Cathodic Protection Close Interval Surveys

Field Manual

Prepared by R.L. Pawson
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1.0 INTRODUCTION

Cathodic Protection systems are an electrical means of mitigating corrosion on buried and submerged metallic structures (primarily steel).

This Field Manual describes many aspects of the equipment and testing required when undertaking a Close Interval Potential survey (C.I.S.) on natural gas and oil piping systems to verify the Cathodic Protection system effectiveness.

Testing of pipeline Cathodic Protection systems is required by law in many countries and is an important means of maintaining pipeline integrity.

One of the most common methods of testing these systems is the annual test station survey. This requires the measurement and recording of pipe to soil potentials at designated test stations each year. While this is very useful information, particularly for well-coated pipelines, the test station data only represents the potentials on less than 1% of the pipeline surface. The test station data does not provide any information on the pipe to soil potentials at a distance from the test station.

On bare or poorly coated pipelines, the test station data may not represent potentials more than a few meters from the test station.

Consequently, it has become a standard practice to undertake “close interval potential surveys” (C.I.S.) on pipelines, every few years, in order to provide the data for assessing the effectiveness of the Cathodic Protection system over the full length of the pipeline. The C.I.S. measures and records the pipe to soil potential on a regular spacing of between 1 and 3 meters (spacing depending on client requirements, field conditions and pipeline physical properties).

Prior to the introduction of computerized dataloggers, undertaking the C.I.S. was very difficult due to the volumes of data that needed to be recorded and plotted. The availability of computerized dataloggers for Cathodic Protection system monitoring enabled the development of the C.I.S. into a viable means of assessing system effectiveness.

Project planning, cooperation of the client and contractor, a high level of technical expertise, fieldcraft and dedicated equipment are required to benefit from this type of survey. The C.I.S. will generate large volumes of data, and it is essential that this data be technically correct and its management and reporting efficient.

2.0 STANDARD FIELD PRACTICES

In order to properly undertake the close interval survey, the survey crew needs to be educated and trained in the all aspects of the work. This section will discuss many of the factors that will affect the quality of the field data.
2.01 Reference Electrodes

The standard reference electrode used for land based C.I.S. is the Copper/Copper Sulfate electrode. This is shown in Figure 1. This reference electrode is practical and can be used in a variety of field applications and soil conditions due to its relative stability.

As pipe to soil and structure to soil potentials are measured using this electrode, it is very important that the measurements are accurate. To achieve accurate readings, it is important that the potential of the reference electrode exhibit a stable half-cell potential within reasonable limits. While the field stability of the Copper/Copper Sulfate electrode is generally acceptable, it can be affected by contamination and to some extent by temperature and ultra violet light.

One predominant type of contamination would be by “chloride ions” entering through the porous plug. It is very important that the Copper/Copper Sulfate reference electrode is not used in areas of salt contamination, such as salt-water marshes, brackish or saline water. Contamination will result in inaccurate pipe to soil or structure to soil potentials, as the reference electrode will no longer exhibit its normal potential.

Temperature changes can affect the reference electrode potential by up to 0.5mV per degree F. Therefore some daily changes will occur. However, as long as the electrode is not exposed to very large variations in temperature, no remedial action is generally required.
It has been documented that Ultra Violet light can also affect stability and it is recommended that the transparent sides of the electrode be covered with electrical tape to reduce any such effects.

Prior to the start of the C.I.S. it is important to check or calibrate the reference electrodes being used. This can be undertaken as shown in Figure 2. The test is simply to place the porous plugs of a standard (unused) electrode and the electrodes for the C.I.S. end to end and measure the millivolt difference. Generally, if the difference is less than 4 to 6 millivolts, no maintenance of the electrodes will be required.

Figure 2

TESTING REFERENCE ELECTRODES PRIOR TO FIELD USE

STANDARD ELECTRODE

VOLTMETER

C.I.S. / FIELD ELECTRODE

Note that a special calibrated reference electrode or a standard reference electrode (neither to be used in the field, except for the above test) should be kept with the field crew.

Testing of the C.I.S. reference electrodes should be undertaken each morning prior to the start of the survey. The millivolt difference and polarity between the working electrodes and the standard should be recorded and inserted into the Daily Progress Log.

Any reference electrodes that fail the test should be kept separate and cleaned as soon as possible to ensure that the crew has usable spares (a typical survey crew will require at least 4 reference electrodes, including two for the C.I.S., one for the Stationary Logger and a minimum of one spare).

The contaminated reference electrodes need to be taken apart for cleaning. The copper rod may be cleaned with a 10% nitric acid solution and the rod should be immersed for several minutes to remove all surface products and contaminants.
While sand paper may be used for cleaning of the copper rod, the sand paper should not contain any Aluminum or other metallic oxide abrasives.

After cleaning of the rod, it should be thoroughly rinsed in distilled water.

The plastic electrode tube can be washed with soap and water with distilled water used for rinsing.

The porous ceramic plug may be soaked in distilled water to reduce or eliminate any contaminants. Soaking for several hours may be required with several changes of the water.

When the electrode has been fully cleaned, it can be re-assembled and filled with Copper Sulfate solution.

The Copper Sulfate solution should be saturated, with loose crystals visible, and the end cap placed over the plug when not in use, to prevent leakage and contamination.

Note: Copper Sulfate gel is now available for use in reference electrodes and reduces the leakage problem that sometimes occurs when using the solution. However, it has been found that while the gel is satisfactory for occasional use of the reference electrode, it may not provide sufficient wetting of the porous plug surface for use in C.I.S. applications. Therefore, it is recommended that the gel not be used in C.I.S. applications.

To reduce ground contact resistance, it is also recommended that the porous plugs be cone shaped to permit penetration of the ground surface.

Because reference electrodes are not locally available in most areas, spares, including extra plugs, have to be carried with the crew.

Note that the words “reference electrode”, “reference” and “half-cell” are all terms used to describe the standard reference electrode.

### 2.02 Structure to Soil Potentials

Prior to taking actual pipe to soil or structure to soil potential measurements, it is important to understand what the potential actually represents.

*Figure 3* shows the typical arrangement at a test station when a pipe to soil potential is being measured.

The reference electrode is positioned, on the ground surface, over the pipeline, so that the porous plug is in good contact with the ground. The reference
electrode is connected by a test lead to the negative terminal of a voltmeter. (the voltmeter must be of high input impedance to ensure accuracy)

![Typical pipe to soil potential measurement diagram](image)

**Figure 3**

The positive terminal of the voltmeter is connected, by a test lead, to the pipeline through the test cable in the test station. The pipe to soil potential will be displayed on the meter. The magnitude of this potential will depend on the Cathodic Protection system status, but may be in the range of -1000 mV to -1500 mV.

This potential represents the average potential of the pipeline at this location. For example, on a bare pipeline, the pipe to soil potential will be the average potential of, perhaps only 2 to 3 meters of pipe (approximately twice the depth of burial). The potential of each square centimeter may contribute differently to the average potential. There will generally be a larger contribution to the average potential from the top of the pipe and below the reference electrode, than from the pipe bottom and away from the reference electrode.

This fact has to be clearly understood, as it means that a potential of –850 mV is only an average, and potentials both higher and lower than this value contribute to the measured potential.

If a connection is made to the pipe test lead in a test station, and the reference electrode is moved down the line as shown in **Figure 4**, the pipe to soil potential can
be measured at numerous sequential locations. This is the basis of the C.I.S. The reference electrode spacing is usually either 1 m or 3 m, and by taking pipe to soil potential measurements over a fixed distance, a graph plot of potential vs. distance can be produced.

Before proceeding to the next topic, the effects of voltage gradients in the ground must be discussed.

Whenever direct current from a Cathodic Protection system flows through the ground, voltage gradients will be produced. This is directly analogous to direct current flowing through a resistor and producing a voltage drop.

In addition to the voltage gradients created in the ground, Cathodic Protection current flow along the pipeline will also create a voltage drop. (e.g. the current flowing back to a Cathodic Protection rectifier)

In coated pipelines systems, there is also current flow across the pipe coating, which can produce a larger voltage gradient than in the ground.

Therefore, in cases where direct current is flowing, the pipe to soil potential that is measured, will include the actual pipe to soil potential, the voltage gradient in the ground, the voltage drop across the coating and the voltage drop (called IR Drop) in the pipeline. This is schematically shown in Figure 5.
In this case, the pipe to soil potential is not the true pipeline potential. If the true pipe to soil potential is to be measured, the direct current flow causing the voltage gradients and pipe IR Drop must be removed.

This can be accomplished by temporary interruption of the Cathodic Protection rectifier current outputs, which will remove the direct current flowing in the system. This is covered, in detail, later.

Therefore, there are two pipe-to-soil potentials that may be measured and recorded at each location when direct current flow in the ground is a factor.

The potential recorded with current flowing is called the “on” potential, and the potential recorded while the current flow is interrupted, is called the “off” or “polarized off” potential. Some surveys require both “on” and “off” potentials to be recorded. Other types of survey, e.g. on sacrificial anode systems, require only “on” potentials. Note that in sacrificial anode systems, the magnitude of current flow is generally less than for rectifier systems, and the current flow is more localized due to anode distribution.
Figure 6 shows some of the difficulty of taking the pipe to soil potential with the reference electrode over the pipeline, when the test station is just out of reach. On coated pipelines, accurate potentials can generally be recorded even with the reference electrode up to a meter off the line. However, on bare or poorly coated pipelines, it is very important to place the reference electrode over the pipeline.

2.03 Rectifier Interruption

As covered in Section 2.2, the “off” pipe to soil potentials can only be measured and recorded if the sources of Cathodic Protection current (rectifiers) are momentarily interrupted.

Prior to the start of the survey, the sphere of influence of the line rectifiers needs to be determined either through testing or from information from the pipeline operator.

If true “off” potentials are to be recorded, it is imperative to interrupt all the line rectifiers that affect the line section being surveyed. If some rectifiers are not interrupted, then the recorded “off” potentials will not be true readings.

The question of bonds and foreign rectifiers also needs to be addressed at this time. Where foreign line rectifiers are known to affect the line, but no bond
exists, it is important to leave the foreign rectifiers operating during the survey (other testing may be required later). This way, any areas of adverse interference should be seen during the survey. It is also important to remember that the “off” potentials recorded during the survey may not be true values due to gradient and current flow effects from the foreign rectifiers.

Special testing of the foreign rectifier effects can be undertaken separately at the end of the C.I.S.

Where bonds exist to foreign lines, it is important to know, in advance, the magnitude and polarity of the bond current. This will determine if this is foreign current or that from the line being surveyed. If the current is from a foreign rectifier, then that rectifier needs to be interrupted for the survey.

Note that interrupting bonds will cause the current to flow in other paths, and bond interruption should be avoided unless special circumstances exist.

Figure 7

*Figure 7* is a schematic showing how several rectifiers can affect locations along a pipeline.

When interrupting Cathodic Protection rectifiers, all interruption must occur at the same time in order that true “off” potentials are measured. Therefore, the current interrupters that are installed for a C.I.S. must stay synchronized and all must switch the current “on” and “off” at the same time. If one interrupter fails, the “off” readings recorded may no longer be valid.
Crystal controlled current interrupters can stay synchronized for perhaps one or two days only.

The G.P.S. controlled current interrupters now available, have the distinct advantage of remaining synchronized for as long as required, as long as satellite communications are maintained.

Figure 8

Figure 8 shows a G.P.S. Interrupter being installed at a typical rectifier. The satellite antenna is placed on top of the rectifier so as to have a clear sight of the sky.

Synchronized interrupters can switch the rectifier current at various time cycles, and various ratios of “on” time to “off” time. The selection of both the cycle time and ratio of “on” to “off” time is very important to the viability of the survey and to the validity of the data.

The cycle time is the total time selected for a complete interruption cycle, including both the “on” time and “off” time. For many surveys, a cycle time of 2 seconds is used and provides for an efficient and valid survey. This time cycle is also used on older rectifiers with outputs up to 50 or 60 amps, without causing
damage. Larger output rectifiers may need a larger cycle time depending on the circumstances.

On well-coated pipelines with only small output rectifiers, a cycle time of 1 second may be also used effectively.

The ratio of “on” time to “off” time has historically been 4:1, i.e. the “on” cycle time is four times longer than the “off” cycle time. However, smaller ratios than the 4:1 have been found to work very well, without adversely affecting the quality of data. Surveys can be undertaken at ratios of 2:1 and even 1.66:1.

The following may be used as a guideline for time cycles and ratios, as long as the rectifier outputs are also considered.

Bare & Coated Pipelines – 2 second cycle time, 1.5 seconds on, 0.5 seconds off. Coated Pipelines – 1 second cycle time, 0.6 seconds on, 0.4 seconds off.

One final item which needs to be discussed under this section, is the “spiking effect often seen on coated pipelines.

**Graph 1**

*Graph 1 shows the pipe to soil potential, at a fixed location, vs. time, for a well-coated pipeline, as the line rectifiers are interrupted.*

The switching cycles are clean, i.e. all the rectifiers are being turned on and off at the same time and the transition from “on” to “off” and “off” back to “on” is uniform.
However, “spiking” can occur at the “on” to “off” and “off” to “on” transition points on coated pipelines. (this is not seen on bare lines)

*Graph 2* shows a typical “spiking” effect that may be seen many times during the survey day.

![SPIKE TESTING, LINE P4, TS 134, 16/03/97](image)

**Graph 2**

In this graph, the switching spikes are up to 500 millivolts. On some lines at specific locations, these spikes can be in excess of 1000 millivolts. Their duration is normally less than 125 milliseconds, and it is extremely important that the “on” and “off” potentials are not recorded during this time period.

If the “on” and “off” potentials are recorded in the first 125 milliseconds after switching, the data collected will be of no value.

The datalogger must therefore be programmed to either ignore the spikes, or only to record the “on” and “off” potentials after the first 125 milliseconds from switching.

**2.04 Dataloggers**

The dataloggers or computerized voltmeters used for C.I.S. must be capable of recording all of the required data during a C.I.S. as well as being able to withstand the survey environment.
This means that the datalogger unit must have large memory capacity, programs designed specifically for the C.I.S., and a full alphanumeric capability in order to enter comments and notes.

The datalogger needs to be programmable to avoid recording data during the “spiking” that is sometimes seen during rectifier interruption.

The unit must accurately record potentials (voltages) and it is recommended that annual calibration be undertaken to a national standard. In addition, the datalogger should also be compared to a second unit or multimeter on a regular basis (this can be undertaken at the starting test station for the C.I.S. each day).

Some survey crews also carry a multimeter, during the survey, for other data collection, such as AC readings and current readings. Having a second meter with the crew allows for checking of the datalogger accuracy at any time, e.g. when unexpected potential changes are seen.

As these units will be operated in rain and high humidity environments, it is essential that they are waterproof and easily dried if moisture penetrates the case.

At least one spare datalogger must be present at site each day, so that the survey crew is not unduly delayed due to equipment problems.

2.05 Pipe Location

In order to accurately record the pipeline pipe to soil potentials, it is necessary to locate the reference electrodes over the pipeline. Even though on well-coated pipelines it often makes very little difference if the reference electrode is a meter or two off the pipeline, every attempt should be made to position the reference electrode correctly.

On bare pipelines, the reference electrode has to be positioned correctly, and this position may depend on the type of Cathodic Protection system protecting the line.

In cases where the protection system is a remote anodebed, the reference electrode should be placed directly over the pipeline. In cases where the protection system consists of distributed impressed current anodes, located alongside the pipeline, the reference electrode positioning may be different.

Where the anodes are located along one side of the pipeline, the reference electrode should be placed over the side of the pipeline on the side away from the anodes. This location can be found by a simple test of moving the reference electrode across the pipeline and looking for the location of the least negative
“off” potential. The alternate method would be to simply follow the pipe location operator, but walking slightly offset to one side. (the side away from the anodes) If the latter method is used, regular testing should be undertaken to ensure that the reference electrodes are being positioned correctly.

There are various types of pipe and cable locators that can be used for the C.I.S., and their usage will depend on personal preference and experience.

The pipe location for the C.I.S. is often undertaken in two different ways.

Some survey crews prefer to have pipe location, distance chaining and flagging undertaken separately from the C.I.S. data collection. In this case, the technician recording the C.I.S. data follows the line of flags and makes a note of each flag as it is passed.

An alternate method involves one technician locating the pipeline immediately ahead of the data collection technician. This can be seen in Figure 9.

![Figure 9](image.png)

Normally, the pipe location would be no more than 6 to 10 meters ahead. No flagging is required, pipe location can always be verified, and the light survey wire is used for distance measuring.

### 2.06 Auxiliary Equipment

Apart from the equipment previously described, a wire dispensing system is also required. The survey wire generally used is an AWG #32 SNLR varnish coated
copper wire. This is used for maintaining constant electrical contact with the pipeline through connections made at test stations. Distance measuring is either by chaining and flagging fixed distances, or by using the survey wire in conjunction with an electronic distance counter to measure how much wire has been dispensed. While G.P.S. may be possible, it is difficult to use on pipelines as they seldom are laid in straight lines, may have many field bends and follow the geographic contours of the right of way.

The survey vest for C.I.S. was introduced in 1985, and is still a very useful piece of equipment. It is designed to carry a wire dispenser, counter and datalogger and is provided with pouches for extra wire, tools and other items.

The survey crew should also carry a variety of small spare parts, tools and tapes, in case emergency field repairs are required.

A basic first aid kit should also be part of the survey crew equipment, and should be carried by the C.I.S. crew in the field.

2.07 Close Interval Survey Data

During the C.I.S., most of the data collected will be pipe to soil potentials. There will also be comments relating to pipeline features and terrain features as well as special tests such as datalogs or continuous logs.

It is very important that the technician recording the data input as much information as possible. This can both be in the field and as extra notes in the data files at night.

Personnel who were not involved in the field survey will normally produce the C.I.S. report, and consequently, any field comments will greatly assist in the data handling and report generation.

If the ground is dry, this information needs to be input into the datalogger. If there is a wire break and the survey has to restart at a different location and proceed in the opposite direction, this must be clearly noted.

On well systems (covered in section 3.1) there will be many comments in the data file, due to all of the short separate lines that have to be surveyed.

Right of way conditions need to be noted, as should survey that has to be undertaken off line due to obstacles or uncut right of way. Sometimes, sections of line have to be temporarily skipped and surveyed later the same day or next day. All of these scenarios should be well documented by the technician.
Figure 10 shows an impassable beaver pond, as an example of a natural obstacle.

In summary, the C.I.S. data collection involves far more than just data collection. The field crew has the responsibility of providing all of the relevant field information so that the final report can be accurate.

2.08 Test Station Data

Test Stations are normally located along the pipeline at locations such as roads, railroads, foreign line crossings, and at 1 to 5 Km separations in more remote areas.

The test stations provide a means of electrically contacting the pipeline for testing purposes. While a pipe to soil potential taken at a test station is not representative of more than a few meters of pipeline, it can be considered as a location for data sampling and comparison of year-to-year potentials.

For the C.I.S., the test station serves several functions:

It provides a means of electrically connecting to the pipeline and a means of verifying the pipe to soil potentials being recorded from the last test station.

The test station is a measurement point at which the voltage drop in the pipeline can be measured. The voltage drop in the pipeline will directly show if the
Interrupters are operating properly and if all of the rectifiers affecting that section of pipeline have been interrupted.

If the test station is located at a road or railroad crossing, it provides a means of testing to verify that the pipeline is isolated from the casing. (if present) If the test station is located at a foreign pipeline crossing, it provides a means of testing the foreign pipeline to check for possible interference.

When the C.I.S. reaches a test station, there are several tests that should be completed in sequence. When the surveyor reaches the test station, the distance and test station designation should be input into the datalogger.

![Figure 11](image)

Next, the “far ground” potential (FG) should be recorded. The far ground potential is the pipe to soil potential recorded with the reference electrodes located at the near test station, but with the electrical connection back at the last test station. This is shown in Figure 11.

After recording the far ground potential, the technician should record the “near ground” potential (NG). The reference electrodes should remain in the same position, on the ground, as for the “far ground” potential, but this time the connection to the pipeline will be to the near test station.

After the near ground potential, the pipe IR Drop will be measured. This is the voltage drop in the pipeline from the far test station to the near test station. The survey wire connected to the far test station is connected to one side of the
datalogger (usually the +ve), and the other datalogger terminal (-ve) is connected to the pipe lead in the near test station. Note the polarity of the readings.

It is a good practice to use the datalogger to record this type of data over at least two full interruption cycles. A Continuous Read program may be used for this data collection. A typical data example would be:

FG, -1.720V, -1.084V, (this is the “on” and “off”)  
NG, -1.796V, -1.086V, (this is the “on” and “off”)  
IR, +76mV, +2mV, (this is the “on” and “off”)  

Note that the difference between the “on” and “off” potentials will be the same as the IR Drop. (Sometimes there will be a small difference)

The “on” IR Drop is positive which means that with the standard meter connections, the current flow in the pipeline is from the last test station to the near test station. If the pipe diameter, wall thickness and distance between the test stations is known, the IR Drop value can be used to calculate the amount of current flowing in the pipeline.

The “off” IR Drop is +2mV, which shows that there is still a small amount of current flowing during the interrupter “off” cycle, and this flow is towards the near test station. Therefore, there is probably another rectifier further down the line which is showing a small effect at this location.

Under normal circumstances, an IR Drop of 2mV would be acceptable on most pipelines, and the survey could continue. However, the next IR Drop down the line should be noted, and if it is still positive and has increased to 4 or 6mV, over a comparable survey distance, then the source of current will need to be investigated.

Test stations are also used for Datalogs (see section 2.10), testing of casings, foreign lines, and for location of the Stationary Logger (see section 2.09).

The test station is therefore a very valuable component of the cathodic protection system and a great asset for the C.I.S. Note, that in general terms, any part of the pipeline that is used for cathodic protection system testing or electrical contact, may be termed a “test station”. This would apply to valves, risers, drips and other above ground appurtenances.

2.09 Stationary Datalogger

The stationary datalogger is a computerized voltmeter that is installed at a fixed location (usually a test station) for the whole of the survey day. For an
interrupted survey, the datalogger would be set to record the “on” and “off” potentials at regular time intervals. The recorded data can serve two useful functions. It can show the amount of depolarization of the pipeline and also whether the pipeline was subject to outside influences. Other pipeline operations, telluric currents, transit system operations or other sources may cause outside influences.

Note that the data is relevant only for the fixed location of the datalogger. A typical stationary log is shown in Graph 3.

As can be seen, both the “on” and “off” pipe to soil potentials do fluctuate to some extent with time. It is more common to see some small fluctuations during the day than to see straight-line graphs.

Bare pipelines are far less susceptible to significant outside influences than coated pipelines, due to the extent of bare metal involved. However, bare pipelines can show more depolarization than coated lines due to rectifier interruption.

If a bare pipeline loses 20 millivolts of polarization, during the day, the “off” potentials recorded by the C.I.S. will be less negative than during normal operation.

Consequently, particular attention must be paid to the interruption cycle times and to the ratio of “on” time to “off” time. It has been found that the 2 second cycle time with a ratio of 3:1 provides minimal depolarization on bare pipelines.

Graph 3
Graph 4 shows the stationary logger results during a thunder and lightning storm.

Graph 4

This graph shows that significant short-term potentials can occur during such storms. Graph 5 is also of interest and shows the effect of a local power outage.

Note that the local power outage shut down the main rectifier affecting this section of the coated pipeline, and this is reflected in the “on” potentials. The “off” potentials show an initial small loss of polarization, but no significant effect over the time that the rectifier was off.
Graph 5

The stationary logger can provide data that validates the C.I.S., provides a better understanding of the depolarization characteristics of the line and may show daily short-term effects previously unknown.

2.10 Datalogs

Datalogs or continuous logs are short-term data recordings taken each day by the C.I.S. crew during the survey. They are used to verify that the rectifier interruption is synchronized and provide an insight into the magnitude of any spiking that may be taking place during the switching cycles.

Usually three or four datalogs would be recorded during the survey day. A normal time span for the datalogs would be 20 seconds. This would cover 10 interruption cycles. Examples of datalogs can be seen in Section 2.3 and in Graph 6.

The datalog shown in Graph 6 exhibits synchronized switching of the rectifiers and no spiking.

Note that if spiking is seen on bare pipeline surveys, it would indicate that some of the bare piping is in fact coated. It is therefore a good idea, even on bare pipeline surveys, to only record data after the first 125 milliseconds after interruption, just in case there are short coated pipe sections present.

Graph 6
2.11 Miscellaneous Testing

During the course of the C.I.S., brief testing of other structures may be required. Such structures would include:

- Casings at road and railroad crossings
- Crossings with other pipelines
- Sales Meter Stations
- Take-offs
- Metersets

2.12 Daily Progress Logs

Each day the crew should prepare a daily progress log, which includes all of the information necessary for those preparing and analyzing the report.

The daily progress log should contain the following information:

- Client Name or Pipeline Operator
- Pipeline Designation
- Date
- Weather Conditions
- Ground Conditions
- Interruption Cycle Time and “On” and “Off” Ratio (if applicable)
- Designation of each Rectifier Interrupted
- Output of each Rectifier Interrupted
- Start and End Time of Interruption
- Stationary Datalogger Location
- Start and End Time of the Stationary Log
- Calibration Results for the C.I.S. Reference Electrodes
- Sections of Pipeline Surveyed
- Comments

When the C.I.S. is plotted and the data analyzed, interpretation of the data will depend on the available information. For example: if pipe to soil potentials do not meet criterion, this must be compared to the rectifier outputs for that section of line, and to the ground conditions. If the survey data shows unexpected variations, the stationary log can be reviewed to see if outside influences affected the line for a given time period and the datalogs can be reviewed to ensure that all interrupters were synchronized.

The progress log also serves as a means of monitoring survey progress and the information may be used for future costing or bidding purposes.
3.0 SPECIAL PIPING SYSTEMS

This section provides some extra information on two specific types of piping: well systems and bare pipelines. Some information on bare pipelines has already been discussed earlier, but there are other factors that also need to be addressed.

3.01 Well Piping

Well piping systems generally consist of a main or backbone line, and lateral or gathering lines leading to the individual wells. Wells may be production or storage. A typical well arrangement is shown in Figure 12.

![Figure 12](image)

The well line is the riser on the left, and the wellhead, with shut-off valve, can be seen on the right. In some cases, the well casing is isolated at the wellhead. This electrical isolation is installed to ensure that the Cathodic Protection system protects only the main line and gathering lines. In older well systems, the piping
may be bare, or a mix of bare and coated piping. Newer well systems will most likely be coated piping.

Special treatment of bare piping systems is covered in section 3.2.

Well systems may typically consist of 5 to 10 Km of main line and 10 to 20 Km of gathering lines. A typical well storage system is shown in Figure 13.

![WELL SYSTEM R-32 SCHEMATIC](image)

Figure 13

When undertaking well system surveys, extra crew and survey organization is required as the survey will be undertaken on many short well gathering lines connected to the main line.

It should be a standard practice to record near ground, far ground and pipe IR, at each take-off valve for the individual wells. Reconnecting at the take-off valve, the survey should proceed along the gathering line to the well riser. Again, near ground, far ground and pipe IR should be recorded, in addition to the well casing potential.
The pipe IR data will show the magnitude and direction of current flow on the gathering line. The current flow direction should always be back towards the main line, for a system with isolated wells. Note that recording the well riser and well casing potentials will verify the casing isolation.

Occasionally the measured pipe IR may show current flow along the gathering line towards the well. This may occur even if the well casing is isolated. This situation generally occurs when the gathering line is long, of small diameter, and a large distance from the rectifier location and the ground is of low resistivity. The current may find a lower resistance path back towards the rectifier by leaving the gathering piping near the well, travelling down the well casing, and back through the ground to the piping close to the rectifier.

*Figure 14* shows the C.I.S. restarting at a location where two well systems cross.

As several well systems may be interconnected, the C.I.S. of one of the well systems may require the interruption of the rectifiers on the other systems as well.

On bare piping or mixed bare and coated piping systems, rectifier outputs may be 30 to 40 amps, and the effects of this level of current output may be seen on interconnected coated piping many kilometers away, and even on bare piping several kilometers distant.

A normal C.I.S. day on a well system may produce only 75% of the survey distance normally achieved on a transmission pipeline. This is due to the multiple short sections of line to be surveyed and the extra time required for well
testing, connections and walking back to the main line after completing a gathering line.

*Figure 15* shows a C.I.S. being undertaken on a well system. Note that the pipe locator technician is locating the line 6 or 7 meters ahead of the data recorder.

![Image of pipe locator technicians](image)

*Figure 15*

Reports for the well system C.I.S. will also take more time than straight line C.I.S. reports. Each gathering line will need to be plotted on its own drawing, there will be more test station data and the report will need to be properly organized to avoid confusion between all of the data.

### 3.02 Bare Piping

Though bare piping systems are not very common, there are still many thousands of miles still in operation, generally ranging from small diameter to “24”. There is, perhaps, more poorly coated piping in operation than bare piping, and some of the information on bare pipeline surveys may be applicable to these lines also.

Cathodic Protection of bare piping systems is sometimes undertaken using remote anode beds or deep wells, but these usually yield mixed results and are often incapable of providing full protection to the pipeline.

The most common means of Cathodic Protection for bare pipelines is through the use of distributed impressed current anodes, installed parallel to the pipeline, and often at a separation of 3 to 4 meters. The anodes may all be installed on one side of the line or may be installed in an alternating arrangement. If the ground
conditions are bad, i.e. large rocks, the anodes may be located at any reasonable location.

The pipeline diameter, and the anticipated soil resistivity range determine the spacing of the anodes. Very often, the impressed current anodes are spaced every 35 to 40 meters down the pipeline right of way. They are all connected to a common header cable that runs from the rectifier to the end of each anodebed. Anode beds may consist of 40 to 70 anodes, and be 1200 to 2500 meters long.

Undertaking a C.I.S. on a bare pipeline, with distributed impressed current anodes, is far more difficult than the C.I.S. on a well coated pipeline with a remote anode bed. When surveying the bare pipeline, the anodes are always close and the voltage gradients in the ground can be very high. Moving the reference electrode half a meter either side of the pipeline may change the “off” potentials by 25 or 50 millivolts. When the anodes are installed on one side of the pipeline, the data recorded on the side of the line away from the anodes will often provide the most accurate representation of the pipeline potentials.

It is imperative in these surveys to work slower and constantly check for pipe location versus reference electrode location. Stopping the survey periodically and moving the reference across the pipeline location can accomplish this. Watching the data will show the where the best line is for surveying. Sometimes this will mean the data recorder will be offset from the pipe locator by up to a meter.

Because the anodes and the header cable are close, and the cable may cross the pipeline several times in a Km, accurate pipe location can sometimes be difficult and the reference electrode may be used extensively to verify pipe location.

In addition to the standard test stations, this type of system will also have cable test stations. The cable test station usually consists of a test cable brought above ground from the header cable or one of the impressed current anodes. This allows for testing of the cable voltage at various locations along the anodebed to check for possible cable breaks.

Because of the difficulty of achieving an “off” potential of –850 millivolts at all locations along the bare pipeline, some pipeline companies are now undertaking depolarization surveys and applying the “100 millivolts criterion”

This is proving to be a viable alternative, particularly when depolarized potentials are in the order of –200 to –400 millivolts. Changing the pipe to soil potential of these potentials by 100 millivolts negative is far easier than moving their potential to –850 millivolts.