This study demonstrates a very effective and economical method



of ensuring the integrity of the casing, casing seals, effectiveness of the corrosion inhibitor in the annulus, and the protection of the carrier pipe at the casing site. The method should be considered when rehabilitating and repairing existing cased crossings for use well into the future.

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