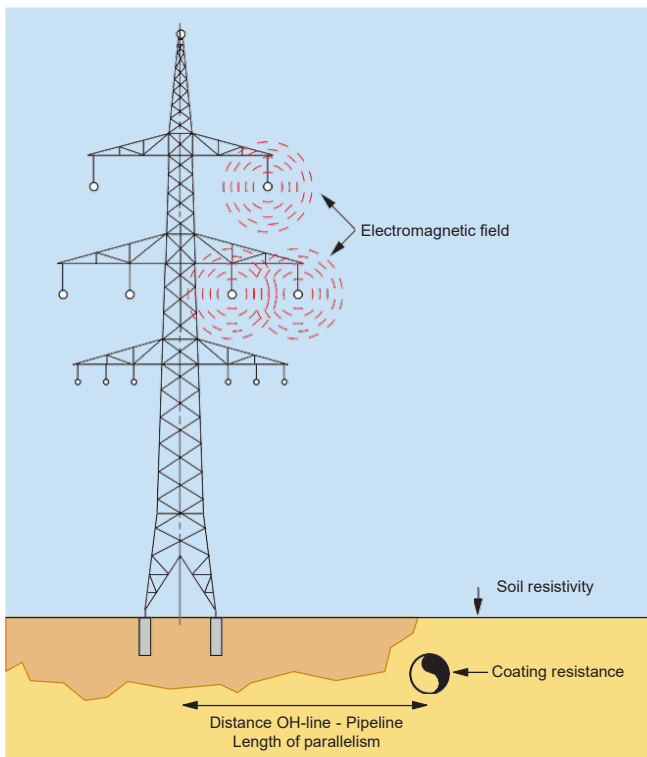


Pipeline Routing

When choosing pipeline routes, important points must be considered, such as the best possible integration in the environment, authority's requirements for reasons of land planning and rural protection, congested residential and industrial centres, which recently led to the necessity of using already existing high voltage overhead line power supply corridors.

By these achievements, it results inevitably in crossings and parallel running of various routes which can lead to interference and to the increase of danger of high voltages to personnel and equipment. For this undergoes the possible appearance of high contact voltages on the pipeline in case of close proximity and crossings with high voltage overhead lines. Reduction of this potential danger for personnel and equipment is only reached by high technical and economical efforts

**Calculations of induced contact voltages**

The calculation of induced contact voltages and therefrom the preventive measures are known by their basic elements since a long time.

Contrary to the conventional methods, a combination of estimations, empirical values and calculation which gives adequate values of the appeared effective voltage, we developed and used a computer program for such kind of calculations. By this way it is possible to calculate the close proximity sections and where required, to optimize the necessary earthing measures on the pipeline. The applied calculation method permits the simulation for each overhead line and pipeline configuration. Changes of the overhead line and pipeline parameters along the influenced section can be considered.

**Gathering Information**

Information gathering is the most important step of high voltage interference problem.

The information required for the investigation can be summarized in the following points:

- The layout drawings of pipelines and high voltage overhead lines routes are needed.
- Top view scale drawings or maps of the entire geographical area of interest, showing all conductors (pipelines) under study in sufficient details, along with major installations.
- High voltage overhead line and pipeline details as follows:

Pipeline data

- Material specification
- Outside diameter
- Coating resistance
- Buried depth
- Specific soil resistivity

High voltage overhead line data

- X-Y Tower coordinates of conductors
- Max. conductor sag
- Height of towers
- Type of conductors
- Type of earth wire on top
- Max. operating current
- Operating frequency
- Short circuit earth fault current
- Neutral point of system

PC based Computer Program

The PC based computer program includes comprehensive electromagnetic coupling equations with a very easy to use interface format to enable both operating and short circuit conditions to be calculated for up to five unbounded pipelines co-located with up to twenty power transmission line circuits.

The program also has been enhanced analytical capabilities including pipeline bond connections and pipeline grounding capabilities for both operating and short circuit mitigation. The format developed for this pro- gram makes many of the computational functions and much of the data input automatic for the user, thus leading to considerable simplification in program usage.

Data input for few computer screens are required to fully exercise the program.

Advantages

The time and costs for AC inducing problems, inductively coupled interference studies, new cathodic corrosion protection design with close or crossing competitive pipelines with existing cathodic corrosion protection systems or high voltage overhead lines, right-of-way and integrity planning, is greatly reduced by using the developed software. The program can be used by pipeline engineering staff or contract consultants drastically reducing engineering time and costs while improving the safety and integrity of cathodic corrosion protection design.

Standards and Guidelines

In 1977, NACE has recognized the problem of induced AC on pipelines and originally issued a Standard Recommended Practice to control corrosion and safety issues.

In 1995, this standard has been updated and re-issued as Standard RP-01-77-95 "Mitigation of Alternating Current and Lightning Effects on Metallic Structures and Corrosion Control Systems".

The standard which has been issued in Canada is CAN/ CSA-C22.3 No. 6-M91 "Principles and Practices of Electrical Coordination between Pipe Lines and Electric Supply Lines".

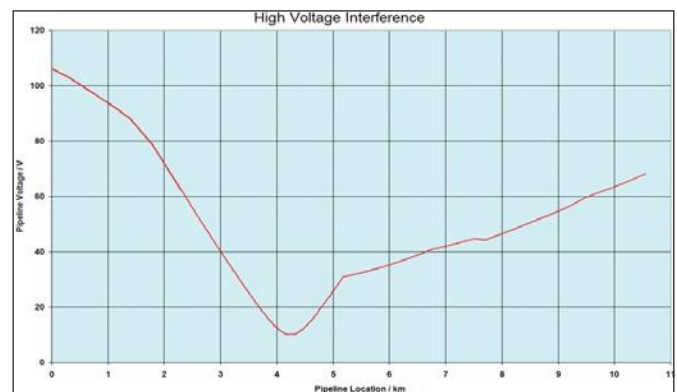
Standards also exist in Europe, such as DIN VDE 0141, (Beuth-Verlag, Berlin, 1976).

The NACE and Canadian standards recommend that the potential on a pipeline from AC be reduced to less than 15 V AC.

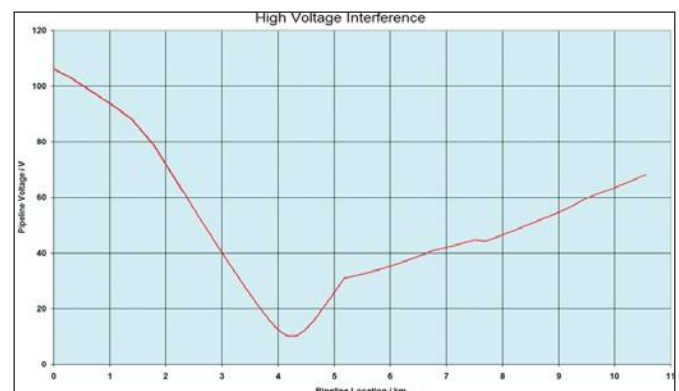
European standards recommend to reduce to less than 60 V AC.

Z-Code	Number for Conductor	Maximum Conductor Sag in m	Height of the Tower in m	E-Code	X-Coordinate in m	Y-Coordinate in m	R.S.T-Code	Masttype
1	FKZ1	8.5	31	E1	0	31		A20
2	FKZ1	R1	-3.25	27.5 S1	-4	27.5 T1	-4.75	19.5
3	FKZ1	R2	3.25	27.5 S2	4	27.5 T2	4.75	19.5
4	FKZ2	Z1	8.5	31				A20
5	FKZ2	E1	0	31				A20
6	FKZ2	R1	-3.25	27.5 S1	-4	27.5 T1	-4.75	19.5
7	FKZ2	R2	3.25	27.5 S2	4	27.5 T2	4.75	19.5
8	FKZ3	Z1	8.5	31				A20
9	FKZ3	E1	0	31				A20
10	FKZ3	R1	-3.25	27.5 S1	-4	27.5 T1	-4.75	19.5
11	FKZ3	R2	3.25	27.5 S2	4	27.5 T2	4.75	19.5
12	FKZ4	Z1	8.5	59.5				BD3
13	FKZ4	E1	0	59.5				BD3
14	FKZ4	R1	-10.75	49 S1	-14.25	38 T1	-7.75	38

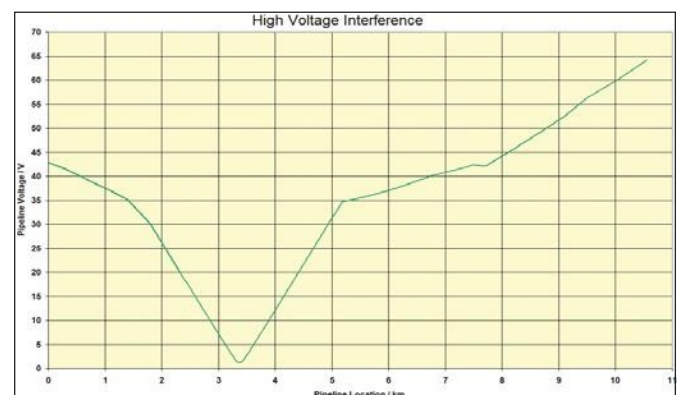
Data input for calculation by using Microsoft Excel as example



Calculation results caused by overhead line **operating** currents without any earthing measures



without any earthing measures



Calculation results caused by overhead line operating currents with earthing measures ($U_{\max} < 65$ V acc. to German Standard)

COMPUTER SOFTWARE

Close Interval Potential Survey – CIPS

Document No.: PSE-310-R622

Sheet: 1 of 4

In order to analyse the external corrosion of buried pipelines, pipe/soil potential measurements are made. Pipe/soil potentials are normally measured at fixed test points spaced about 1 km to 5 km along a pipeline. However, reliable information about the status of CP of the pipeline between these test points is unknown since measurement is only valid at the reference electrode location.

High local differences in soil resistivity, interference and other effects may cause corrosion at intermediate locations even having good potentials at the test points. Therefore, the necessity to decrease the distance between successive potential measurements yields more accurate information concerning the CP-conditions on the pipeline and hence a “close-interval” or an “intensive” measuring technique was developed with potential measurement in steps of 5 m or less over the line.



Reasons to use closed interval potential survey - CIPS

It is impractical and uneconomical to measure pipe/soil potentials manually at close-intervals of 5 m along a pipeline. Recording these results and plotting them by hand especially for a long transmission pipeline system, uses lots of time even when using strip-chart recorders for potential measurements. Therefore, a quick and reliable system has been developed.

CIPS overcomes these problems by automatically recording, storing, calculating and displaying the potential data. The data is given in table and graphical forms by a micro-computer for this purpose.

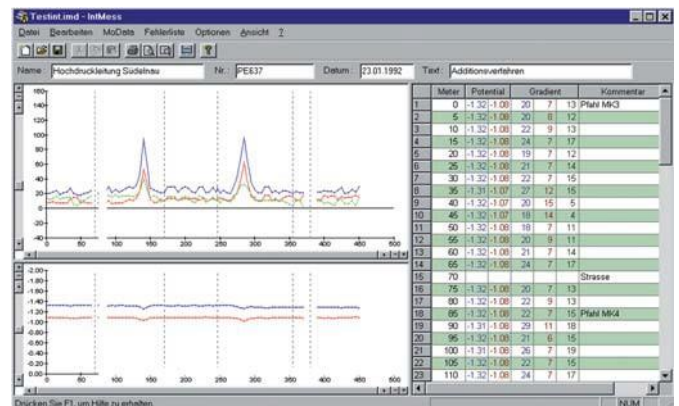


Required hardware

- Modata2 including Handheld PC Itronix fex21
- Modata2 scope of delivery package

Required software

- NaMobil 3.0
- IntMobil 3.0
- WinTrans 1.0
- IntMess 3.0



The MoData2 is used for field recording of pipe/soil potentials and voltage drops in cathodic protection measurements. The measured potentials are displayed. Pipe-to-soil potential data are recorded in the internal memory of the MoData2, Multifunction Instrument.

4 measuring methods are directly integrated into mobile software package:

- 2-electrode method
- 3-electrode method
- Adding-up method
- IFO-method

Method: IFO

IFO (Intensive Fault Location) is preferentially being used with new pipelines with intact coatings and a relatively small number of defects.

IFO only serves to detect faults and does not allow measuring potentials. For checking the potential at a test point during the IFO measuring, it is necessary to switch to either 2- or 3-electrode method.

In order to optimize the measurement of even the smallest voltage differences, it is common habit to increase the feeding current of the rectifier while measuring with the IFO method, which produces a higher potential gradient at fault locations.

Description of the measuring method

The IFO method measures the on- and off-voltage drops along pipelines. For this, two electrodes are placed at ground level along the line at distances of 5 or 10 m. The standard step size is 5 m, i.e. both electrodes will be shifted by another step (of 5 m) in the measuring direction after each measurement has been completed.

For an evaluation of the values of the IFO measurement, the difference between the measured on- and off-voltages will be compared. An increment of the voltage differences followed by a reversed polarity indicates a likely defect location.

Note regarding the electrode placing

Selecting a distance of 10 m between the two moving electrodes offers advantages when measuring small voltage drops. A distance of 5 m, however, allows to determine the absolute voltage gradient by simply adding up the voltage drops measured.

Measuring array: IFO

The measuring array for the IFO measurement is very simple to implement: Just connect terminal channel B and the ground to the 2 electrodes used.

Method: 2-electrodes

This method is definitely the most frequently applied one for intensive measurements.

The switching-on and -off potentials as well as the values of the respective voltage gradients are measured at each individual measuring point.

The measuring of the on- and off-potentials is performed by means of a direct connection of the measuring contacts, while the measuring of the on- and off voltage gradients takes place perpendicular to the pipeline axis at a distance of about 5 to 10 m. To ensure a reliable comparison of the voltage gradient values, the measurement has to take place at a constant perpendicular distance to the pipeline.

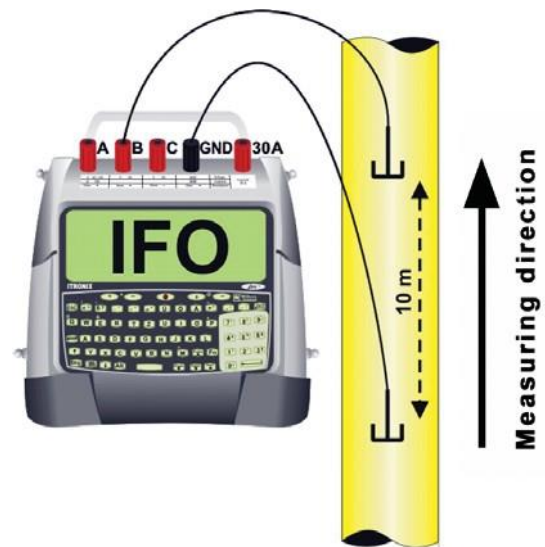
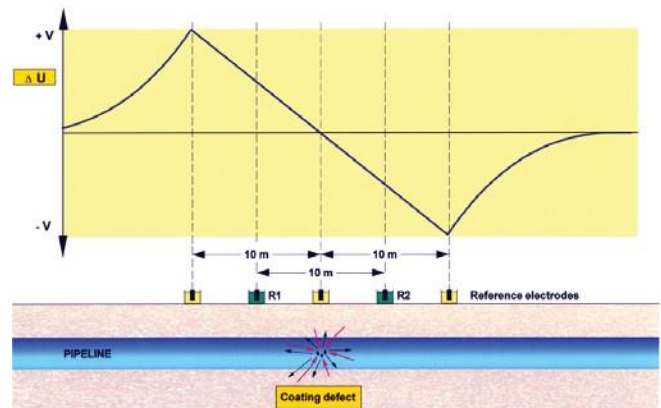
Advantages of the 2-electrode method

Since this direct way of collecting measuring values does not require any adding up, it is very easy to perform from the measuring technique point of view.

Disadvantages of the 2-electrode method

As this method requires a direct connection to the test point it possibly requires rather large cable lengths, i.e. at least half of the distance between the two test points.

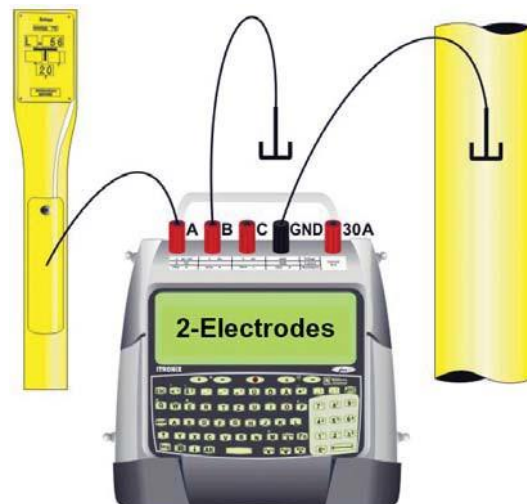
Moreover, taking the perpendicular measurements of the voltage gradients requires a constant and relatively large distance to the pipeline axis (about 10 m), which means that difficulties may arise in uneven terrain, residential- or industrial areas.



Measuring array: 2-electrode method

Applying this method requires a proper connection to the test point. For measuring potentials, channel A of the MoData2 multi task converter (MTC) is to be linked with the test point. The lateral measuring electrode is to be connected to channel B of MoData2.

The reference electrode being directly on top of the pipe axis is to be connected to the black ground terminal of the MTC.



Method: 3-electrodes

The 3-electrode method constitutes an extension of the 2-electrode method. In contrast to the latter, the 3-electrode method allows measuring two voltage gradients symmetrically along both sides of the pipe axis.

The MoData2 system thus allows the calculation of IR-free potentials according to the so-called "extrapolation method" by measuring the potential and the two voltage gradients on the left and right sides of the pipe exactly simultaneously.

Advantages of the 3-electrode method

This method offers considerable advantages when evaluating intensive measurement data of parallel pipelines. Interfering external voltage gradients on one side of the pipe axis can be suppressed during the evaluation of the measurement data thus allowing a more realistic data evaluation.

Frequent use is being made of the 3-electrode method when re-measuring pipe locations that have been detected earlier with the IFO method as being flawed. The measurement of the left and right side voltage gradients combined with a calculation of the IR-free potential allows in most cases a more precise assessment of the cathodic protection at the flawed pipe spots than it would be the case with other measurement methods.

Disadvantages of the 3-electrode method

The voluminous measuring array requires a relatively large number of staff to operate the system. The double-sided measurement of the voltage gradients at the largest possible and constant electrode distance (e.g. 20 m between the left and the right electrode) leads in difficult terrain to a slow daily progress.

Measuring array: 3-electrode method

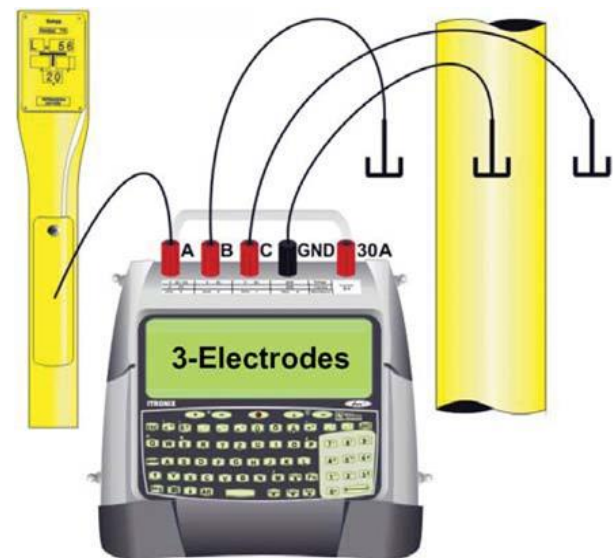
Applying this method requires a proper connection to the test point.

For measuring potentials, channel A of the multi task converter (MTC) is to be linked with the test point.

The perpendicular measuring electrodes are to be connected to channels B and C of the MTC.

The reference electrode being directly on top of the pipe axis is to be connected to the black ground terminal of the MTC.

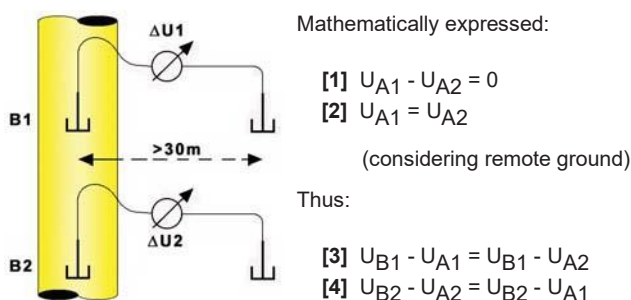
It will be sensible to compensate electrode differences to ensure a reliable calculation of the IR-free potential.



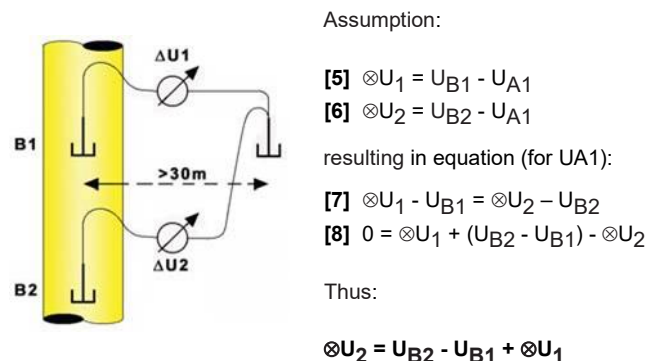
Method: Adding-up

The adding-up method allows to easily perform longitudinal voltage measurements and a subsequent calculation of potentials and voltage gradients.

The adding-up method is based on the assumption that the voltage between two reference electrodes being installed on "remote ground" is more or less 0 mV. This means that, for instance, during a voltage gradient measurement the position of the laterally mounted reference electrode is of no importance as long as it is installed on "remote ground" only.



The laterally positioned reference electrode may be installed on remote ground.



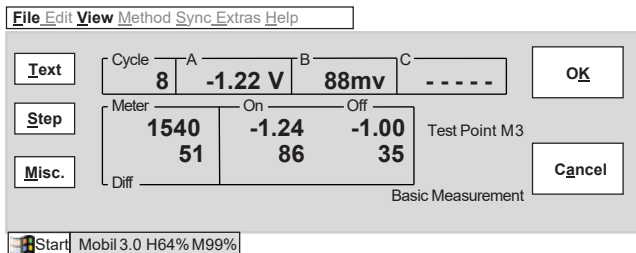
This means that the voltage gradient $\otimes U_2$ can be calculated by taking the differential voltage $U_{B2} - U_{B1}$ (voltage drop alongside the pipeline) and adding $\otimes U_1$ (basic voltage).

The procedure of calculating the potential is similar.

Basic value collection

Prerequisites for any calculation are the so-called “basic values” that are to be collected when commencing the measuring and again whenever further measuring contacts are being reached.

Each time basic values are measured, IntMobil shows “Basic Measurement” beneath the line for the text entry on the display of the current measuring mode.



Basic values are taken using the 2-electrode method. Please refer to for the measuring array.

Basic values may be taken and calculated at any test point. This results in a higher accuracy of the calculation of further potentials and voltage gradients.

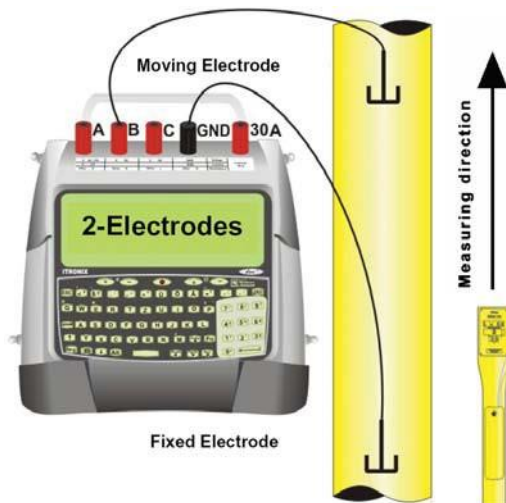
Notes regarding the adding-up method:

When taking basic values at stray current-influenced pipes, problems may arise during the adding-up procedure. The basic values may drift during the intensive measurement thus leading to incorrect values.

Furthermore, it must be noted that upon each electrode shifting larger electrode differences may lead to significant step changes of the voltage gradient and/or potential values. Therefore, keep the number of electrode shifts as small as possible.

Measuring array: Adding-up method

After the measurement of basic values has been completed, the so-called “fixed electrode” has to be placed exactly where the reference electrode was positioned during the basic measurement of voltage gradients and potentials. The so-called “moving-electrode” has to be placed according to the step size along the pipeline.

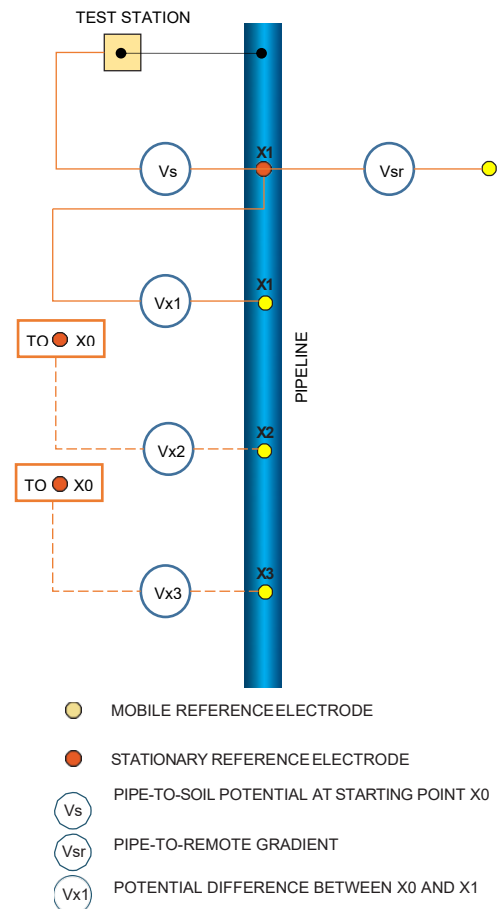


After a measurement has been completed, the moving electrode will be repositioned by one step size in the measuring direction along the pipeline. The fixed electrode remains at its location and will only be moved and repositioned after an electrode shift or in the course of a new basic measurement.

Shifting electrodes

The fixed electrode remains positioned during the basic measuring value collection. During the progress of the measuring procedure increasingly larger cable lengths will be required between the fixed electrode and the multi task converter (MTC). If an extension cable is unavailable, the fixed electrode has to be shifted to make further intensive measurements possible.

BASIC METHOD FOR MEASUREMENT OF POTENTIAL



IntMobil stores the latest voltage gradient and potential values measured during the electrode shift and uses these values as new basic values for the addition of measured longitudinal voltages between the fixed and the moving electrode.

Note regarding the shifting of electrodes

Shifting electrodes is not only helpful after the available cable length has been fully used, but also when crossing railway lines or roads. Collect the measuring values beyond the railway line. Afterwards, shift the electrodes as described above with the fixed electrode being positioned beyond the railway line. Cabling across the obstacle will then be necessary for the period of one measurement only.

COMPUTER SOFTWARE

Calculation of Cathodic Protection Systems

Document No.: PSE-410-R622

Sheet: 1 of 2

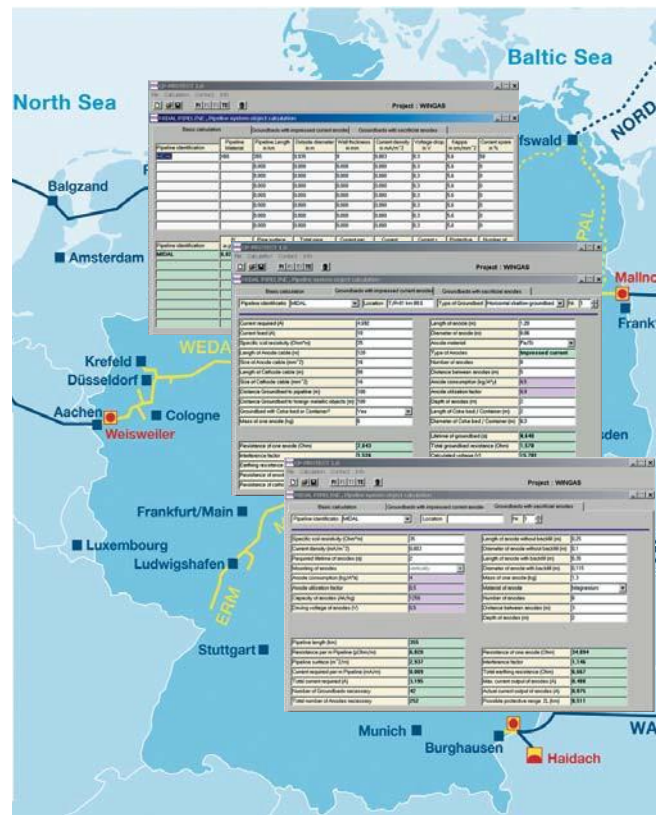
The continuous development of user-orientated computer software based on practical experiences is one of the major activities of the company for design and engineering of various kinds of cathodic protection projects.

CP-CALC - a calculation software package - has been devised to solve the planning problems for design and engineering of cathodic protection systems for various types of structures.

The software package is the award-winning calculation software for professionals who need to calculate cathodic protection systems simply and precisely.

With **CP-CALC** you get a whole array of time saving devices to help you work better than you ever thought possible.

System requirements: Windows



CP-CALC: PIPELINES

- ☐ current requirement calculation
- ☐ protective range calculation
- ☐ stations with horizontal shallow groundbed
- ☐ stations with vertical shallow groundbed
- ☐ stations with open hole groundbed
- ☐ stations with closed hole groundbed
- ☐ galvanic anode systems
- ☐ temporary protection with magnesium anodes
- ☐ current density as a result of drain test
- ☐ offshore pipes with bracelet anodes

CP-CALC: INDUSTRIAL PLANT AREAS

- ☐ current requirement calculation
- ☐ stations with horizontal shallow groundbed
- ☐ stations with vertical shallow groundbed
- ☐ stations with shallow sub-groundbeds
- ☐ stations with open hole groundbed
- ☐ stations with closed hole groundbed

COMPUTER SOFTWARE

Calculation of Cathodic Protection Systems

Document No.: PSE-410-R622

Sheet: 2 of 2

■ current requirement calculation

■ galvanic anode system

■ with aluminium, magnesium, zinc anodes

■ impressed current system

CP-CALC: STORAGE TANKS, INTERNAL



■ current requirement calculation oil tank

■ current requirement calculation water tank

■ galvanic anode system

■ with aluminium, magnesium, zinc anodes

■ current requirement calculation

■ stations with open hole groundbed

■ stations with closed hole groundbed

■ stations with horizontal shallow groundbed

■ stations with vertical shallow groundbed

■ current drain (E-log I) test

CP-CALC: OFFSHORE STRUCTURES



CP-CALC: PRODUCTION WELL CASINGS



COMPUTER SOFTWARE

Well Casing Potential Profile (WCPP)

Document No.: PSE-510-R622

Sheet: 1 of 1

Well Casing Potential Profile (WCPP)

The electrical potential is the most important criterion in cathodic protection to determine the degree of protection on a buried or submerged metal structure.

The degree of protection is indicated by the potential difference measured against a reference electrode placed in the surrounding medium.

Commonly used reference electrode is the saturated copper/ copper sulphate (Cu/CuSO_4) electrode.

Potential differences of at least $-0.85 \text{ V} / \text{Cu}/\text{CuSO}_4$ is widely accepted as the criterion for the protection of steel in soil or water. The potential difference should be measured with the reference electrode placed as near as possible to the structure, to minimize voltage drops (IR) errors caused by cathodic protection current flowing through the medium.

Physically and electrically a well casing is similar to a pipeline installed vertically. The decrease of current and voltage with distance from the drain point of the cathodic protection station is like that along bare pipeline.

However, the cathodic protection test methods applicable to pipelines are not suitable to well casings. Whereas test leads can be installed at any point on most pipelines to measure potentials and currents, such measurements on well casings can be done at the well head only.

For this purpose, the company has developed the software package WCPP, well casing potential profile calculation.

This calculation method gives, under consideration of the physical data of the well casings and electrical measurements of potentials and current at well head, the possibility of determining potentials and currents at various points along the depth of the casing.

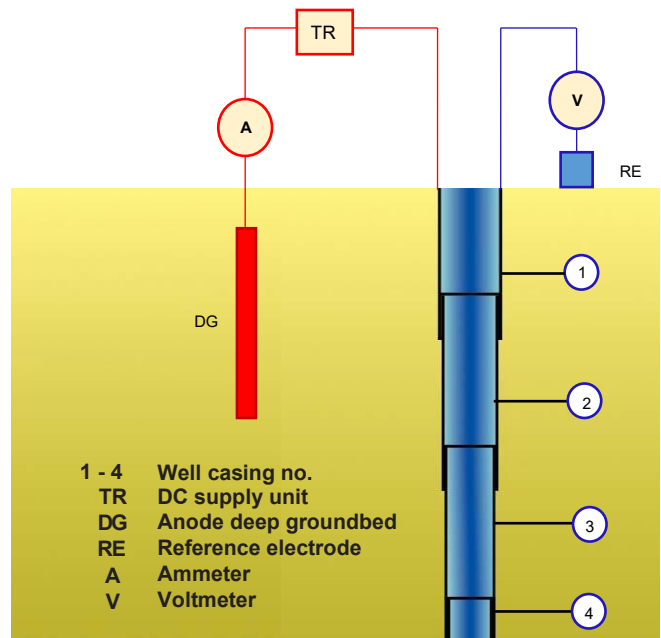
Variables which can be used are as follows:

Physical

number of casings	: n
length of casings	: L
diameters of casings	: D
specific weight of casings	: W

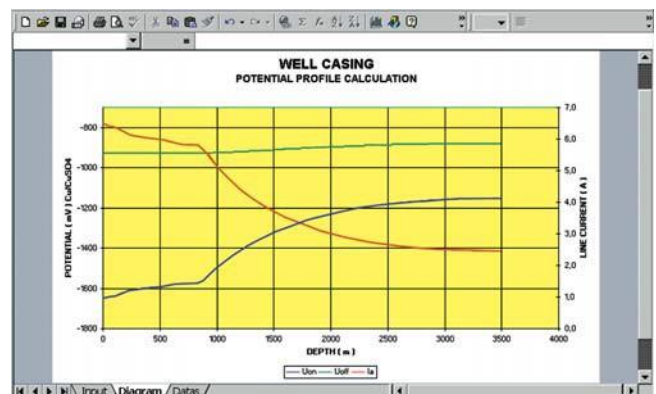
Electrical variables measured at the wellhead

natural potential	: E nat
on – potential	: E on
off - potential	: E off
drain current	: I



L13							
casings							
A	B	C	D	E	F	G	H
WELL CASINGS							
POTENTIAL PROFILE CALCULATION							
PHYSICAL DATA							
6	CUSTOMER	AGOCO					
7	PROJECT No.	CT 24-00-1E					
8	SITE	NAFOORA					
9	LOCATION	GOSP 3					
10							
11	DATE	12.03.1992					
12	WELL-No.	C 116					
13	DATA TAKEN BY	Tasfeg					
14							
15							
PHYSICAL DATA							
17	TYPE OF CASING	CASING No.	LENGHT OF CASING	INNER DIAMETER OF CASING	WALL THICKNESS OF CASING	rho	rs
18	Inner Casing	1	3500 m	160 mm	9.00 mm	0.2573 Ohm.m	5.72E-05 Ohm.m
19	Outer Casing	2	850 m	250 mm	8.00 mm	0.1992 Ohm.m	3.07E-05 Ohm.m
20	Outer Casing	3	500 m	300 mm	7.00 mm	0.2000 Ohm.m	2.96E-05 Ohm.m
21	Outer Casing	4	100 m	320 mm	6.00 mm	0.2000 Ohm.m	3.25E-05 Ohm.m
22							
23							
24							
ELECTRICAL DATA (taken at well head)							
26	NATURAL POTENTIAL	Un	-620 mV	against Cu/CuSO4 electrode			
27	ON-POTENTIAL	Uon	-1650 mV	against Cu/CuSO4 electrode			
28	OFF-POTENTIAL	Uoff	-928 mV	against Cu/CuSO4 electrode			
29	DRAIN CURRENT	Id	6.5 A				

Input Menu



Potential Profile Diagram

Potential Output Data

available on monitor or on printer