Surface Potential Surveys Training Manual – DA Meter Version

M. C. Miller Co., Inc.

CONTENTS

SECTION 1

INTRODUCTION

The "Surface Potential (SP)" pipeline survey method, also called the Cell-to-Cell Potential survey method, is similar to the DCVG survey method, at least in terms of how the reference electrodes are employed to measure the difference in potential between two points on the surface of the soil above a buried pipeline. SP surveys, however, are typically performed on uncoated pipelines that are not cathodically-protected.

In the case of SP surveys, any localized current flow that gives rise to potential gradients on the surface of the soil above a buried pipe is due to the presence of corrosion cells (combinations of anodic and cathodic areas) on the pipeline, as opposed to impressed current from a CP system which is responsible for the "signal strength" in the case of DCVG surveys.

In the case of bare pipe, typically only about 10-15 % of the pipe will be subject to galvanic corrosion and, in addition, typically this small percentage is made up of small, highly-localized, corrosion areas (anodic areas) that are randomly-distributed along the length of the pipe. Thus, an "above-the-ground" survey technique that can accurately locate these isolated areas is invaluable.

The objective of SP surveys is to locate anodic areas existing along a segment of pipeline, as evidenced by potential gradient fields presenting themselves on the surface of the soil directly above the anodic areas. Once any anodic areas have been located, remedial action can be taken, such as the installation of "sacrificial" anodes to suppress current flow from the corroding area, with a view to preventing further external corrosion in that particular area .

SECTION 2

PHYSICAL PRINCIPLES

When current flows onto (or away from) a localized area on a buried-pipeline, a voltage gradient field presents itself on the surface of the soil directly above the localized area.

In the case where current is flowing onto a pipeline at some localized area, that localized area is considered a cathodic area and the voltage gradient field on the soil above the pipe will have a negative polarity. The largest negative potential will exist directly above the anomaly and the negative potential will decrease in magnitude to remote earth potential with distance away from the pipe.

The opposite is true in the case where current is flowing away from an isolated (localized) area on a buried-pipeline. In this case, the area is considered an anodic area and the voltage gradient field presenting itself on the surface of the soil above the pipe will have a positive polarity. The largest positive potential will exist directly above the anodic area and the positive potential will decrease in magnitude to remote earth potential with distance away from the pipe.

Since corrosion occurs on an uncoated buried pipeline via the development of "corrosion cells", both anodic and cathodic areas must exist simultaneously. The current flowing away from the anodic area will be collected by the cathodic area and the return path for the current will be the pipeline itself.

This situation is illustrated schematically in Figure 1 below (top diagram).
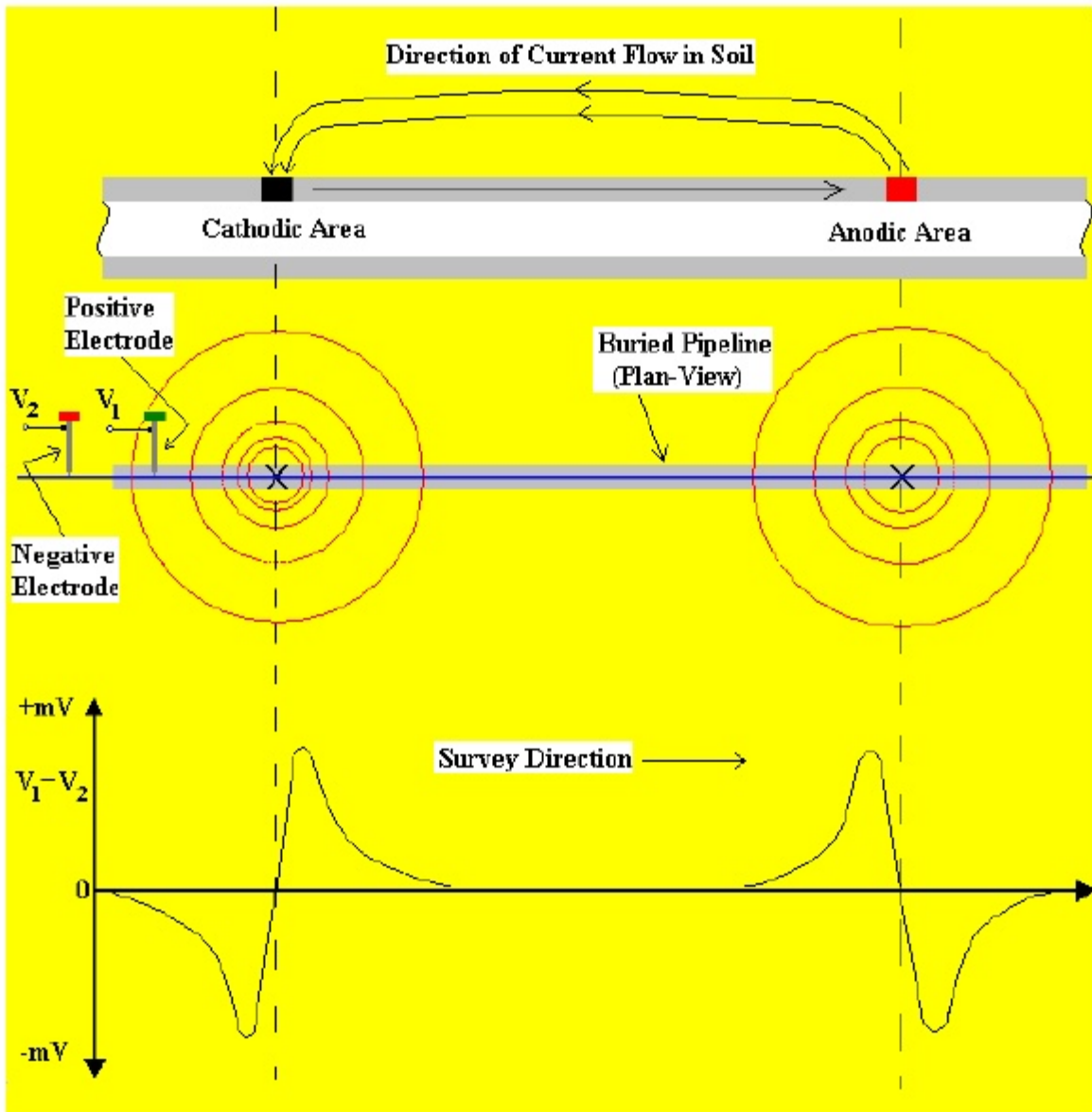
Figure 1: In-Line method of conducting SP surveys. Soil-to-soil potential difference readings are plotted in the bottom diagram against the position along the pipeline of the center point between the reference electrodes
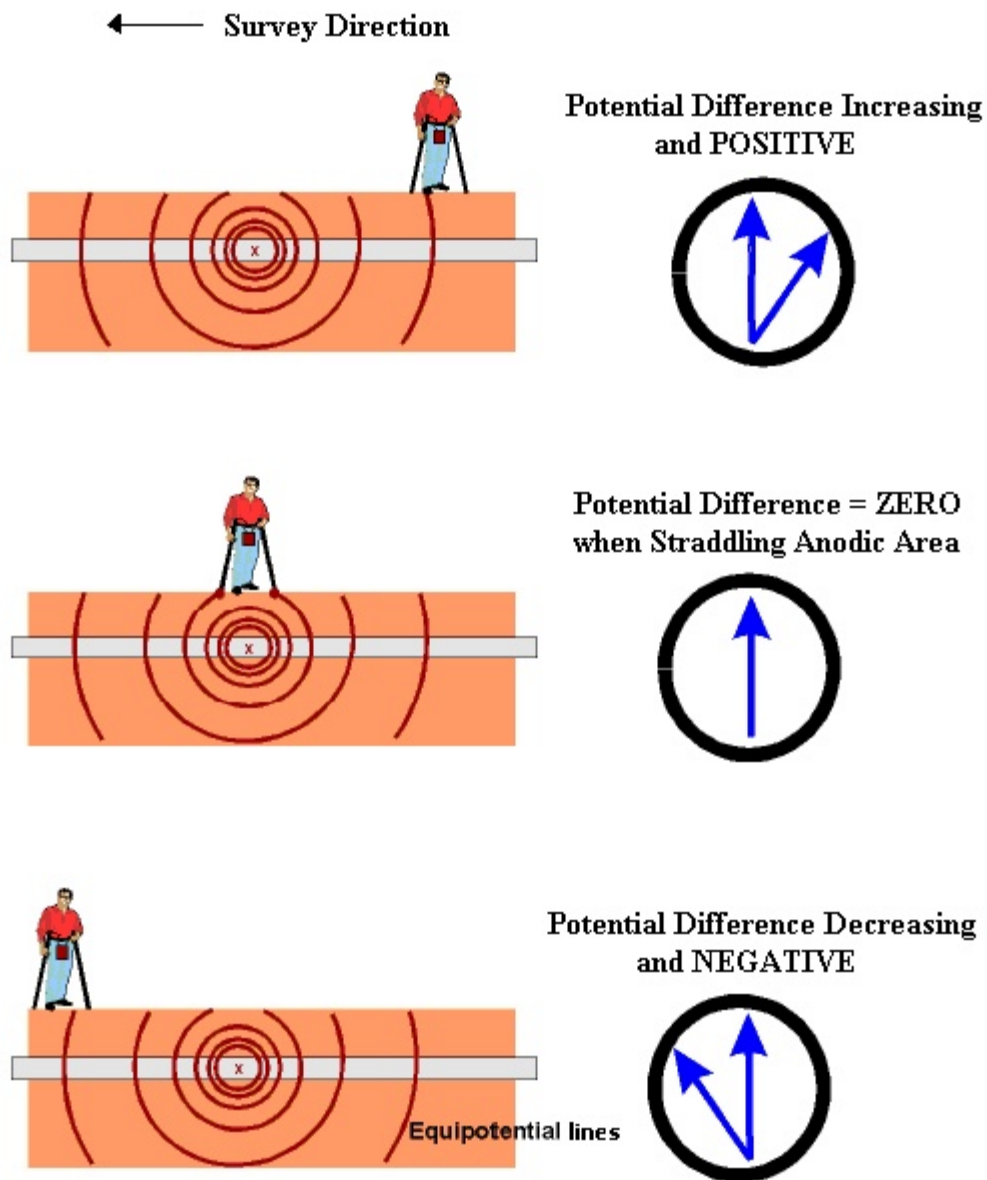
In-Line SP Survey Method

One way to perform a SP pipeline survey is to use the, so-called, "In-Line" method. In this case, the reference electrodes are both positioned over the pipe and their separation is kept fixed as the operator, or operators in the case of large electrode spacings (for example, a 20 feet spacing), walks down the length of the pipeline section. With a view to detecting localized anodic areas and accurately measuring the longitudinal voltage profile, the survey needs to be close-interval in nature.

With the electrodes positioned as illustrated in Figure 1, i.e., with the positive data-probe leading, when cathodic and anodic areas are encountered, the polarity of the longitudinal voltage (V^1 minus V^2) switches from negative to positive, in the case of isolated cathodic areas, while in the case of isolated anodic areas, the polarity switches from positive to negative as the voltage gradient fields are traversed.

The (longitudinal voltage) polarity switching phenomenon is explained with reference to Figure 2 below.

For the case of a localized anodic area, the potential gradient on the surface is positive and, so, when the positive data-probe enters the gradient field, a positive potential difference will be measured, relative to the zero potential difference measured with both data-probes positioned outside the gradient field. The potential difference measured between the probes will continue to increase, as the data-probes advance into the gradient field, and will go through a maximum value before dropping through zero (as the data-probes straddle the epicenter of the anodic area) and becoming negative. After going through a maximum negative value, the potential difference measured between the probes will decrease (staying negative) and eventually become zero again with both data-probes positioned on the far side of the potential gradient field. This type of longitudinal voltage profile is illustrated in Figure 1.

It should be noted that the nuances of the profile shown in Figure 1 will only be observed if the survey is close interval in nature (relative to the size of the potential gradient field).

Figure 2:   In-Line SP Survey Method.

Illustration is for the case of transiting a localized ANODIC area with the lead data-probe being the positive probe, in which case the polarity of the longitudinal voltage switches from positive to negative as the operator walks through the voltage gradient field.

Anodic Area "Severity" Factor:

In addition to locating anodic areas, there is interest in determining some sort of "severity factor" for each location.

However, unlike in the case of DCVG surveys which utilize a known "signal strength", i.e., the IR drop in the soil in the vicinity of the anomaly, there is no directly measurable "signal strength" in the case of Surface Potential surveys.

Consequently, some other approach is required to come up with a "severity factor".

At the present time, the specification upon which our software is currently based calls for the generation of a "Corrosion Factor" value for each "marked" anodic location. The calculation is as follows:

Corrosion Factor = [Maximum longitudinal voltage reading logged on either side of the SP anomaly (within 2 reading intervals of the "marking" location)] / [Soil resistivity in the vicinity of the SP anomaly]

Since the magnitude of the current flowing away from an anodic area correlates with the rate of corrosion in that area, factoring in soil resistivity makes sense, if we're trying to get a handle on the rate of corrosion for a given magnitude of voltage gradient. For instance, for a given magnitude of voltage gradient on the surface, the corrosion rate will be higher (current flow away from the pipe will be larger) if the soil resistivity in the area is relatively small. Conversely, for the same magnitude of voltage gradient on the surface, the corrosion rate will be lower (current flowing away from the pipe will be smaller) if the soil resistivity in the area is relatively large.

Another approach regarding Corrosion Factor determination would be to use the sidedrain readings, which are a direct measure of the gradient field magnitude, as the numerator in the Corrosion Factor calculation, as opposed to the "maximum longitudinal voltage" whose value is subject to data-probe placement, relative to the potential gradient field.

SECTION 3

**HOW TO SET UP THE DA METER FOR
SURFACE POTENTIAL SURVEYS**

The following section outlines the steps required to setup the DA Meter to participate in Surface Potential survey applications. The setup process establishes the conditions of the particular survey about to be performed and identifies the section of pipeline that is about to be examined by the Surface Potential survey application. The setup process also establishes a file in which the voltage recordings (survey data) will be stored.

Step 1:

Switch on the DA Meter by pressing the power button. Assuming that the battery pack is charged (see Section II), the screen will light up and will display the Windows desktop screen as shown below (assuming that the operating system running your DA Meter is Windows Handheld PC 2000).

Step 2:

Double tap (using the special pen (stylus) provided with the DA Meter) on the "DA Meter PLS" icon. This will open the software program that will run the DA Meter in pipeline survey mode. The window shown below will appear.

**Note: It may take a few seconds for this window to appear.**
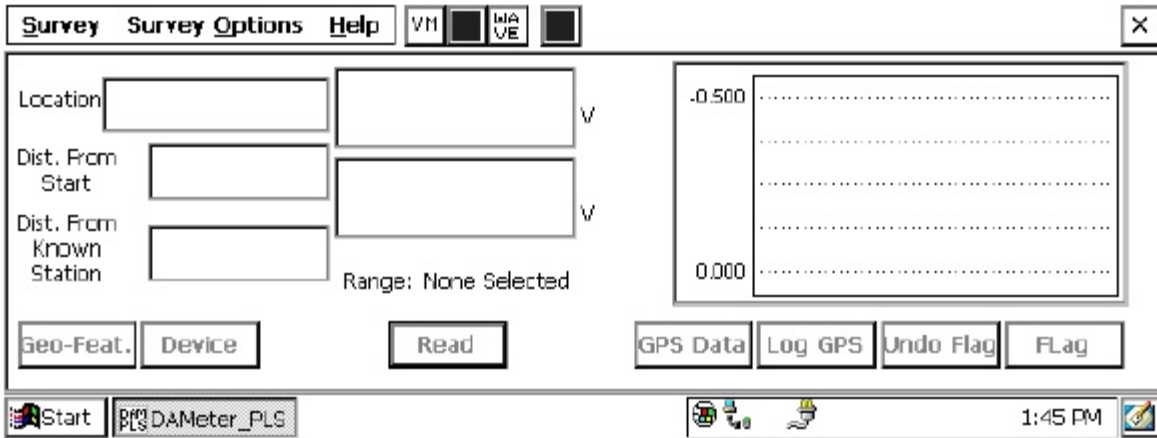
This is the Main Survey Window. At this point, a survey has not been set up (the setup process is what we are going through here) and so no information is currently displayed in this window.

Step 3:
Tap once on the "Survey" button situated in the Menu Bar in the top left-hand corner of the window. The window shown below will appear.
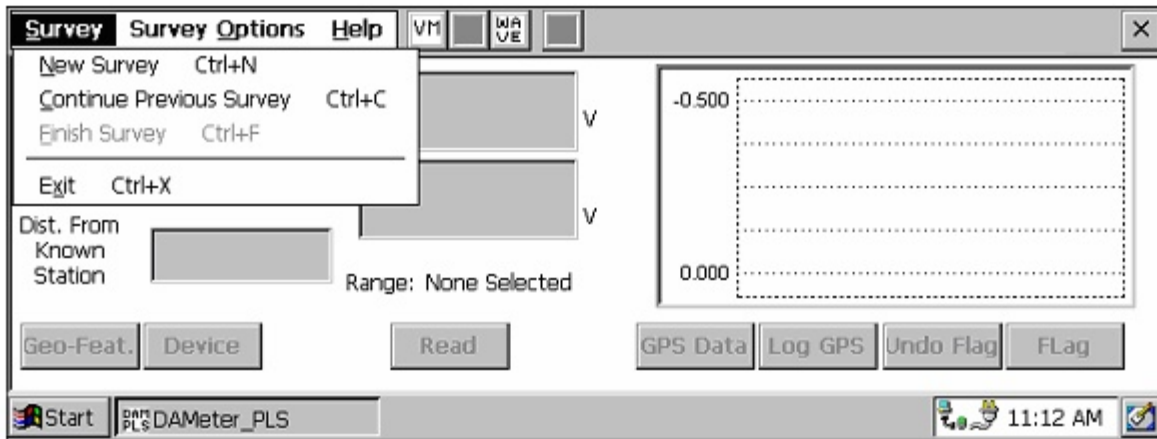
Under "Survey" there are several options. If this is a new survey (not a continuation of a previous survey), tap once on "New Survey". The window shown below will appear.

New Survey

Enter New Survey Filename :

[   ]

[OK]   [Cancel]
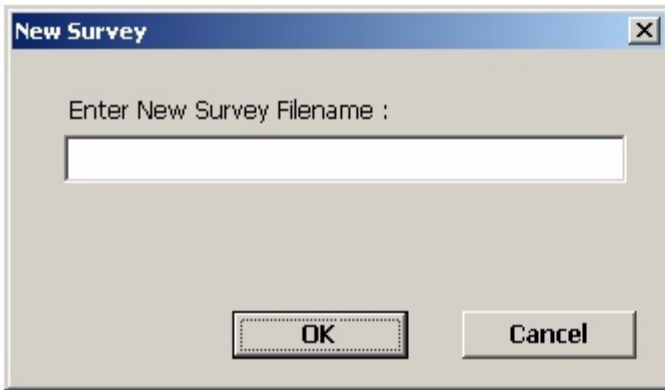
Step 4:

Enter a "filename" for the Survey using the keyboard.

Note: This is an important step as the filename is used to identify the survey and, also, recorded data (voltages) will be stored in this named file for future retrieval. It is highly recommended that a protocol be established for selecting Survey Filenames. Critical information should be included in the filename, such as pipeline company's name, city or state in which the pipeline is located, pipeline number and section of pipeline number under survey. The protocol developed should be applied consistently for each survey.

For example, let's assume that pipeline company XYZ has a pipeline located in Texas and that the pipeline is identified as pipeline 12 and a survey is being performed on section 085 of this pipeline. A good filename for this survey would be:

XYZ TX 12 085 SP

When this survey file is later accessed, with this filename we know the name of the pipeline owner, we know the state in which the pipeline is located, we know the pipeline number, we know the section of the pipeline that was surveyed and we know that it was a SP survey.
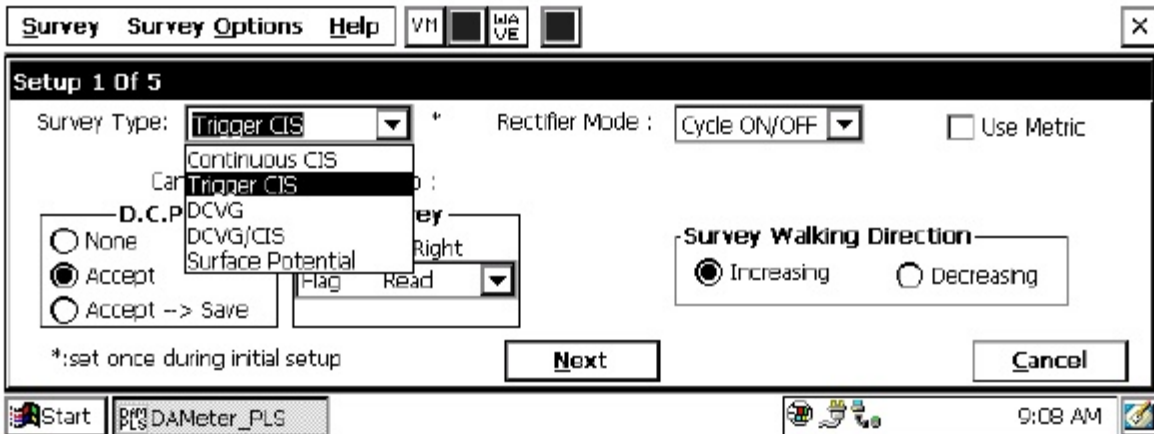
Step 5:

Tap once on the OK button. The window shown below will appear (depending on previous settings). This is the first of 5, so-called, setup windows.
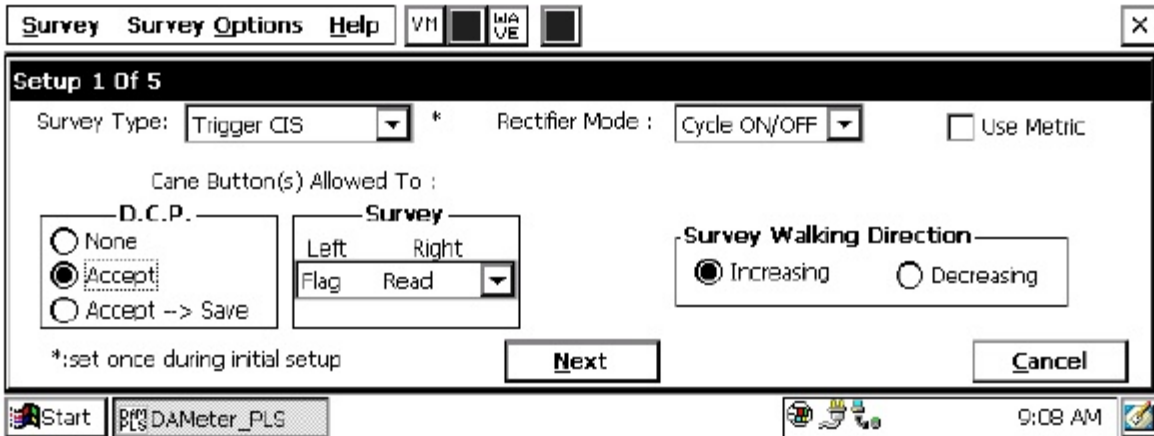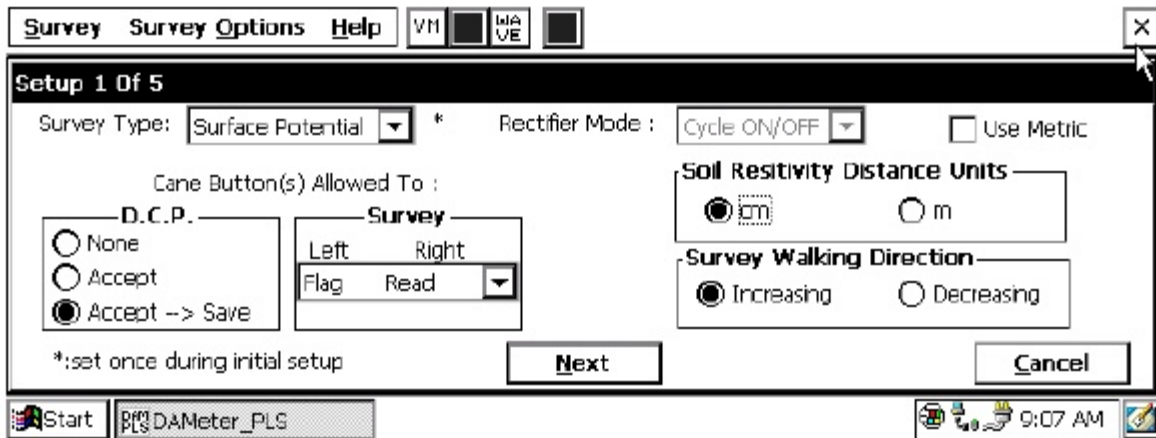
Step 6:

Select "Survey Type".

Tap once on the pull-down list arrow button in the "Survey Type" field to reveal the 5 choices shown in the screen below.

By tapping once on "Surface Potential", the screen shown below will appear.

Step 7:
Select Rectifier Mode.

A menu option is not available for "Rectifier Mode", in the case of Surface Potential surveys, as such surveys are conducted on non cathodically-protected pipe.

Step 8:
Make "Cane Button" Functionality Choices

Typically, for Surface Potential surveys, you would "trigger" voltage recordings using either the positive (green-handled) reference electrode data-probe or the negative (red-handled) reference electrode data-probe. In the case where an "in-line" survey is to be performed by two crew members (one holding the positive electrode (green-handled data-probe), the other holding the negative electrode (red-handled data-probe), the choice of which push-button switch to designate as the "trigger" for readings will depend on which data-probe the crew member operating the DA Meter is holding. If the DA Meter operator holds the red-handled (negative) data-probe, the selection should be "read flag" in the "Survey" category and, if the DA Meter operator is holding the green-handled (positive) data-probe, the selection should be "flag read". In either case, the crew member who is not the DA Meter operator could use his push-button switch to designate the location of survey flags.

You can also use either cane button when recording voltages at D.C.P.'s (data collection points (devices)) to "accept" or "accept and save" a device

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reading, as opposed to tapping on the "accept" or the "save" buttons on the screen.

Note: When "Marking" SP anomalies (see the Surface Potential Training Manual – DA Meter Version), the cane push-button functionality becomes "accept", regardless of whether "save" or "none" is selected here.

Step 9a:
Select Walking Direction

On the Setup 1 of 5 screen, you should indicate whether station numbers will be increasing or decreasing as you proceed in the survey direction by tapping on either the "Increasing" or "Decreasing" radio button in the "Survey Walking Direction" field.

Step 9b:
Select the length units for your "Soil Resistivity" measurements.

As indicated in the Surface Potential Survey Training Manual, you have the option to manually enter a value for soil resistivity measured at the location of a "marked" SP anomaly, which will allow the software to calculate a "Corrosion Factor". The units "Ω.cm" or "Ω.m" for soil resistivity that will appear on the SP anomaly "marking" screen, for your manual data entry, will depend on your selection here in the "Soil Resistivity Distance Units" field (cm or m)

Step 9c:
Make selection of "Metric" units if required.

By checking off the box labeled "Metric", the reading interval (distance between voltage recordings) and the flag internal (flag spacing) will be displayed on the Setup 3 of 5 screen in meters, as opposed to feet.

Step 10:
Select GPS Receiver Type and GPS Options

Tap once on the "Next" button

The Setup 2 of 5 screen will appear as shown below.
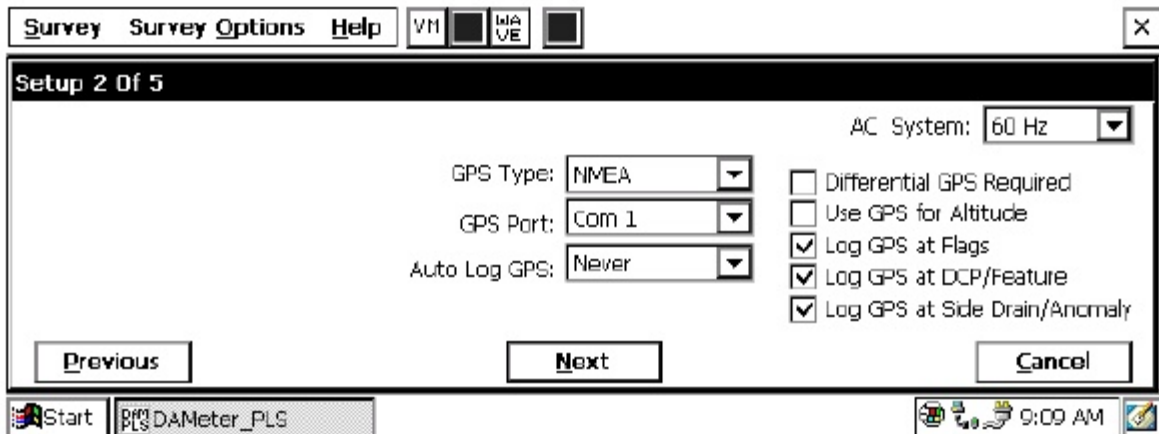
By tapping on the pull-down-list arrow button in the "GPS Type:" field you can select the type of GPS unit you will be using (if any) from the list shown below.

There are 4 choices for "GPS Type":

None: This means that a GPS receiver is not being used

MCM :   This means that an MCM GPS receiver is being used

NMEA: This means that a GPS receiver (other than the MCM receiver) that is capable of outputting NMEA data is being used

Manual: This means that location data will be entered manually when the GPS button is pressed on the survey screen during a DCVG survey.

Select the appropriate choice by tapping on your selection.

Step 11:
Select GPS Options:

After selecting the GPS Receiver Type, choices need to be made regarding GPS Options.

If a GPS receiver has been selected for use with the DA Meter for a particular SP survey, all, or some of the functions available can be enabled (box ticked). A box can be "ticked" or "unticked" by tapping inside the box. The GPS options available are as follows:

Differential GPS Required:
This box should be ticked if you only want differentially-corrected (real-
time corrected) GPS data to be logged by the DA Meter. If this box is
ticked, only GPS data that have been derived using a correction message
signal (in real-time) will be logged by the DA Meter. If this box is left
unticked, it means that you will allow the DA Meter to log either standard
GPS data or differentially-corrected GPS data, depending upon what is
being output by your receiver at any given time. Please note that if this box
is checked (ticked), GPS data will not be logged unless a real-time
correction signal has been received by the correction message receiver
component of your GPS unit. In most instances, logging standard (ie,
uncorrected) GPS data would be preferable to not logging any GPS data.

Use GPS Altitude:
If this box is ticked, altitude data will be included with the position data
whenever GPS data is logged. (Note: Altitude data on some GPS units is not
particularly accurate in survey applications).

Log GPS at Flags:
If this box is ticked, GPS position data will be logged automatically at flags
when either the flag button is tapped (directly on the Survey screen) or when
the push-button on the designated "flag cane" is pressed.

Log GPS at DCP/Feature:
If this box is ticked, GPS position data will be logged automatically at
"Devices" or "Geo-Features" when either the "Device" button is tapped on
the Survey screen and a "Device" reading is logged or when the "Geo-Feat."
button is tapped on the Survey screen and a geo-feature is registered.
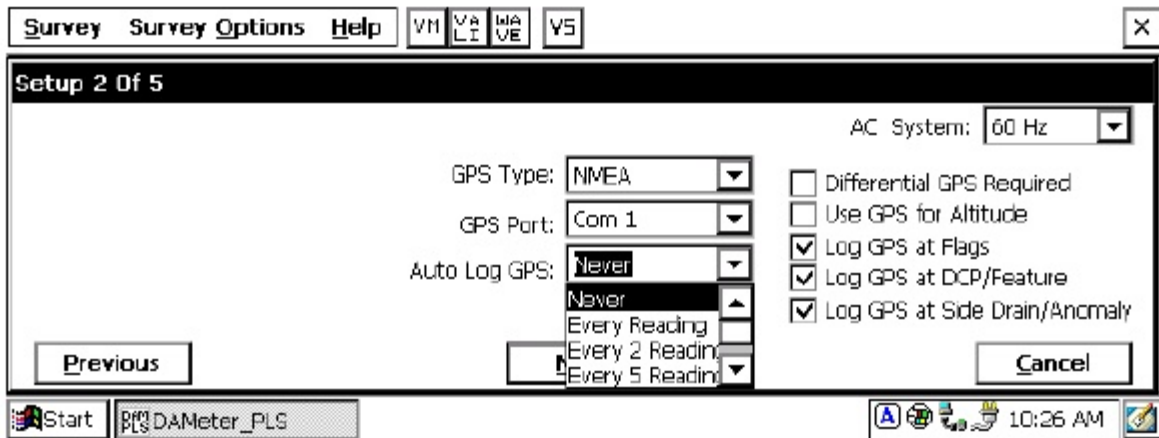
Log GPS at Sidedrain/Anomaly:
If this box is ticked, GPS position data will be logged automatically when
SP anomalies are "marked".

Auto Log GPS:
By tapping on the drop down menu button in the "Auto Log GPS" field, the
selections available will be displayed as indicated below.

By selecting one of these options, you can elect to have the GPS position data logged automatically at every survey reading, at every second reading, at every fifth reading, at every tenth reading, or not at all (never) at survey readings.
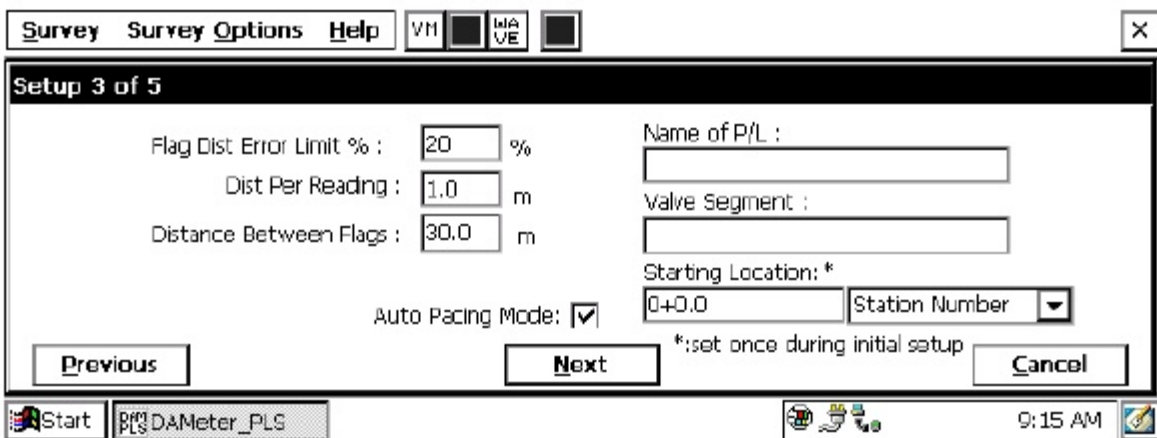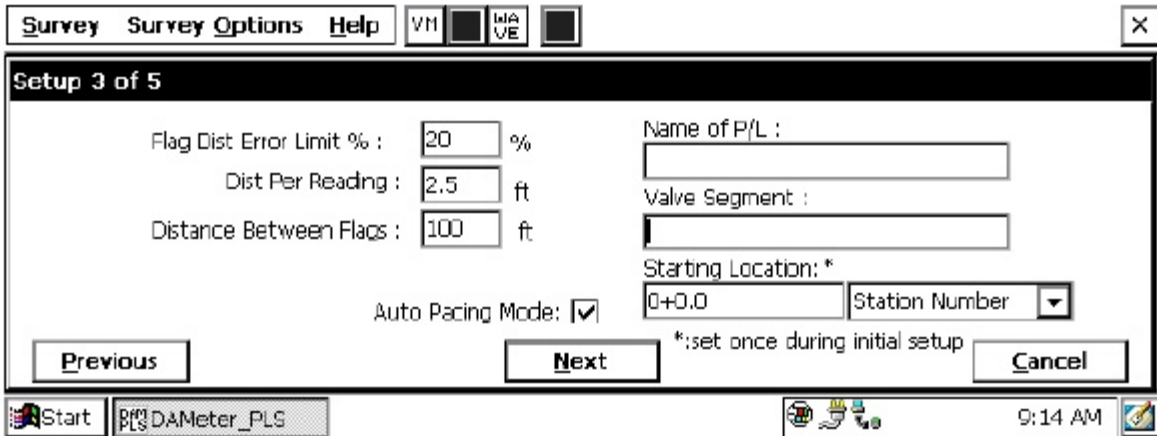
Step 12:
Finally on the above screen, select the electricity supply operating frequency of the country in which you are performing the surveys (60Hz or 50Hz). For the U.S., select 60Hz.

Step 13:
Tap once on the "Next" button.

The specific screen that will appear (Setup 3 of 5 screen) will depend on whether or not you selected "Metric" units.

The screens shown below will appear for the non-metric and the metric cases, respectively.

Step 14:
Select Voltage Recording Interval (Distance Between Recordings)

By tapping once in the field in the Setup 3 of 5 screen labeled "Distance Per Reading" you can type in the voltage reading interval (distance in feet (or meters) expected between recordings) for the SP survey.

Step 15:
Select Survey Flag Interval (Distance Between Survey Flags)

By tapping once in the field in the Setup 3 of 5 screen labeled "Distance Between Flags", you can type in the survey flag interval (distance between survey flags) for the section of pipeline being measured. Typically, survey flags are located at 100 feet (or 30 meter) intervals.

Step 16:

Select the maximum permissible error between the actual number of recordings made between 2 survey flags and the expected number of recordings.

By tapping in the field labeled "Flag Distance Error Limit %" you can type in the maximum permissible error. For example, the maximum permissible error is indicated as 20% on the above screen.

If the recording interval is expected to be 5.0 feet and the survey flag separation is 100 feet, that means that 20 recordings are expected. If, however, only 15 recordings are actually made between survey flags, an error window will appear on the screen, since there is a 25% difference between the expected and actual number of recordings made. No error window will appear if the difference is less than 20% for this example, ie, you could have a minimum of 16 recordings and a maximum of 24 recordings between survey flags to stay within the 20% (max.) error allowance.

Step 17:

Select whether or not you would like the recordings to be uniformly spaced between survey flags in cases where the actual number of recordings made between flags deviates from the projected number (flag separation ÷ recording interval).

By tapping in the box labeled "Auto Pacing Mode", and inserting a tick in the box, you will enable the DA Meter to automatically adjust the actual recordings and space them evenly over a 100 feet span (distance between survey flags), regardless of the actual number of recordings made. This selection is highly recommended.

Step 18:

Provide the Name of the Pipeline:

By tapping once in the field labeled "Name of P/L", you can type in the pipeline name. Note: This is not the same as the filename for the SP survey that was selected back in Step 4. This is the actual name of the pipeline.

Step 19:

Provide the Valve Segment Identification Number (or Name)

By tapping once in the box labeled "Valve Segment", you can type in the valve segment number, or name (if known).

Step 20:

Provide the Starting Location Information

Tap the pull-down list arrow button in the "Starting Location" field, which will reveal the options available regarding how you would like location information to be displayed. The Setup 3 of 5 screen will be as shown below for the non-metric case.

You can select to have location information displayed on the survey screen as station number, feet or milepost (station number, meters or kilometers for the metric case).

Whichever selection you make here will determine how you enter your starting location information.

For example, if your pipeline locations are represented by station numbers, you would select "Station Number" from the drop down list and you would enter a starting location for the survey in the form of a station number. [If you do not know the station number where you're beginning your survey, enter 0+0.0].
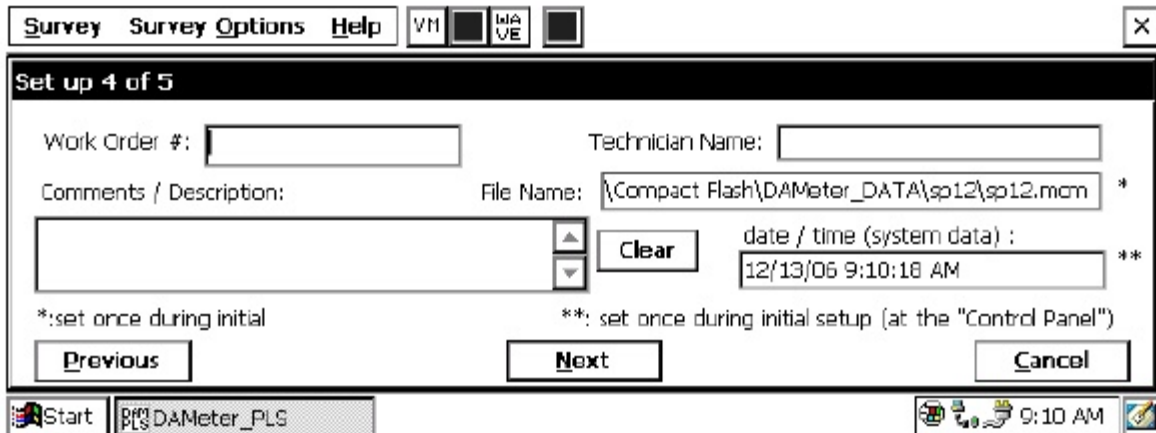
As an example, if you are working on pipeline ABC within valve segment 45 and you are about to begin a SP survey at station number 12+0.0, your Setup 3 of 5 screen would be as shown below.
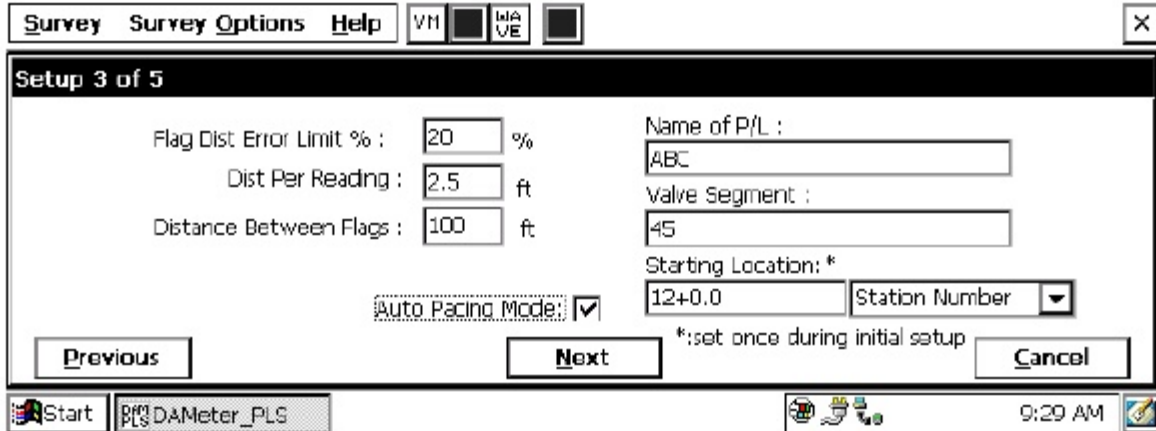
Step 21:

Tap once on Next button on Setup 3 of 5 screen.

The Setup 4 of 5 screen will appear as shown below.

Step 22:

Provide the Work Order Number for the SP survey

By tapping once in the field labeled "Work Order #", you can type in the work order number for the SP survey, if known.

Step 23:
Provide Your Name

By tapping once in the field labeled "Technician Name" you can type in your name.

Step 24:
Provide Comments

By tapping once in the field labeled "Comments/Description", you can enter any comments you might have regarding the survey (perhaps weather conditions, soil conditions etc.).
Also shown on the Setup 4 of 5 screen are the File Name and the date/time.

Note: Do not attempt to change the File Name indicated here as this identification will be required by the ProActive software to transfer your SP survey data to your PC.

Step 25:
Select Voltmeter Settings
Tap once on the Next button on the Setup 4 of 5 screen
The Setup 5 of 5 screen will appear as shown below.
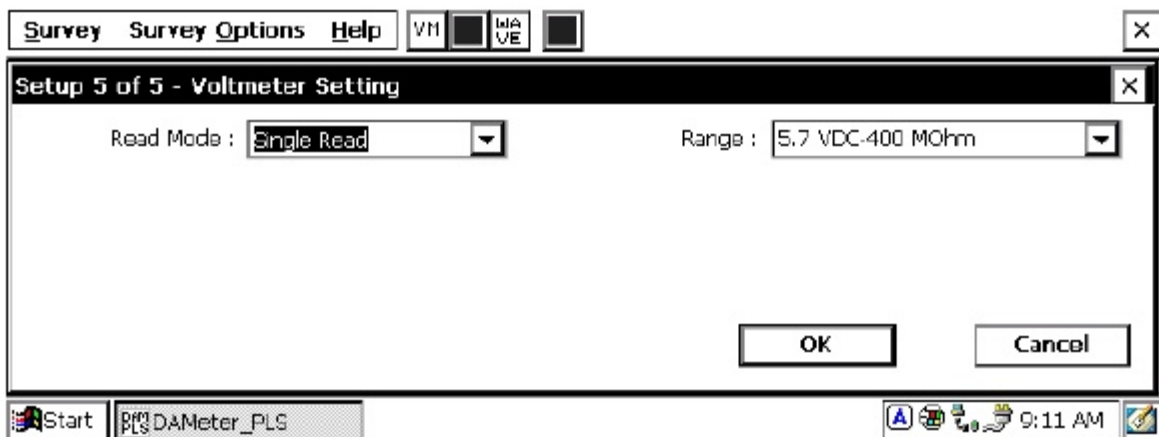
Select the "Read Mode":
SP surveys are typically performed on pipelines that are not cathodically-protected with impressed current from rectifier sources and so the

appropriate choice of "Read Mode" would be "Single Read", i.e., "On-Off Pair" read modes are not appropriate, since rectifier current interruption is not a factor.

Select the "Range":
As can be seen by viewing the drop down menu in the "Range" field, a number of selections are possible.

The fastest response setting is the 5.7V/400MΩ setting (~80ms response time), however, the noise level on this setting is ±5mV, which could make small anomalies difficult to detect.

Lower noise level settings (±1mV noise level)) can be selected, such as the 40mV or 400mV settings to increase sensitivity, however, please note that the speed of response on these settings is around 1 sec.

Step 26:
Pull-up "Active" Survey Screen

By tapping on the "OK" button on the Voltmeter Settings screen, the "active" Survey screen would appear and you would be ready to proceed with your SP survey.

An example starting "active" Survey screen is shown below.
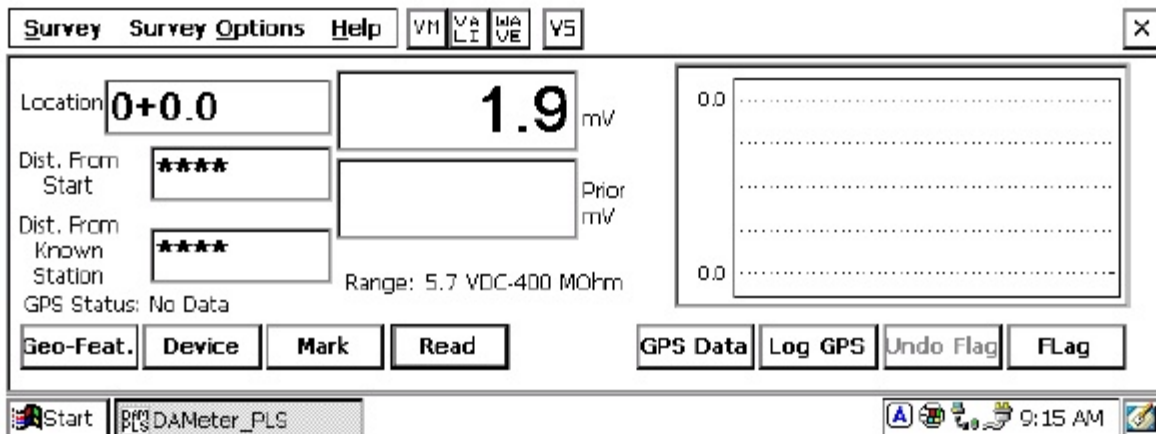
As SP voltages are recorded by the DA Meter, the "Distance From Start" (total distance from the start of the survey) parameter will increase in increments of 5.0 feet, or whatever the "Distance Per Reading" value was that was entered back at Step 16. (Distances would be in meters if the metric option had been selected).

Also, the "Distance From Known Station" parameter will increase in the same increments as voltages are recorded. The difference in this case, however, will be that when a known station is registered, this distance parameter will begin again at zero. In other words, this will show the distance you are assumed by the DA Meter to have traveled from the last known station that you encountered (and registered).

**You are now ready to perform a Surface Potential survey.**

SECTION 4

EQUIPMENT HOOK-UPS

The DA Meter, data-probe and data-probe cable hook-ups for Surface Potential surveys using M. C. Miller equipment are illustrated in Figure 3 below.

As can be seen from Figure 3, two reference electrode data-probes are illustrated, a RED-handled data-probe and a GREEN-handled data-probe. These data-probes, which will be placed on the soil above the pipeline in either the "Perpendicular" or the "In-Line" configuration (see Section 2), have push button switches on top of the handles so that the operator can "trigger" voltage recordings at each of the survey measurement locations and can also designate the locations of survey flags (see Section 3).

The reference electrode data-probes are connected as shown to the "input" terminals of the dual-probe adapter and the "output" terminal of the adapter is connected to the 5-pin socket on the top side of the DA Meter.
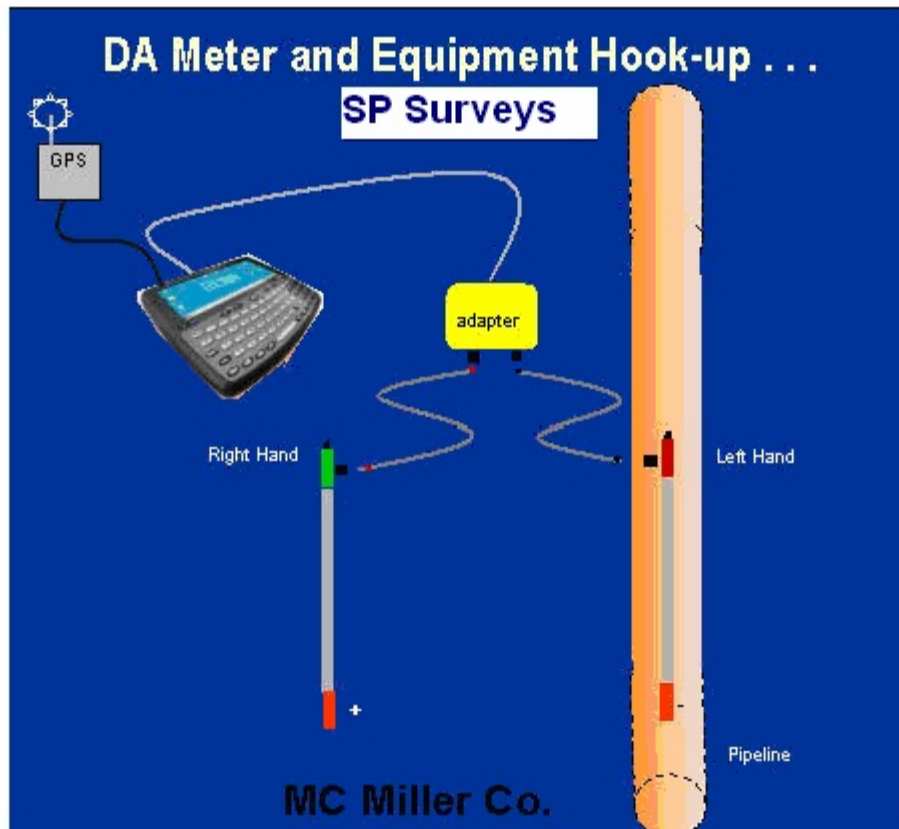
Figure 3

NOTE: The red-handled cane is connected to the dual probe adapter via a "black-band" cable while the green-handled cane is connected to the dual-probe adapter via a "red-band" cable. This results in the reference electrode of the red-handled data-probe connecting to the negative side of the data **logger's voltmeter and the reference electrode of the green-handled data-**probe connecting to the positive side of the voltmeter. The red-band and the black-band cables can be connected to either one of the dual-probe adapter's "input" terminals.

Consequently, the data-logger's voltmeter will measure the potential at the location of the green-handled (positive) data-probe minus the potential at the location of the red-handled (negative) data-probe.

A GPS receiver is also illustrated in Figure 3. Such a unit can be connected to the DA Meter (via the 9-pin serial data terminal on the top side of the DA Meter) (COM 1 Port) in order that the position of items such as SP anomalies, flags and geo-features can be recorded during the performance of

a SP survey, either manually, by tapping on the "Log GPS" button on the survey screen at each critical location, or automatically, by programming the DA Meter as described in Section 3.

SECTION 5

HOW TO PERFORM A SURFACE POTENTIAL SURVEY

5. 1   How to carry the test equipment during a SP survey

With the equipment connected as shown in Figure 3 (Section 4), and the DA Meter "setup" as described in Section 3, you are ready to perform a SP survey.

To make a pipeline survey more manageable, MCM has developed a special "belt pack" which allows the DA Meter to be carried around the waist area in a "hands-free" fashion.

With the belt pack assembly, the DA Meter sits on a tray at waist level allowing the operator to view the screen at all times and to make any selections required by tapping on the screen. Also, the dual-probe adapter shown in Figure 3, is attached to the underside of the tray, allowing convenient (5 pin cable) connection of the adapter's "output" to the DA Meter.

### 5. 2 How to locate and "mark" SP anomalies

The objective in SP surveys is to locate anodic areas, i.e., areas on the buried pipe where current is "leaving" the pipe. As discussed in Section 2, such areas can be located by observing a polarity switch in the recorded "in-line" (or longitudinal) voltage. As also discussed in Section 2, the nature of the polarity switch (i.e., positive-to-negative, or negative-to-positive) depends on whether the lead data-probe is the "positive" or the "negative" probe.

For the case where the "positive" data-probe is leading (i.e., leading with the green-handled data-probe), since the potential gradient on the surface is positive over an anodic area, a positive potential difference will be

measured, as a gradient field is entered, relative to the zero potential difference measured with both data-probes positioned outside the gradient field. The potential difference measured between the probes will continue to increase, as the data-probes advance into the gradient field, and will go through a maximum value before dropping through zero (as the data-probes straddle the epicenter of the anodic area) and becoming negative. After going through a maximum negative value, the potential difference measured between the probes will decrease (staying negative) and eventually become zero again with both data-probes positioned on the far side of the potential gradient field.

Consequently, in this case, the polarity switch would be positive-to-negative as the anodic area is traversed. The opposite polarity switch would be observed if the lead data-probe was the red-handled (negative) probe.

In order to make the process of determining polarity switches easier, the survey screen displays the prior reading (including its polarity) in addition to displaying the current SP reading, as shown in the screen below.
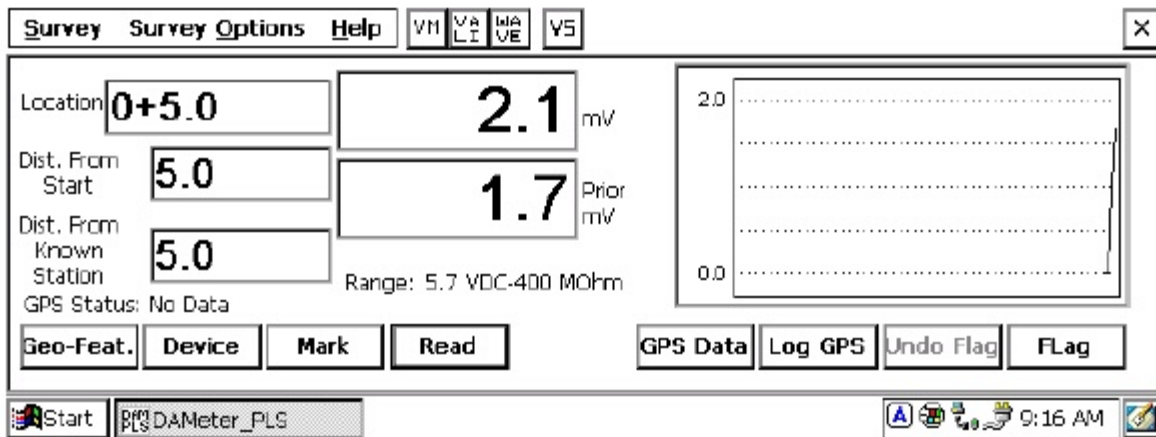

By fine-tuning the location of the epicenter of the anomaly, i.e., by straddling the epicenter with the data-probes and reading (close to) zero mV, the anomaly can be "marked".

To do so, you would tap on the "Mark" button on the survey screen which would pull up the screen shown below.
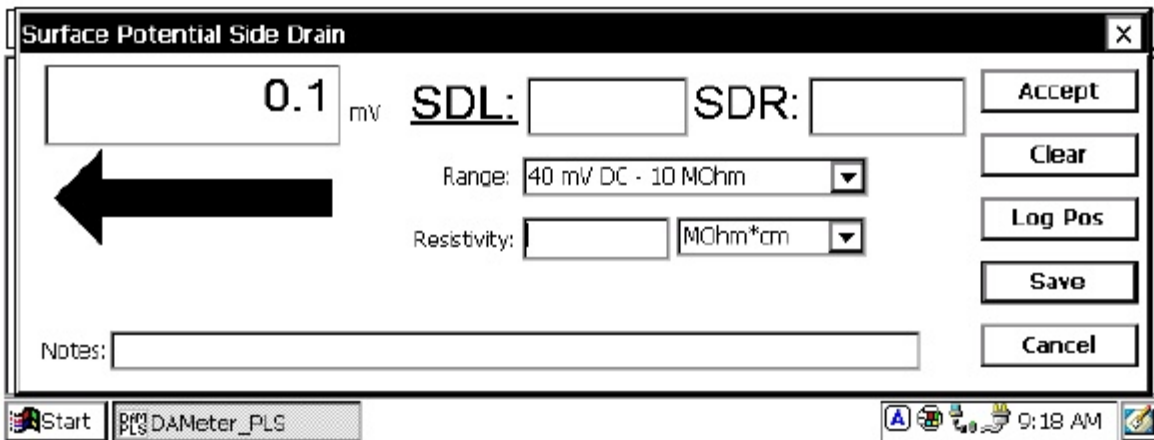
You are being given the opportunity to manually enter a value for the soil resistivity measured in the vicinity of the anomaly. As discussed in Section 2, the software will use this value in its calculation of "Corrosion Factor" for the anomaly.
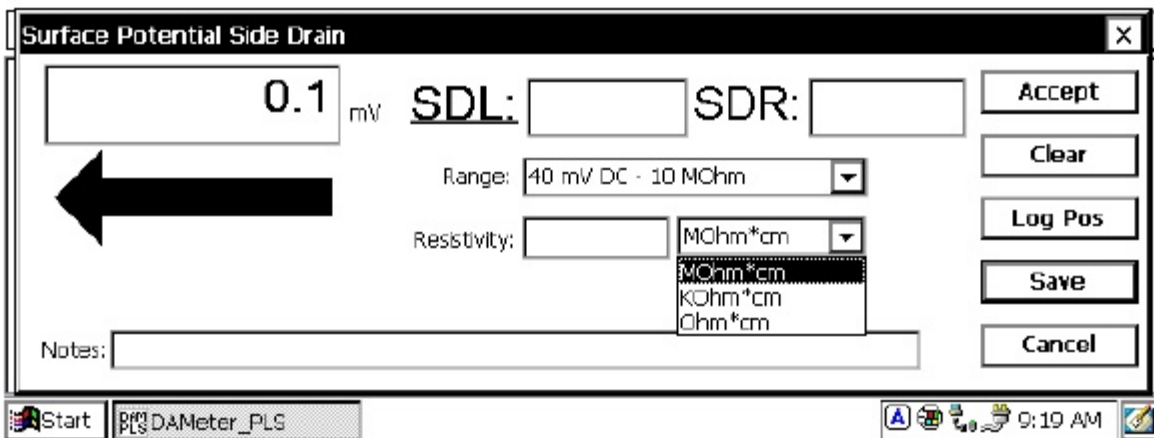
As indicated in the above screen, you can select the units (MΩ.cm, KΩ.cm or Ω.cm) for your resistivity value.

Also, you are being given the opportunity to record the left and right sidedrain readings.

When you have the data-probes positioned for the left sidedrain reading (SDL), you would tap on the "Accept" button which would result in the mV reading being displayed in the SDL field as indicated in the screen below.
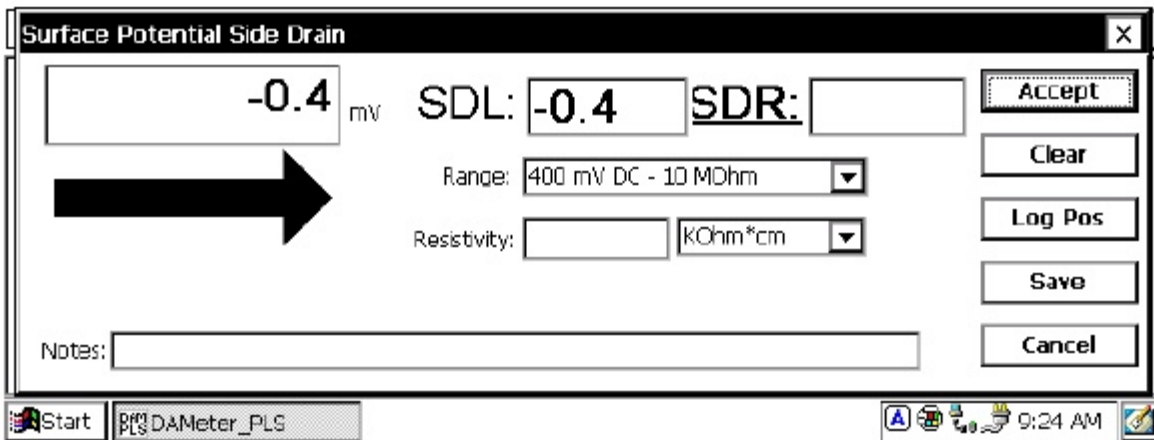
Next, you would position the data-probes for the right sidedrain reading (SDR), and you would tap again on the "Accept" button which would result in the mV reading being displayed in the SDR field as indicated in the screen below.

Note: Alternatively to tapping on the "Accept" button on the screen, you could press the push-button switch on either data-probe handle to "accept" the SDL and SDR readings.
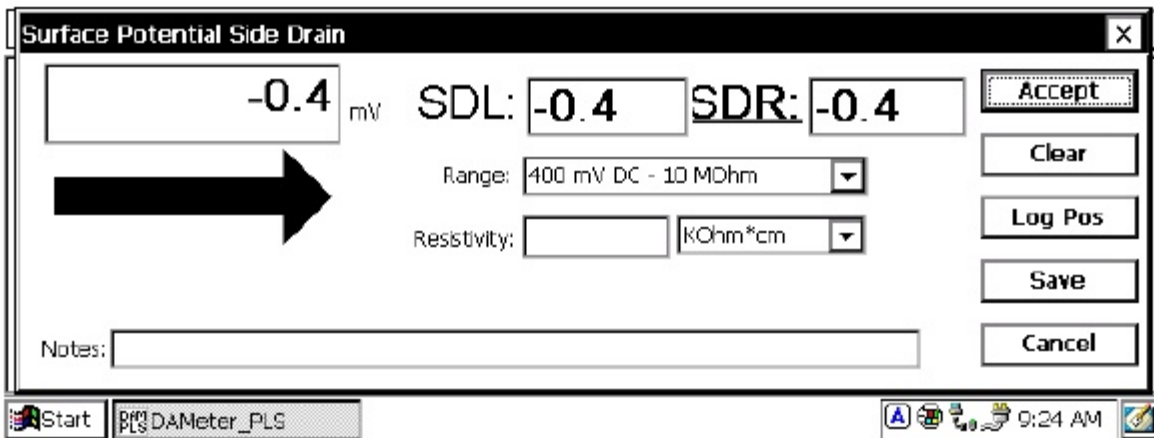
Finally, you would tap on the "Save" button which would result in all of the data associated with the "marking" process being saved. This would return you to the SP survey screen and you would continue with the survey.

For information on copying SP survey data to ProActive for graphical report generation, etc., please consult the ProActive Training Manual.