

Engineering Encyclopedia

Saudi Aramco DeskTop Standards

Special Operating Problems

Note: The source of the technical material in this volume is the Professional Engineering Development Program (PEDP) of Engineering Services.

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Recommending Corrective Actions to Reduce the Effects of Interference

Interference is corrosion damage to an underground structure caused by stray current electrolysis. Stray current is a man-made electric current that is intended to perform work on a grounded structure. However, the current uses the earth as a conductive path to flow onto other nearby grounded structures. Stray current electrolysis causes corrosion on buried structures that are not electrically connected to Saudi Aramco's cathodic protection systems (e.g., pipelines). Stray current flows onto a buried foreign structure in one area and leaves the structure to reenter the earth in another area. Corrosion occurs at the point where the current leaves the structure.

Stray current electrolysis is normally associated with impressed current systems. Galvanic anode systems do not normally cause stray current problems because they have low voltage and low current output. Sources of stray currents include the following:

- Other cathodic protection systems
- Welding operations
- Electrical transmission systems

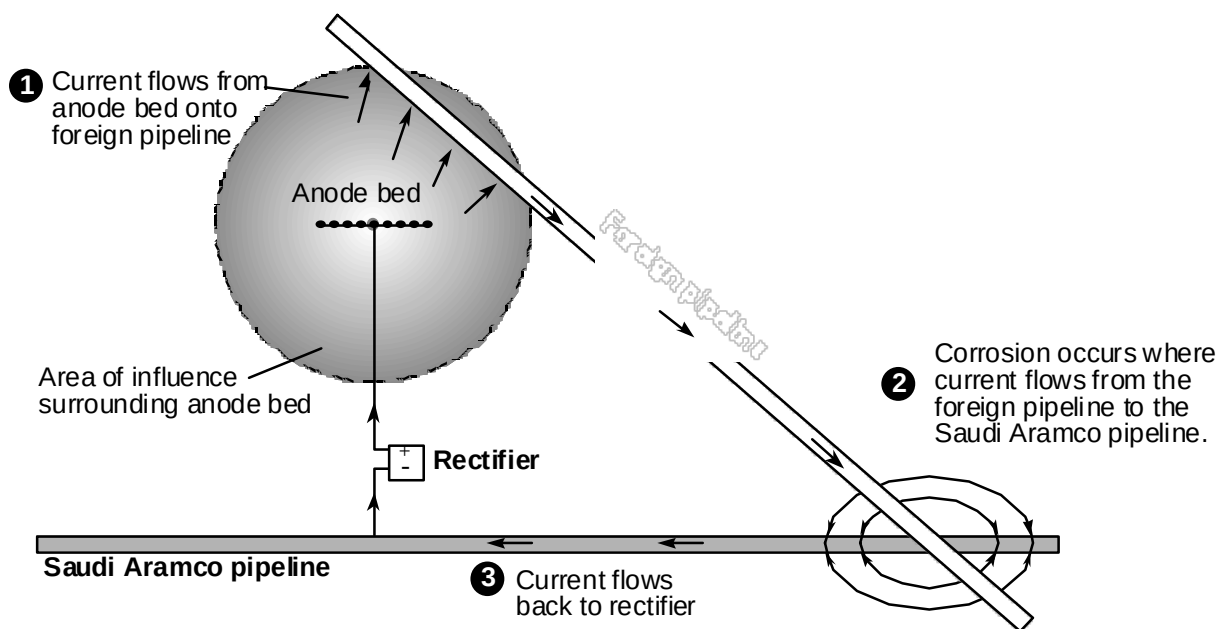
This section will provide examples of interference and will describe corrective actions to reduce the effects of interference.

Examples of Interference

In oil and gas production operations, interference may be encountered when: (1) a foreign pipeline is within the area of influence of a Saudi Aramco anode bed, or (2) a foreign pipeline crosses a bare pipeline under cathodic protection. The following information provides examples of these situations. Well casing and pipeline interference are rare within Saudi Aramco operations because most structures are electrically bonded together.

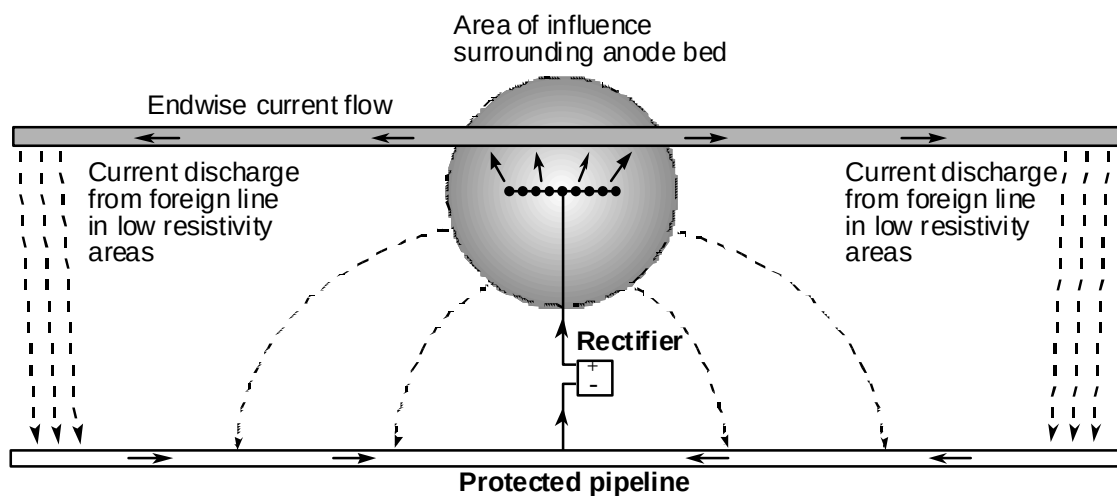
Foreign Pipeline is Within the Area of Influence of an Anode Bed

Figure 1 shows a foreign pipeline that lies within the area of influence of a Saudi Aramco anode bed. In this case, current will flow onto the foreign pipeline from the anode bed as shown in the figure. The current will flow along the foreign pipeline to the crossing point of the two pipelines. At the crossing point, the current will flow off the foreign pipeline, through the surrounding soil, and onto the Saudi Aramco pipeline. The current then flows back to the rectifier to complete the circuit. The foreign pipeline will corrode where current leaves its surface. The severity of the corrosion damage depends on the impressed voltage on the anode bed and the distance between the anode bed and the foreign pipeline.



Interference at a Pipeline Crossing
Figure 1

Figure 2 shows a second situation where interference occurs between two pipelines that do not cross. As previously shown, the foreign pipeline picks up current in the area of influence of the anode bed. In this case, current flows towards the ends of the foreign pipeline in both directions. The current flows from the foreign pipeline (in low soil resistivity areas) to the protected pipeline and returns to the rectifier.



Interference Caused by a Non-Crossing Foreign Pipeline

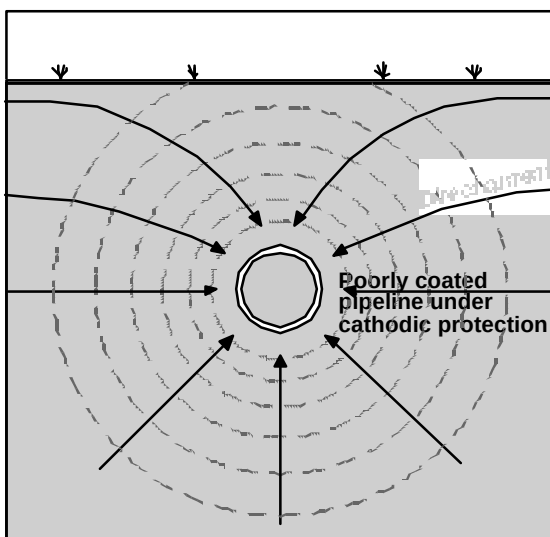
Figure 2

In both of the examples in Figures 1 and 2, interference can be detected by a close interval potential survey. The potential survey of the pipeline that experiences corrosion will show a drop in pipe-to-soil potential (a more positive reading) at the point of interference. The potential survey of the pipeline that receives the stray current will show an increase in pipe-to-soil potential (a more negative reading) at the point where the stray current flows onto the pipeline.

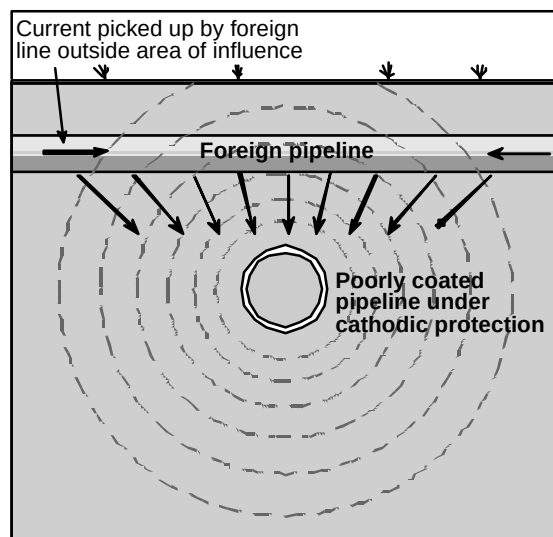
Foreign Pipeline Crosses a Poorly Coated Pipeline Under Cathodic Protection

Figures 3 and 4 illustrate what occurs when a foreign pipeline crosses a poorly coated pipeline under cathodic protection. Figure 3 shows the earth potential gradients that surround a poorly coated, cathodically protected pipeline. The potential gradient field is caused by current flowing onto the pipeline from remote earth. A poorly coated, cathodically protected pipeline can collect so much current that substantial potential gradients can be measured in the earth around the pipeline.

Figure 4 shows an unprotected foreign line that passes through an earth potential gradient field around a poorly coated, cathodically protected line. The foreign line picks up current outside the area of influence surrounding the protected line. The foreign line is eventually forced to discharge current back to the poorly coated pipeline. The greatest current discharge and greatest corrosion damage to the foreign line is normally at the point of crossing. The foreign line can develop leaks in a short time in extreme cases. If the foreign line is also too close to an impressed current anode bed, the two effects are additive and the corrosion rate at the point of crossing will increase.



Earth Potential Gradient Surrounding a Poorly Coated, Cathodically Protected Pipeline
Figure 3



Foreign Pipeline Crossing Through Earth Potential Gradient
Figure 4

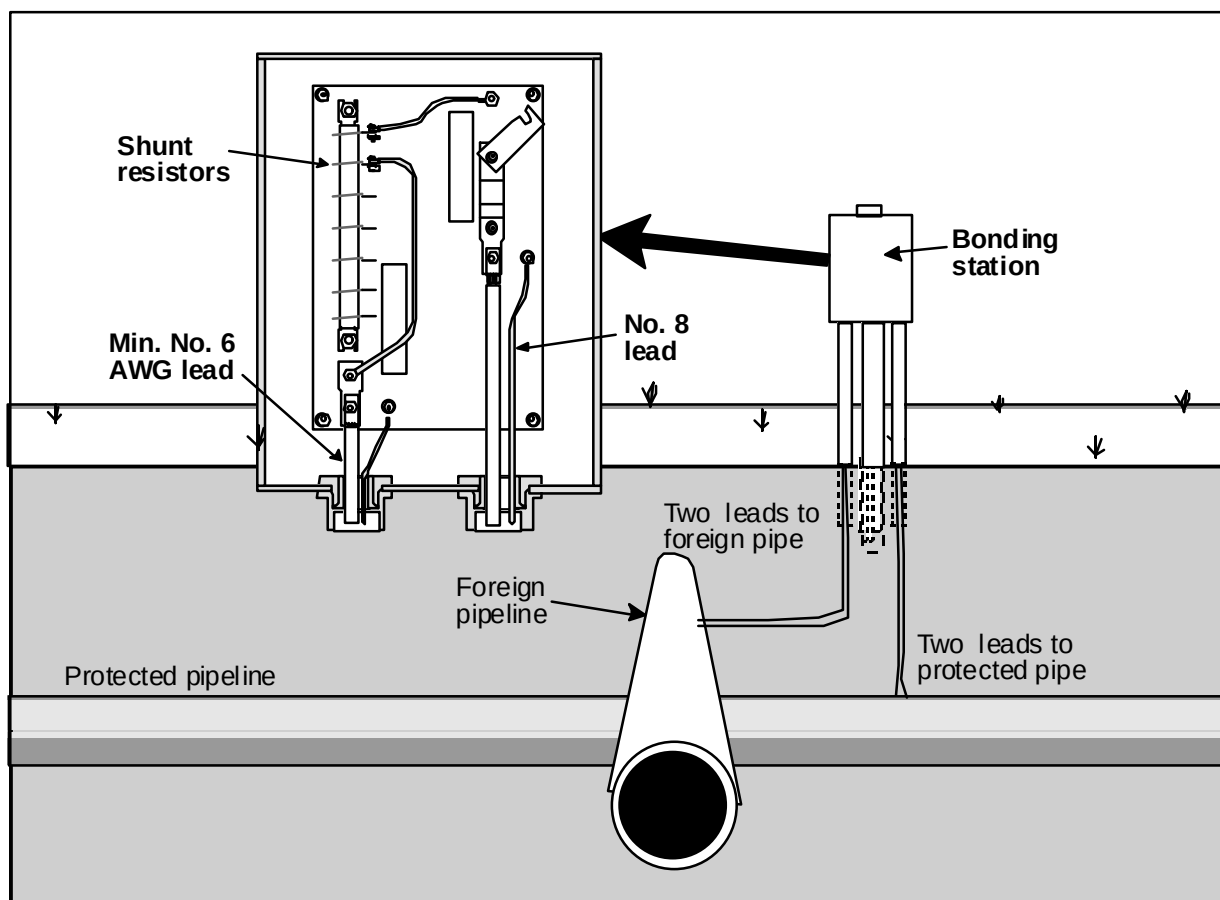
Even if the foreign line were well coated, a single coating defect within the gradient field can result in a leak. If the potential gradients that surround the poorly coated, cathodically protected line are strong enough, damage could occur to the foreign line even if it was cathodically protected.

Recommending Corrective Actions for Pipeline Interference

The three most commonly used corrective measures for pipeline interference are drainage bonds, external coatings, and galvanic anodes. These measures are described below in more detail.

Drainage Bonds

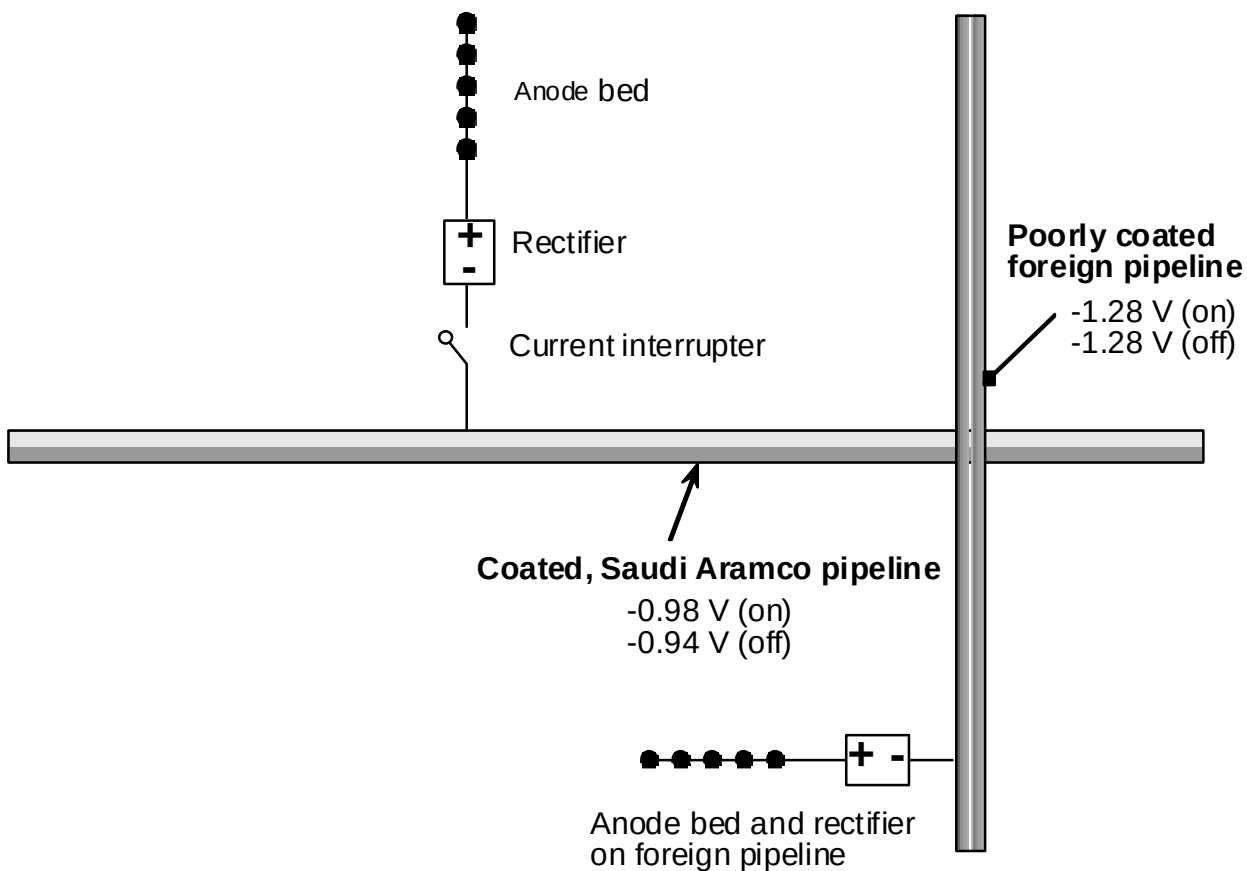
Drainage bonds are used primarily to avoid or overcome interference. A drainage bond is intended to provide enough current to maintain the foreign line's potential at the same value with the rectifier (for the protected pipeline) "on" or "off." Bonding may be accomplished by a direct or a resisted (shunt) connection in a bond box. Figure 5 illustrates a bond box that contains shunt resistors. Saudi Aramco installs bond boxes at all pipeline crossings but no longer uses shunt resistors.



Typical Drainage Bond
Figure 5

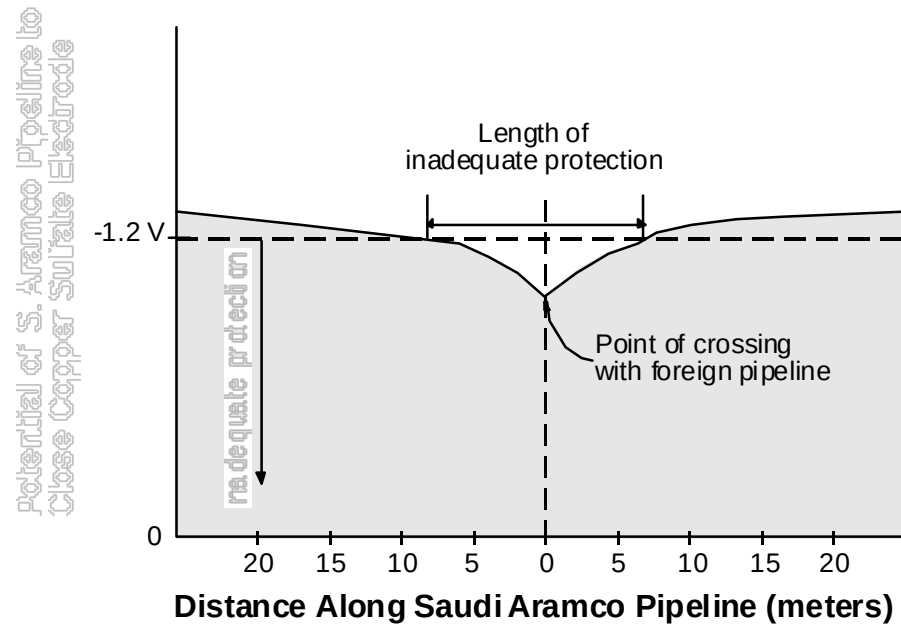
External Coatings

Sometimes, interference conditions cannot be corrected with a drainage bond. In Figure 6 for example, a coated Saudi Aramco pipeline is crossed by a poorly coated foreign pipeline. Potential readings at the foreign line crossing indicate that the Saudi Aramco pipeline is inadequately protected. Apparently the Saudi Aramco pipeline is inadequately protected because of interference from the cathodically protected foreign line. Potential readings on the foreign pipeline indicate that this pipeline is not adversely affected.



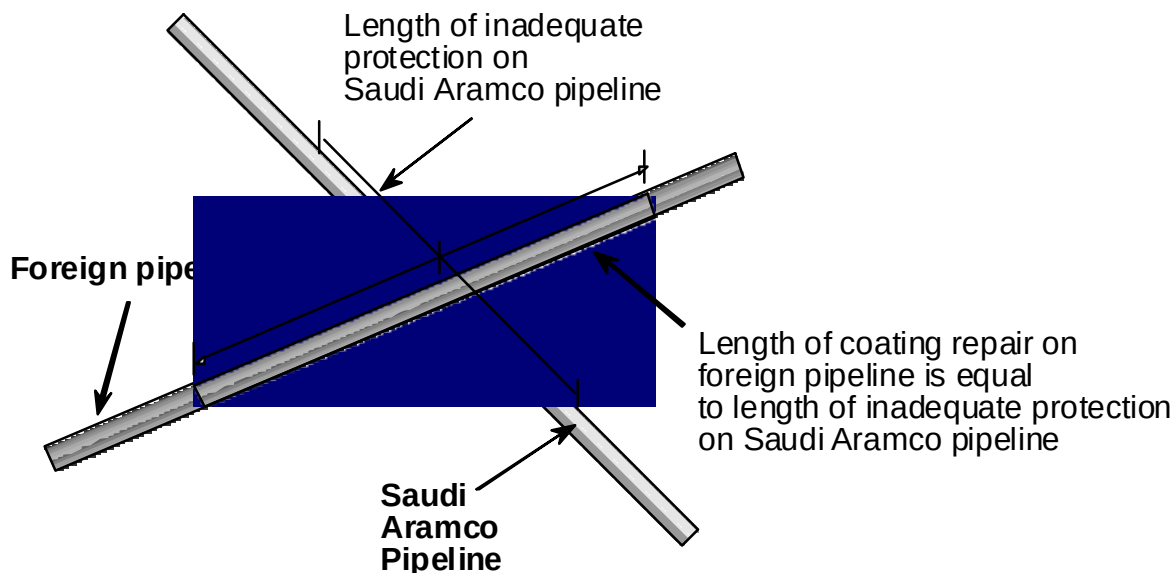
Crossing of Two Cathodically Protected Pipelines
Figure 6

The length of the Saudi Aramco pipeline that is below -1.2 volts can be determined from a plot of close electrode readings as shown in Figure 7.



Close Interval Potential Readings on Saudi Aramco's Pipeline
Figure 7

There are two possible corrective actions. One corrective action would be to install a drainage bond. Another corrective action would be to reduce the current flow to the foreign line in the crossing area. To reduce the current flow, the foreign line coating should be repaired. The length of the coating repair should be equal to the length of inadequate protection on Saudi Aramco's line shown in Figure 7. Figure 8 illustrates the use of coating repair to correct the interference problem.

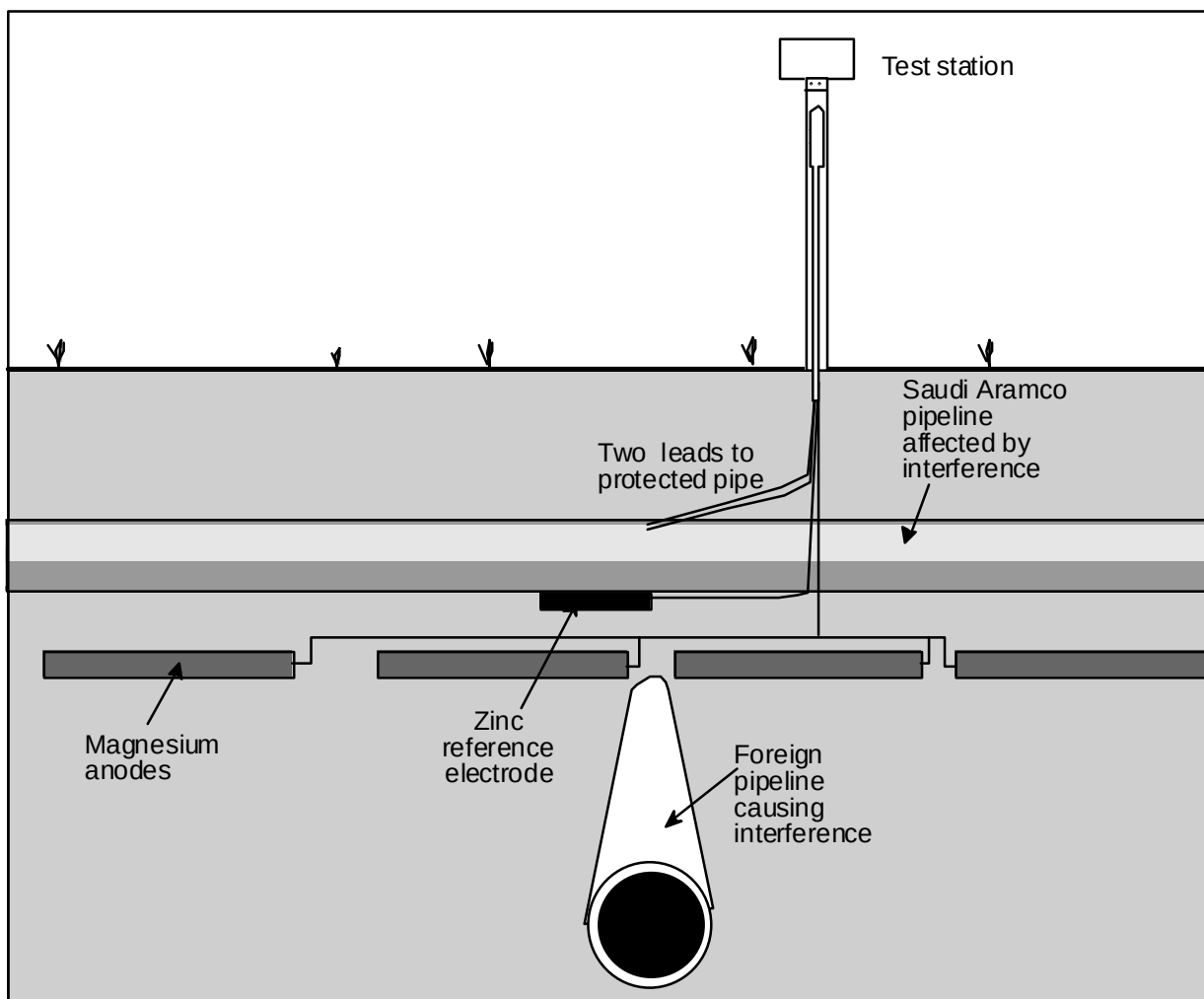


Use of Coating to Correct Interference

Figure 8

Galvanic Anodes

Saudi Aramco normally uses bonding to prevent interference at foreign line crossings; however, interference can also be corrected by installing galvanic anodes through the crossing area. Figure 9 illustrates the use of magnesium galvanic anodes to correct interference. Corrosion current is discharged from the Saudi Aramco pipeline as a result of interference from the foreign pipeline. Galvanic anodes supply enough cathodic protection current to offset this corrosion current. For most applications of this type, a single line of anodes between the two pipelines is sufficient to reduce the harmful effects of interference. The current discharge is from the anodes rather than the previously affected pipeline. A zinc reference electrode is placed under the affected pipeline to allow potential measurements at the point of maximum exposure.



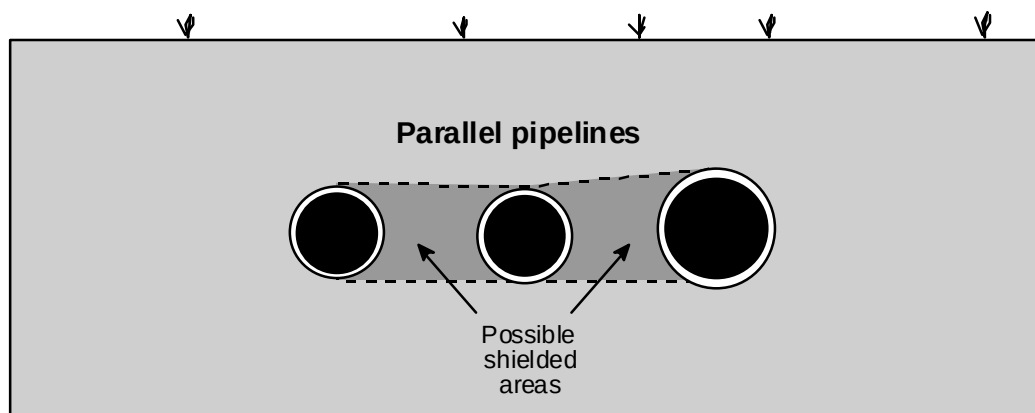
The Use of Galvanic Anodes to Correct Interference at a Pipeline Crossing
Figure 9

Recommending Corrective Actions To Reduce the effects of Electrical Shielding

An electrical shield is any barrier that prevents or diverts the flow of cathodic protection current to a structure for which it is intended. There are two types of electrical shielding. One type may result from a non-metallic insulating barrier which prevents the flow of cathodic protection current. The other type involves diversion of current to other metallic structures surrounding and in electrical contact with a pipeline to be protected. This section will describe both types of electrical shielding and will recommend corrective actions to reduce their effects.

Conductive Shielding

Conductive shielding can occur when several parallel pipelines are laid close to each other as shown in Figure 10. It is very difficult to cathodically protect all of the pipelines' surfaces, particularly in areas where the pipelines are closest to each other. Conductive shielding occurs because electrical current always takes the path of lowest resistance. Cathodic protection current that arrives at a group of bonded pipelines tends to be collected by the more accessible pipe surfaces. The problem of conductive shielding becomes worse as pipelines are placed closer together.



Conductive Shielding Caused by Closely Spaced Pipelines

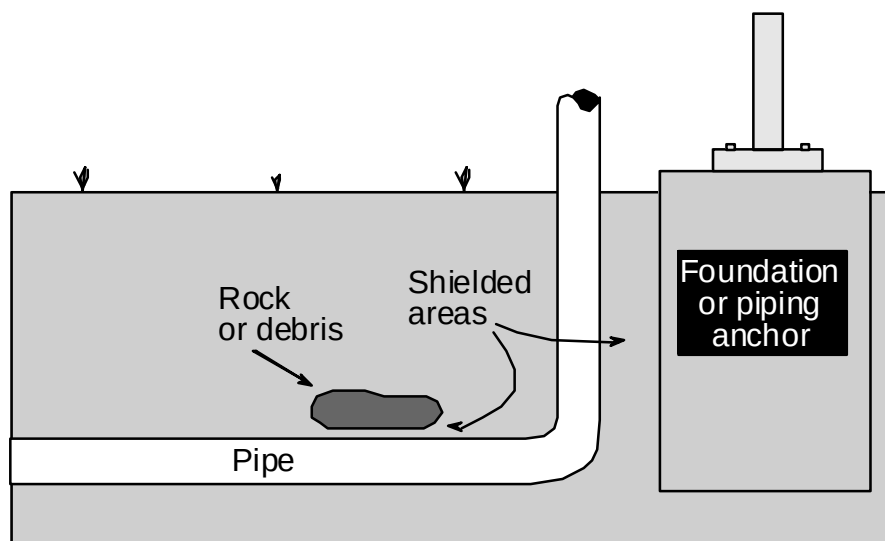
Figure 10

Corrective Actions for Conductive Shielding

Corrective actions for conductive shielding depend on soil resistivity and pipeline potential. In high resistivity soils, galvanic anodes are not effective. Distributed, impressed current anodes are better than deep anode beds. Because electrical power is available in plant areas, impressed close and distributed anodes are used instead of galvanic anodes. Another corrective action is to isolate (coat) other structures that are close to cathodically protected structures.

Insulating Shielding

Insulating shielding is another form of shielding that reduces or prevents cathodic protection current from reaching a buried metal surface. Insulating shielding may occur whenever buried metal structures under cathodic protection are close to non-conductive or partially conductive objects as shown in Figure 11. Below grade rocks, concrete piping anchors, or pilings on foundations that are close to protected structures may prevent current from reaching the structure.



Examples of Insulating Shielding

Figure 11

Corrective Actions for Insulating Shielding

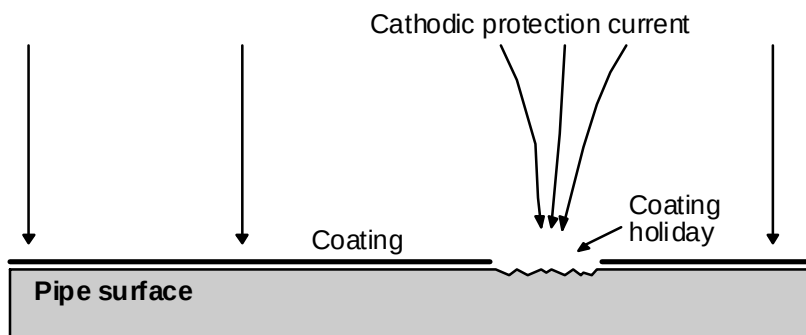
Where insulating shielding in congested areas is a problem, it may not be practical to rely on a remote anode bed. Cathodic protection still can be provided by the use of close, or distributed, galvanic anodes. Distributed CP systems are applicable in congested areas such as plants because (1) remote anode beds are electrically shielded by other buried structures, and (2) some buried metal in the plant does not require cathodic protection (e.g., a bare copper electrical grounding grid).

Recommending Corrective actions to reduce the effects of coating defects

Coatings are the primary method of corrosion protection for buried pipelines. Well applied coatings improve cathodic protection because only the small exposed areas (coating holidays) have to be protected. If the coating is improperly applied or becomes damaged, the current required from the CP system increases considerably. The increased expense associated with larger current demand can waste the investment that was made in the coating. This section will describe two types of coating defects--holidays and disbonded coating--and the corrective actions that can be taken to reduce their effect.

Coating Holidays

Cathodic protection current flows through the coating as well as to coating defects. If the coating has a high electrical resistivity, the amount of current that flows through the coating is negligible compared to the current that flows to coating holidays. Cathodic protection current preferentially flows to a coating holiday because the resistance to earth is lower at the holiday than at the coated surface (Figure 12).



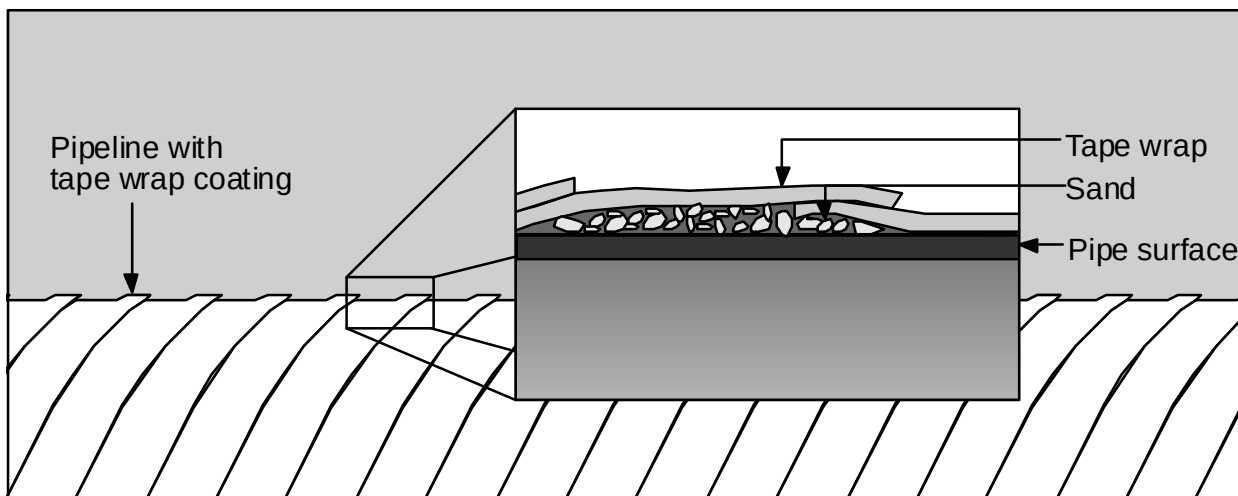
Increased Cathodic Protection Current Density at a Coating Holiday

Figure 12

As cathodic protection current flows through the soil to the pipeline, the soil resistance creates a potential gradient around the pipeline. The potential gradient is greatest at the coating holiday because of the larger current density around the holiday. The current flow and voltage gradient are lower where the coating is good.

Disbonded Coatings

A disbonded coating is a coating that has lost its adhesive bond with the pipe surface. In Saudi Aramco operations, disbonded coatings occur mainly on pipelines that are coated with tape wrap. During application of the tape coating, wind-blown sand gets between the tape and the pipe surface. The sand causes the coating to disbond as shown in Figure 13.



Disbonded Coating Caused by Wind-Blown Sand During Coating Application

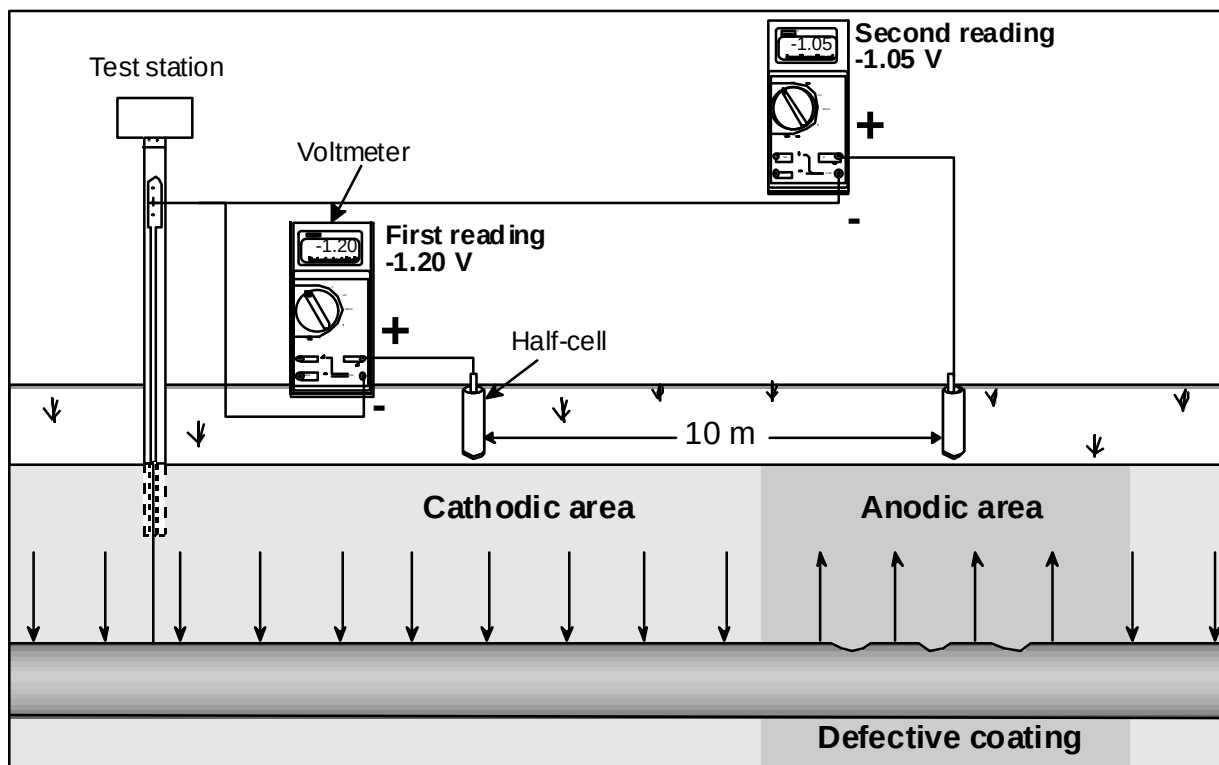
Figure 13

A disbonded or damaged coating can shield cathodic protection current and leave the pipe surface underneath the disbonded coating susceptible to localized corrosion. When this type of shielding occurs, more current is required to protect the pipeline. Unfortunately, very little or none of the extra current reaches the pipe surface under the disbonded coating.

Recommending Corrective Actions for Coating Defects

There are a variety of techniques to locate coating defects and damaged coatings on buried pipelines. Saudi Aramco uses close interval potential surveys and side drain surveys to locate coating defects. Both of these surveys are conducted to determine where current is being picked up or is being discharged by the pipeline.

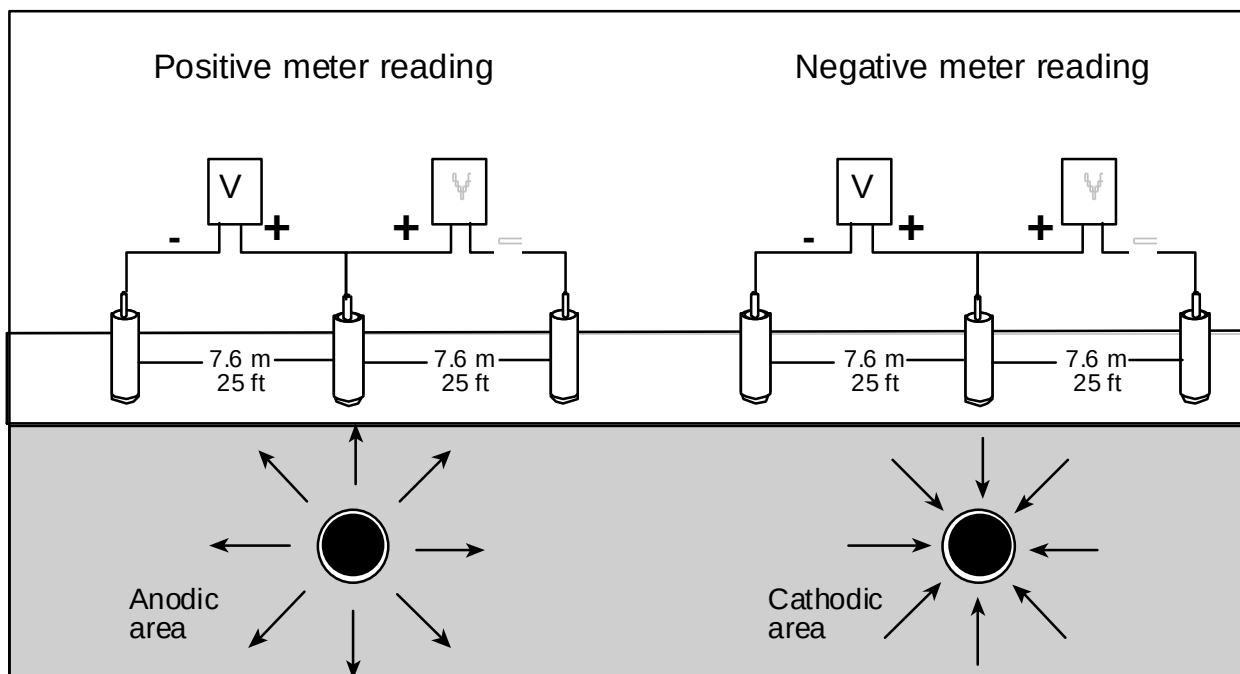
During a close interval potential survey, potential readings are made with respect to a "close" reference electrode at 10 meter intervals, as shown in Figure 14. Readings are taken with the CP system "on." Lower (more positive) pipeline potentials may indicate current discharge. Higher (more negative) potentials may indicate current pick up. For example, in Figure 14, the pipeline is more likely to corrode where the pipe-to-soil potential is lower (more positive). If two successive readings are significantly different, potential readings are taken again at 1 meter intervals to locate the coating defect.



Close Interval Potential Survey

Figure 14

A side drain survey involves measuring the voltage change in the soil between two closely matched Cu-CuSO₄ electrodes. One electrode is connected to the positive terminal of a voltmeter and is placed over the structure (Figure 15). The other electrode is connected to the negative terminal of the voltmeter and is located 7.6 meters (25 ft) to one side of the structure. The difference in voltage between the two electrodes is displayed by the voltmeter. A positive reading indicates that the current is flowing away from the pipe (an anodic zone). A negative reading indicates a cathodic zone. This procedure is repeated on opposite sides of the pipe as shown in Figure 15 to confirm the current flow.



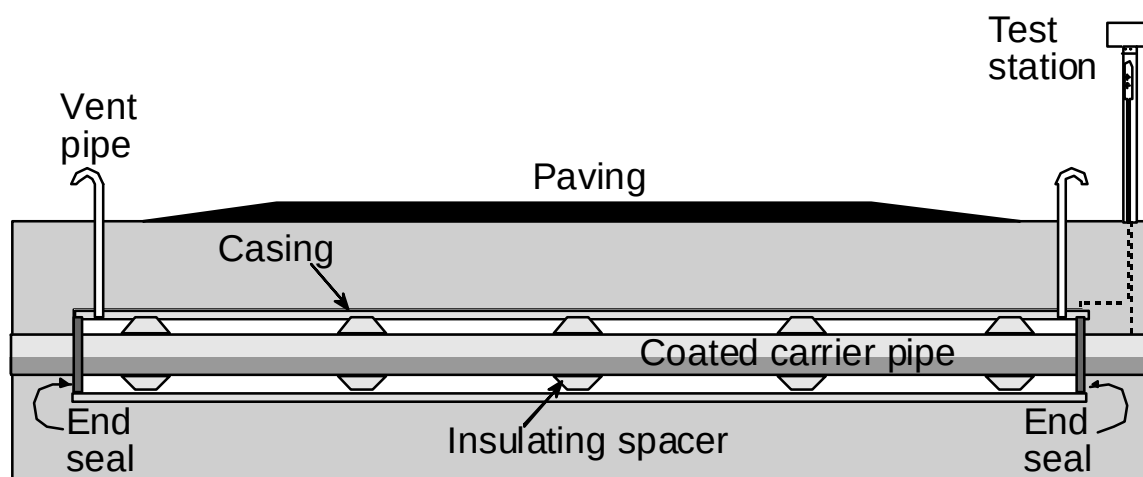
Side Drain Survey
Figure 15

The locations with the greatest positive potential differences (50 mV or more) are noted so that the coating can be inspected and repaired. The reference electrodes must be carefully matched since these voltage changes are only slight. If the soil is known to be nonuniform and the structure is unusually deep, this data may be misleading.

The type of coating defect determines whether or not a defect can be detected during a pipe-to-soil potential survey. A disbonded coating that is shielding the metal surface cannot be detected during either a standard pipe-to-soil potential survey or a close interval survey. Disbonded coating is almost impossible to detect other than with a bellhole inspection. There are two types of bellhole inspections: focused and secondary. Focused bellhole inspections are expensive because the pipeline is uncovered specifically to inspect the coating. Secondary bellhole inspections are performed when the pipeline is exposed for other operational and maintenance purposes. A secondary bellhole inspection is an easy and inexpensive way to assess the condition of a coating.

Locating a Short Circuit in a Cased Crossing

Saudi Aramco uses casing to protect pipelines that cross under roads and railroads. A typical cased crossing installation consists of a coated carrier pipe inside a bare casing as shown in Figure 16. It is necessary to electrically insulate the casing from the cathodically protected carrier pipe. If the carrier pipe electrically contacts the casing, the level of cathodic protection for a section of the carrier pipe will decrease. For this reason, plastic casing insulators are installed every 1.5 to 3 meters to help support the pipeline or carrier pipe in the casing and to prevent electrical short circuits. End seals provide a tight seal between the carrier pipe and casing to keep moisture, soil, and other backfill materials from entering the casing. Typically, one or two steel vent pipes are welded to the casing pipe. Vent pipes allow leak detection and evaporation of moisture in the casing. One or more test stations are normally provided to take potential readings of the casing and carrier pipe.



Cased Road Crossing

Figure 16

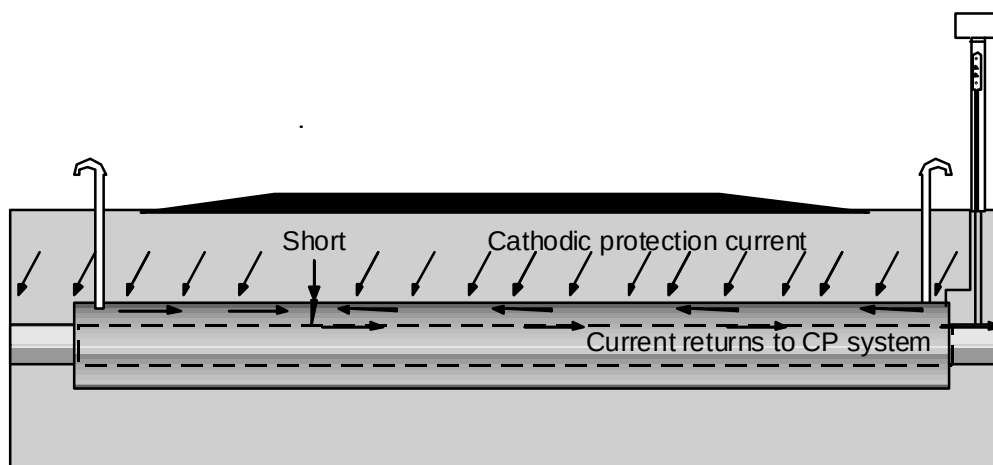
The carrier pipe inside the casing can corrode due to the following factors:

- Coating deterioration due to age or physical damage.
- Electrical shielding caused by defective spacers, insulators, or by coating damage.
- Water entry into the casing through defective end seals or condensation.
- Electrical contact between the casing and carrier pipe.

Pipeline coatings are susceptible to damage when the pipelines are pushed into casing sleeves. The longer the casing, the greater the probability of damage to the coating. Insulating spacers and end seals are intended to prevent electrical contact between the casing and pipeline; however, electrical contact may occur due to any of the following conditions:

- Improperly installed end seals.
- Insufficient number of, or failed, spacers.
- Forcing line pipe through crooked casing.
- Welding "icicles" inside casing which may contact carrier pipe where clearances are small.
- Test point wiring that contacts the end of the casing or vent pipe.
- Metallic objects or scrap metal inadvertently left in the casing during construction.

When the casing is properly insulated, cathodic protection current flows through the casing to the carrier pipe. If a short circuit exists, cathodic protection current gathers on the outside of the casing and flows along the casing to the point of contact between pipe and casing (Figure 17). At the point of contact, the cathodic protection current flows through the metallic contact to the carrier pipe. The current then flows along the carrier pipe back to the cathodic protection installation. Under these conditions, the section of the pipe inside the casing is left unprotected. The current, which should flow through to the carrier pipe, is collected by the casing.

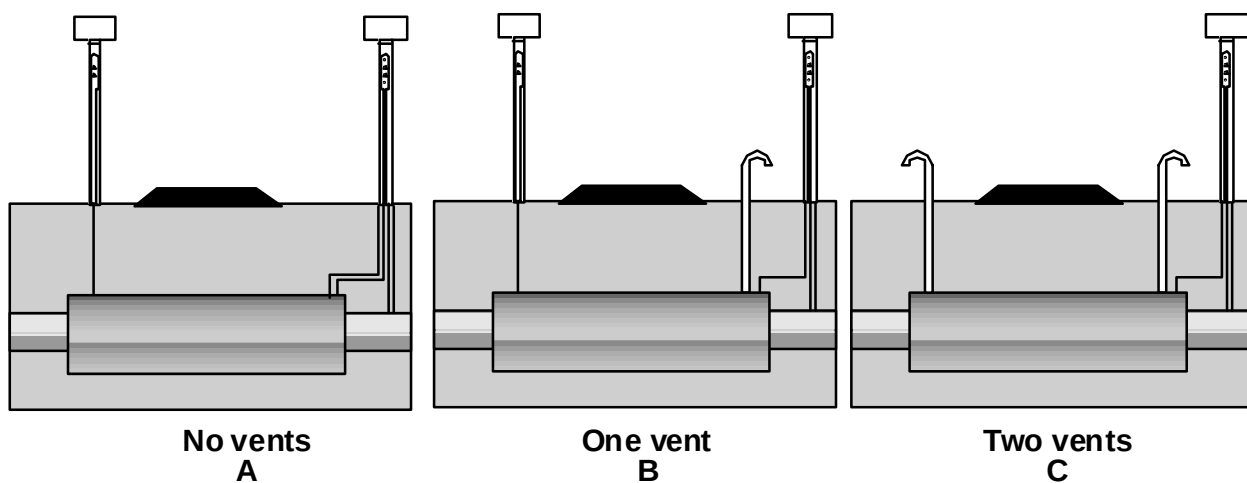


Short Circuit in a Cased Crossing

Figure 17

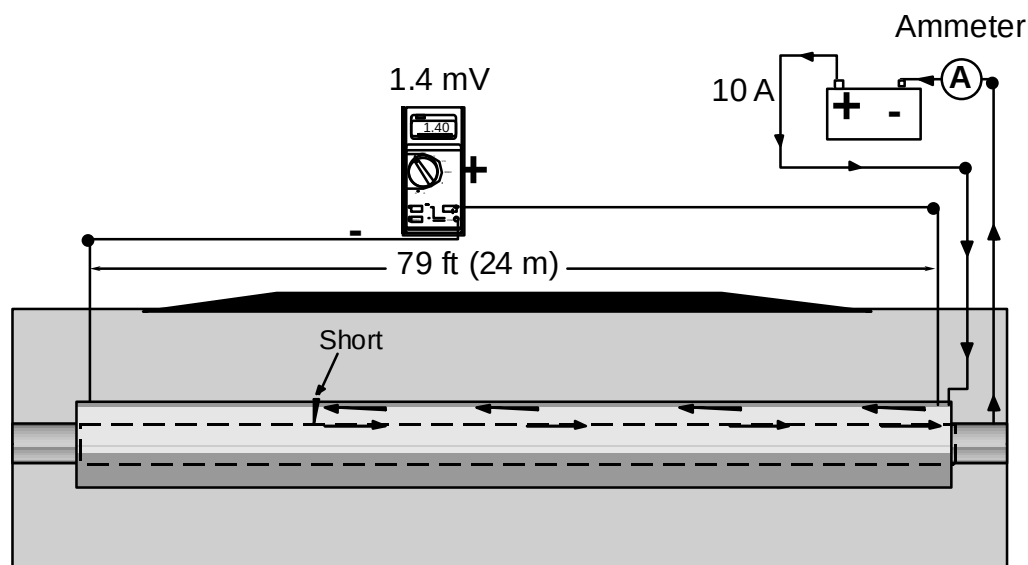
Testing Method for Cased Crossings

Test points make it possible to determine the location of an electrical short circuit inside a cased crossing. Figure 18 shows three test point configurations. If no vent pipes are installed (Figure 18A), two test leads are thermite welded to the carrier pipe and two leads are thermite welded to the casing. Another lead wire is welded to the opposite end of the casing to aid in casing resistance measurements. The configurations in Figures 18B and 18C are used if one or two vent pipes are installed. Although vent pipes can be used to take potential readings, these pipes should not be used to measure casing resistance.



Cased Crossing Test Points
Figure 18

The test set-up to locate an electrical short in a casing is shown in Figure 19. A voltmeter is connected between the two ends of the casing. A battery is used to produce current that is passed through the casing onto the pipe. The current flows along the casing to the short circuit, where it transfers to the carrier pipeline. The current returns to the battery through the pipeline test lead and is measured with an ammeter. The voltmeter reading is determined by the current that flows through the casing to the short circuit.



Test to Locate an Electrical Short Circuit Inside a Cased Crossing
Figure 19

For example, assume that the casing in Figure 19 is 26 inch O.D. pipe with a wall thickness of 0.375 inch. The distance between the test connections is 24 meters. A voltage of 1.40 mV was measured after the current was applied.

The resistance per foot of the casing is found in the Pipe Data Table in Work Aid 1. For 26 inch O.D., 0.375 inch thick pipe, the resistance per foot is 2.49×10^{-6} ohm/ft.

If the battery current is 10 amperes and the voltmeter reading is 1.4 millivolt, the distance traversed by the current in the casing would be:

$$\text{Distance} = 1.4 \times 10^{-3} \text{ V} / (10 \text{ A} \times 2.49 \times 10^{-6} \text{ ohm/ft}) = 56.2 \text{ ft}$$

The short would be 56.2 ft (17.1 meters) from the voltmeter connection on the right side of the casing.

Corrective Actions

When a short circuit occurs between the casing and carrier pipe, repair can be expensive. The critical nature of cased crossings justifies making an extra effort to ensure that pipe that is inside casings is protected properly. For instance, the manufacturer's recommendations for the number and size of insulating spacers must be followed. Top quality materials and careful attention to installation are essential because stresses can be very great during installation. Stresses can be especially great when larger pipe sizes are installed at long cased crossings. If a casing insulator is accidentally damaged on the casing end during the installation, the insulator should be replaced before continuing. If insulators are not close to the end of the casing (such as within one meter), additional spacers should be installed on the carrier pipe to ensure electrical insulation.

The casing must be prepared properly before the carrier pipe is pulled into it. Welds should be smooth on the inside to prevent damage to insulating spacers. The casing needs to be straight and round so that the carrier pipe, with spacers attached, can be pulled in without binding.

If vent pipes are set after the carrier pipe is installed, burning a hole in the casing may damage the carrier pipe coating. All hole burning should be done prior to pulling the carrier pipe. All debris must be removed from the casing.

Work Aid 1: Procedure and Data Base to Locate a Short Circuit in a Cased Crossing

Use the procedure below to locate a short circuit in a cased crossing.

Procedure

1. Obtain the following information:
 - The distance between the test points on the casing.
 - The voltage reading between the test points on the casing (in volts).
 - The amount of current from the battery (in amperes).
2. Obtain the resistance per foot from Figure 27; as a basis, use the diameter and thickness of the casing.
3. Divide the voltage reading by the product of the current and resistance per foot to obtain the distance of the short from the positive voltmeter connection.
4. Multiply the distance in feet by 0.3048 to convert it to meters.

Data Base

O.D (inches).	Wall Thickness (inches)	Cross-Section Area (Sq. in.)	Weight (lbs/ft)	Micro Ohms/ft mW/ft	A/mV/Ft
26	0.285	23.02	78.30	3.66	273.2
	0.312	25.22	85.73	3.34	299.4
	0.325	26.22	89.12	3.22	310.5
	0.375	30.20	102.63	2.49	401.6
	0.500	40.10	136.17	2.10	476.2
30	0.312	29.10	99.08	2.90	344.8
	0.325	30.10	102.89	2.79	358.4
	0.344	32.05	108.88	2.63	380.2
	0.360	33.52	113.96	2.51	398.4
	0.375	34.90	118.65	2.42	413.2
	0.406	37.75	128.40	2.23	448.4
	0.438	40.63	138.13	2.07	483.1
	0.500	46.34	157.53	1.82	549.4
36	0.344	39.30	130.90	2.19	457.0
	0.375	42.00	142.68	2.01	497.0
	0.406	45.40	154.43	1.85	540.0
	0.469	52.35	177.88	1.612	620.0
	0.500	55.76	189.57	1.511	661.8
	0.562	62.57	212.89	1.345	742.5
	0.625	69.46	236.13	1.212	824.5
	0.687	76.22	259.28	1.104	904.0
42	0.375	49.00	166.70	1.72	583.0
	0.390	51.03	173.31	1.65	606.0
	0.438	57.20	194.40	1.47	680.0
	0.500	65.20	221.60	1.29	775.0
	0.562	73.20	248.70	1.15	772.4
	0.625	81.20	276.20	1.037	966.0
	0.700	90.80	308.70	0.928	1077.6

Pipe Data Table
Figure 27

glossary

area of influence	The area in which the potential of a structure exceeds the minimum potential required for protection.
bellhole inspection	An inspection method that is used to monitor the condition of the buried pipeline coatings.
close interval potential survey	A pipe-to-soil survey that is usually conducted at 5 to 10 meter intervals to determine where current is being picked up or discharged by an unprotected pipeline.
conductive shielding	The diversion of cathodic protection current to other metallic structures that surround the structure to be protected.
electrical shielding	Preventing cathodic protection current from reaching the structure for which it is intended.
foreign structure	Any buried metal structure that is not electrically bonded to Saudi Aramco's cathodic protection system.
insulating shielding	A form of shielding that may occur whenever buried metal structures under cathodic protection are close to non-conductive or partially conductive objects.
side drain survey	A survey to measure the potential change in the soil by using two similar reference electrodes. One electrode is placed directly over the structure while the other electrode is placed a short distance from the structure.
stray current	Current that flows through paths other than the intended circuit.