Pipeline Protection with Clamp-On DC Ammeters

Introduction: Why Measuring Current Is Important

Corrosion generally occurs where current leaves a line into an electrolyte, so we need to know the direction of current flowing in a line. The amount of metal lost by a line is proportional to the magnitude of the current leaving the line into soil or sea water. As Dr. John Leeds has said, "Industry would do well to shift to methods that read Cathodic Protection (CP) current amperage and direction..." [*Pipeline & Gas Industry* - April 1997 - page 55.]

Real ammeters are now available in non-contact or clamp-on form. These MER™ Clips and MER™ Clamps measure the actual CP current in a line at the spot where you put them. In one form or another, they measure 5 milliamps to 200 amperes in conductors from ¼ inch to 82 inches in diameter. Resolution of 1 milliamp DC can be provided from ¾" to 30" diameter with sensitivity accuracy typically 1% of reading. Adjacent conductor interference and zero offset error due to residual local magnetism are reduced by new technology.

Five figures are presented to illustrate the use of these ammeters. Specific data refers to the ammeters known best: DC Amp Clips and Clamps manufactured by the Swain Meter Co.

Real CP Current Measured in situ, Quickly and Accurately

Fig. 1A illustrates a method for finding the resistance of an insulated flange by accurately measuring real flange current at the flange using the normal CP system with an interrupter. "...faults consuming large amounts of current are top candidates for repair". [*Pipeline & Gas Industry* - April 1997 - page 57.] The MER™ Clamp is used to evaluate the seriousness of a fault, and to set repair priority.

Fig. 2 shows how the actual anode current during normal use is accurately measured at an offshore tower. Assessing anode life expectancy and integrity of mount are but two of the reasons for this work.

In Fig. 1 and Fig. 2 the current measured is that from the operator's rectifier or anode, through his pipe to a specific access, preserving influences from foreign lines, shorts, excess resistance, etc., intact.

Fig. 3A and 3B illustrate the use of a portable current generator to locate a pipe to rebar short in a crowded sector where line tracers don't work.

Fig. 4 shows how to detect, evaluate, and find a fault on an adjacent foreign line which causes a sharp increase in the corrosive action of current leaving our line.

Fig. 5 is a common corridor illustration of how to detect, evaluate, and find a fault. Both gas line and URD line troubles are evaluated.

Fig. 1A: Resistance of Flange

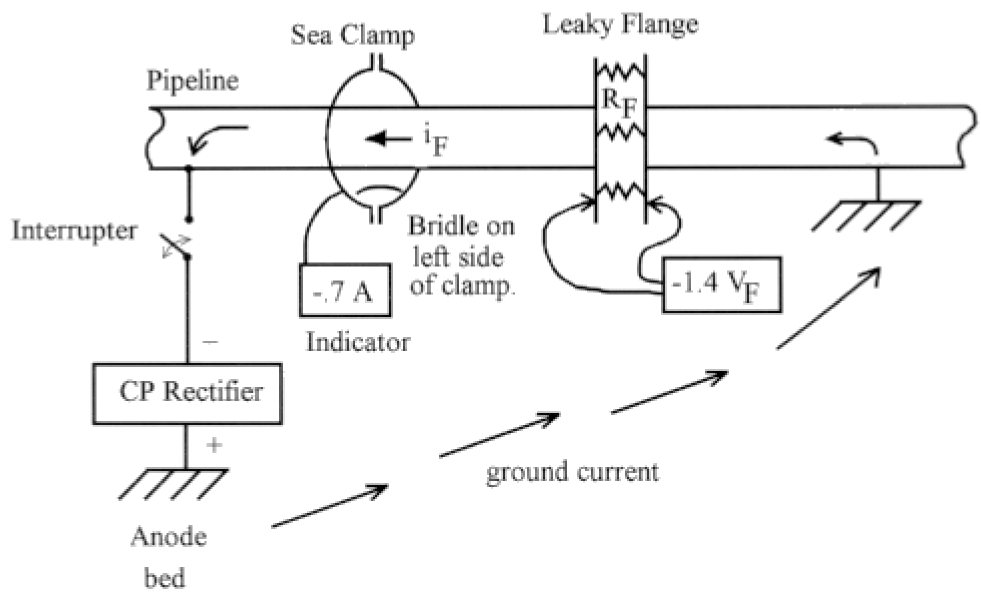


Fig. 1A illustrates how the resistance R_F of a leaky insulating flange in a pipeline can be measured. The change in flange voltage V_F is divided by the change in flange current i_F. Accuracy is enhanced by interrupting the CP rectifier if there is residual system voltage, and/or local line magnetism which causes a zero offset in the indicated line current.

The interrupter on the CP rectifier produces the necessary change in V_F and i_F. If these are too small, a portable interrupted current supply can be connected closer to the clamp.

Polarity

The indicator in Fig. 1 reads -.7 A because the current i_F is shown flowing through the aperture of the Clamp and out on the bridle side. This is the reverse of our direction for positive current.

The ammeter reads positive when conventional current flows from left to right through the aperture of the sensor when the cable to the indicator is up. If the sensor is a clamp, the bridle is on the left when the indicator cable is up.

Fig. 1B: Interrupter Used to Change Flange Voltage & Current

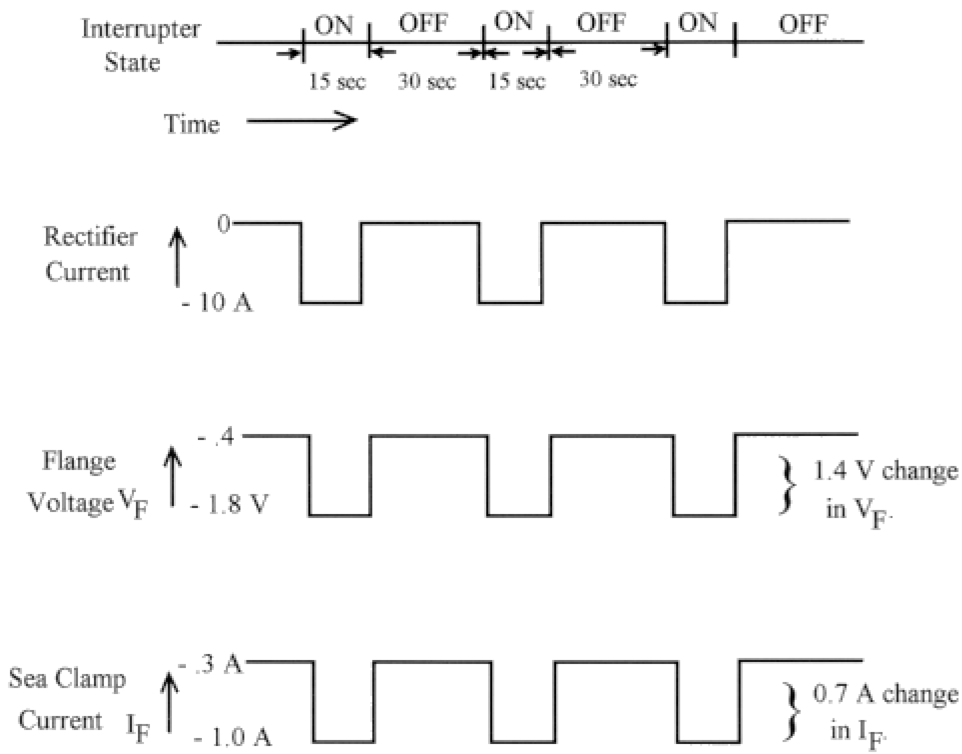
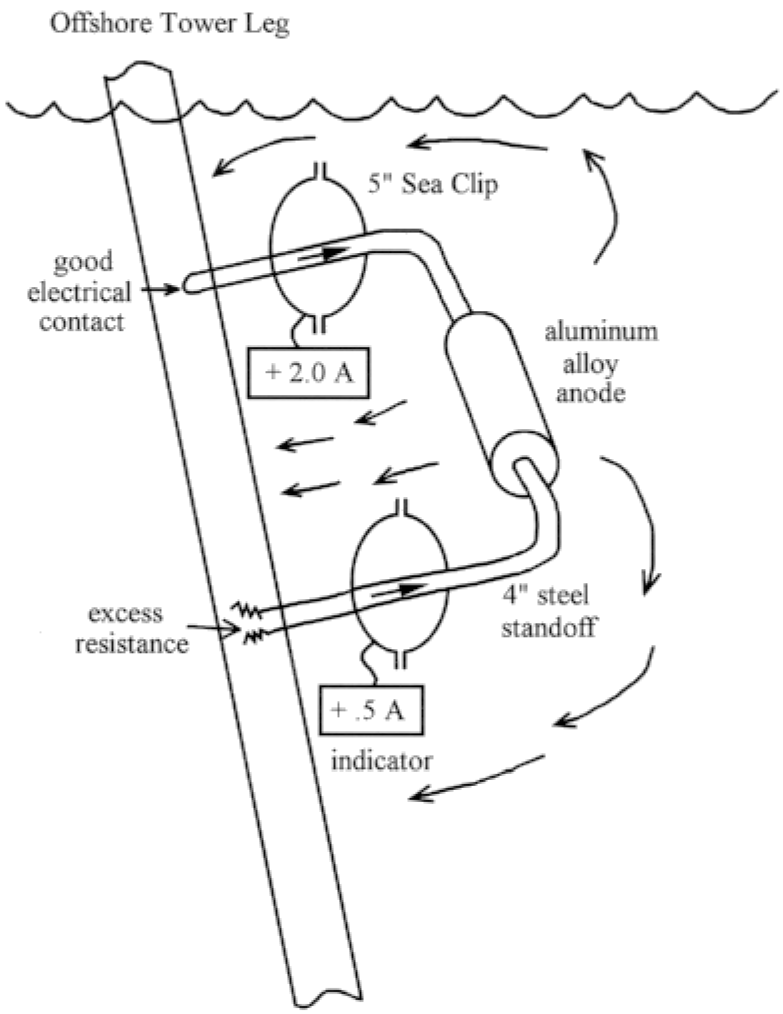


Fig. 1B illustrates the changes in voltage and current in Fig. 1A over time. When the interrupter is in the OFF state for 30 seconds, the rectifier's current output is zero, but the voltage V_F and current I_F are likely to have residual magnitudes; for example; -0.4 V & -0.3 A. This can be due to polarization potentials, interference current, zero offset, etc. We only require that they be reasonably constant for about 60 sec.

When the interrupter goes to the ON state for 15 seconds, the rectifier's output may be -10 Amp. In this example, the flange is some distance from the rectifier so the flange voltage V_F changes by -1.4 V and the flange current i_F changes by -0.7 A. Then in this example the flange resistance R_F is:

$$R_F = \frac{\Delta V}{\Delta i} = \frac{1.8 - 0.4 \text{ V}}{1.0 - 0.3 \text{ A}} = \frac{1.4 \text{ V}}{.7 \text{ A}} = 2\ \Omega$$

Fig. 2: Sacrificial Anode Current



In Fig. 2 a single MER™ Clip is used to measure the anode current flowing in each 4" standoff secured to an offshore tower. In this example, the total output current is 2 A + .5 A = 2.5 A.

The current in the lower standoff is much less than the upper because of poor electrical contact to the tower leg.

Tests such as these are used to verify electrical contact of retrofit electrodes, and to estimate the operational life of similar anode installations. The indicator may be on the surface with up to 700 feet of cable to the clip. Or the indicator may be in the ROV or diver's bell so a separate long cable is not required.

Longevity in Sea Water

MER™ Clip and MER™ Clamp sensors are intrinsically stable and reliable, whether in air or under water. To demonstrate stability in water, we tested a bare 5" sensor having no epoxy coating and no special waterproofing -- first in air, and then immersed in about a foot of natural sea water. It was stable in the air and also under water for over a year.

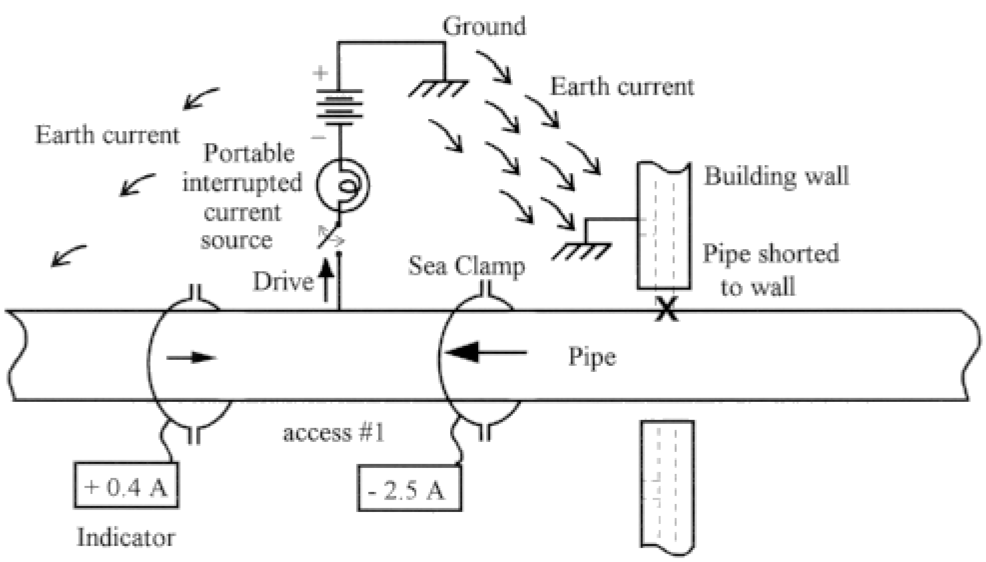
Buried MER™ Clamp

To sense instant defects and to measure their severity, CP current may be continually measured for many months. MER™ Clamps are considered suited for long term burial on a pipe. This will also permit measuring gradual coating degradation.

More Stable

MER™ Clamps are generally more stable when subject to mechanical and electrical stress than Hall devices because the sensing action is distributed over practically the whole core. Sensors for DC Amp Clips resemble the familiar current transformer. There is a fine steel core, split into two halves, with a sense winding wound around the core. This forms a distributed sensor, because the magnetic field set up by the current flowing through the aperture acts on the whole circumference of the core.

Fig. 3A: Finding a Short to a Pipeline



A systematic method for finding a short to a pipeline is outlined in Fig. 3A and 3B. We are told that this direct current method works in a congested urban environment where alternating current fault locators are ineffective.

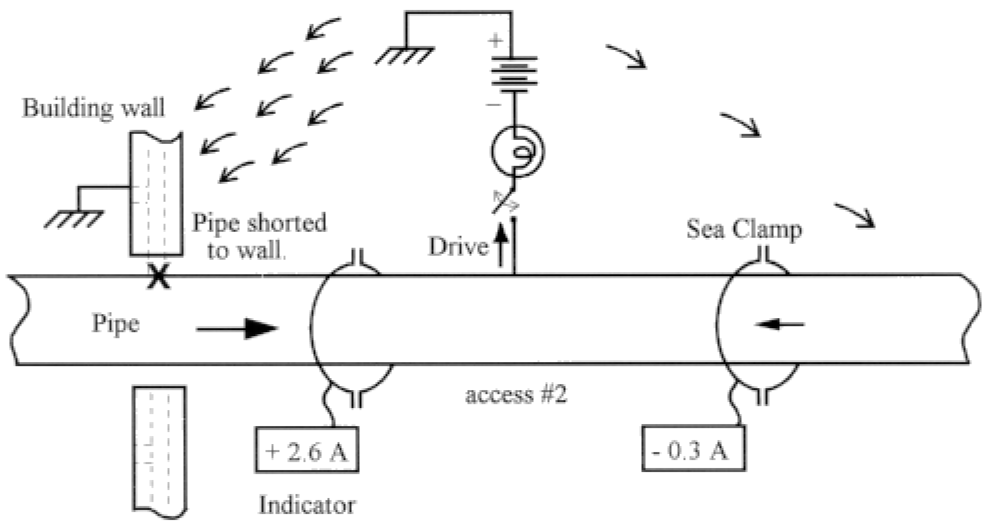
Fig. 3A

At Pipeline access #1, a single MER™ Clamp and a single indicator measure the interrupted current from a portable current source, first to the right (-2.5 A) of the current drive point on the line, and then to the left (+0.4 A). The major current entering the drive point from the right indicates that the short is to the right.

Polarity

Current flowing into the drive point from the left reads positive (+) because it goes through the aperture of the sensor from left to right when the cable from the sensor to the indicator is up, as shown. Current flowing into the drive point from the right is indicated as negative (-) because it is flowing in the reverse direction from our convention for positive.

Fig. 3B



Since the major current (-2.5 A) in Fig. 3A showed that the ground fault must be to the right of access #1, the search is continued using access #2 which is well to the right of #1.

Fig. 3B

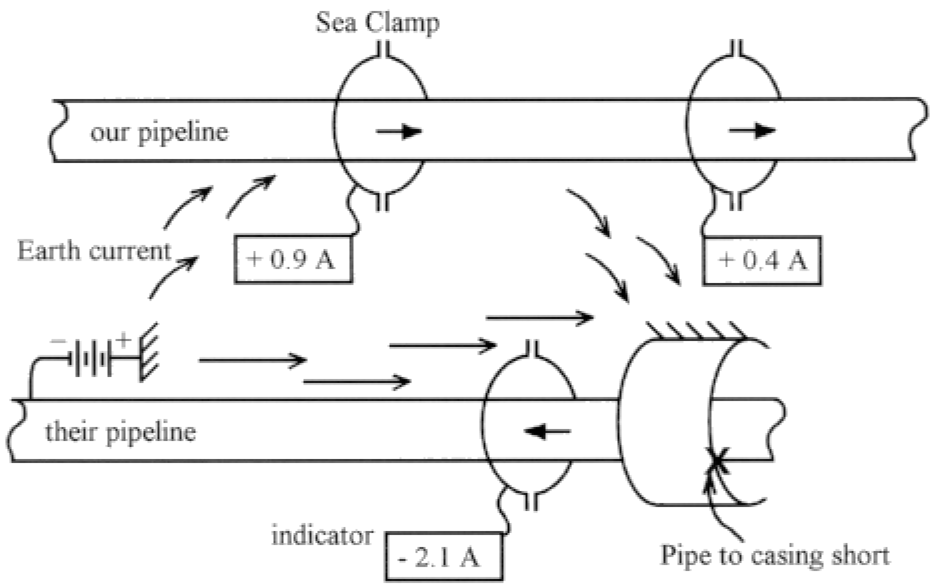
The same MER™ Clamp and indicator and portable current source are set up and used at access #2 as shown in Fig. 3B. Here the major current (+ 2.6 A) is to the left of the drive point. It appears that the short is between access #1 and #2.

Search is made at other accesses closer together, between 1 and 2. The process is repeated until the short is found.

Or experience is used. Since it is known that the pipe goes through the wall of a building having grounded rebar, a search is made at the wall as soon as it is seen that the major currents bracket the wall.

Fig. 4: Interference

Earth current leaving our pipeline is 0.9 - 0.4 = 0.5 Amp.



["Their pipeline" here means any foreign pipeline, or another pipeline owned by us which is not now the center of our attention.]

Fig. 4 illustrates interference to our pipeline when an adjacent foreign line draws much more than normal earth current from its anode bed. This can be due to a pipe to casing short, or some serious flaw in their coating.

The earth current fans out, and some enters our pipe where it has a few coating defects. The damage is done where this current leaves our pipe to go to the shorted casing.

The severity of a flaw may be judged by measuring pipeline current at several access points. The MER™ Clip is used to find high concentrations of current loss along our line.

The current loss over a pipeline span between two access points is the difference between the current measurements at each one. In this example, a single MER™ Clamp and indicator are used to find the 0.5 Amp (.9 A - .4 A)* leaving our line. The weight of the steel leaving our line each year is directly proportional to the current leaving the line into the soil**. Ten pounds loss in a year is serious if it all occurs in a small length on a small pipe. However, if our line is large and the 0.9 A and 0.4 A sectors are widely separated, the 0.5 A current leaving our line may be widely distributed and hence less important. If not very much steel is lost in any one place, the pitting may not be deep enough to be serious.

* Direction of current flow i.e., polarity, is important. An unexpected fault could cause a reading to be (-) 0.6 A. Then the loss in the +.9 A to -.6 A span is 1.5 A.

** Twenty pounds of steel lost due to 1 Amp leaving the line for one year is a widely accepted figure.

However, if a relatively short span has most of the current loss (for example, 0.8 A - 0.5 A = 0.3 A loss), then our line may be in danger.

Fig. 5: Short to Gas Line in Common Corridor

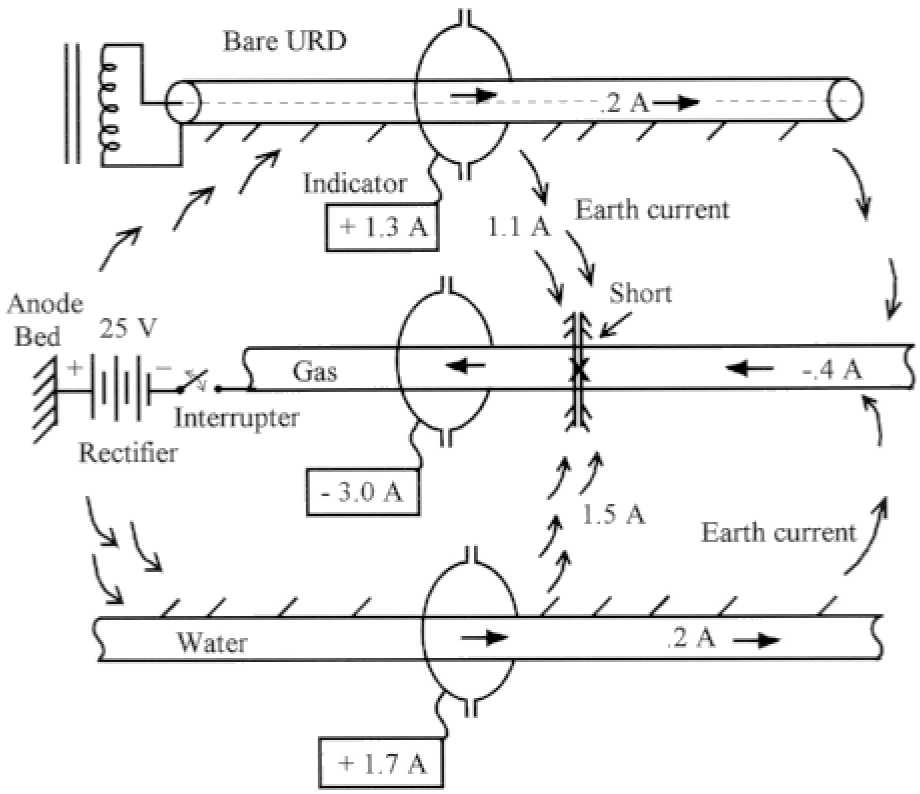


Fig. 5 illustrates how a MER™ Clip or MER™ Clamp can be used to discover that there is a sudden defect, to locate the short, and also to evaluate the damage that is being done.

In this example, the gas main in the center of the common corridor is shorted to a conductor making good earth contact. The short may be a new pipe in a bored hole that nicked the gas line, a metal tray, or a bridge support. With the short, the URD and water pipes act as channels for anode current of the gas pipe.

The corrosive effect of current lost by the URD line will likely increase the resistance of the return conductor at this position. If allowed to continue, this will cause alternating current to flow in the soil and gas line. This trouble can regenerate, with AC and DC corrosion becoming ever more serious.

The table below summarizes the URD and water line currents lost to earth. These are corrosive. The negative loss currents to the gas line are likely not corrosive.

Summary of current lost to earth from each of the 3 lines			
	URD	Water	Gas
Current loss between rectifier and short	1.1 A	1.5 A	-2.6 A

+ Current loss on far side of short	0.2 A	0.2 A	-0.4 A
= Total current leaving the line to the earth	1.3 A	1.7 A	-3.0 A

In Fig. 5 a bare URD coaxial power cable and a water pipe are on either side of a gas line -- all buried in a common corridor between accesses. Normally this is made to work fine, primarily because although under CP, the gas line is well coated. Typically, very little rectifier current from the anode bed enters or leaves the URD or water lines because the gas pipe is well insulated by its coating.

However, everything changes for the worse when a bare pipe in a bored hole nicks the gas line, cutting through its coating and electrically connecting the gas line to the bare pipe. An instant defect such as this can suddenly endanger lines. A current sensor can be installed permanently and connected to sound an alarm if a defect occurs.

In Fig. 5, the defect is most apparent as a large increase in rectifier output, from perhaps 0.5 A to 3 A. At least three problems are created:

a. The gas line does not have enough voltage drive from the rectifier for effective CP, especially beyond the short. The gas line may start to corrode further on down.

b. Anode current is leaving the bare outer conductor of the URD power line in the span adjacent to the short. This will eventually strip out a lot of return conductor and cause power current to flow in the earth. This can be a hazard to persons or property nearby.

c. In like manner, current is leaving the bare water pipe in the span near the short. This can even endanger the water main if it persists.

A single MER™ Clamp and indicator can be used at several access points as shown in Fig. 5 to locate the fault and stop corrosion.

Bond Current

One or more bond cables may be added to fig 4 so that most of the earth current flowing between our pipeline and theirs is rerouted through a copper path. This bond current should be measured because as Dr. Leeds reminds us, significant bond current can introduce an IR drop error in measuring pipe-to-soil potential.

A MER™ Clip may be used to measure the current magnitude and direction of flow in each bond safely, quickly and accurately. Lifting the bond or adding a series shunt resistance is not necessary. This is important, because adding resistance changes the current.

The 5 inch clip used in Fig. 2 will do for measuring current in higher current bonds. A ¾" or 2 ½" MER™ Clip is better because the zero offset error is less important when measuring current less than 1 Amp.

Conclusion

Clamp-on DC ammeters are used by corrosion engineers and others to accurately measure actual pipe and cable current -- on the line -- during normal operations. This saves time and trouble.