**LUXEMBOURG 16th – 19th May, 2017**

# Specialised Surveys: an exceptional tool for pipeline integrity

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## 1. – Main risk factors for pipeline integrity

The integrity of pipelines mainly depends on the criteria used when choosing the pipe way, the construction, their coating types, the burial techniques for avoiding any damage during these phases. Gas pipelines have been laid down since the 50ies by using various coating types, various laying techniques, different criteria established by laws which were in their validity at those times. The evolution of these techniques has made possible an improvement and sometimes a complete revolution of the techniques used to lay down pipelines in their trenches. Gas Companies in particular, due to the fundamental importance of their network integrity mainly for safety purposes, have continuously increased strict obligation for the constructors before, during and after pipe-laying. Also the Governments have implemented some strict obligations so that the safety of public is achieved and maintained over time. In the US, for example, the Recommended Practice "*External Corrosion Direct Assessment*" is mandatory since the 80ies. "It addresses external corrosion on on-shore, below-ground sections of transmission and distribution piping systems constructed from ferrous materials. It may be used in conjunction with or in place of other integrity assessment tools including in-line inspection, pressure testing, or proven new technology. The ECDA process applies to coated as well as bare pipe, however, all inspection methods do not apply to both coated and bare pipe and may require different interpretation based upon the particular application".

Many companies in Europe since the 60ies started a programmed use of intelligent pig inspections to verify the real conditions of the metal of pipelines. For older pipelines this was not an easy task: in order to inspect a pipeline with an intelligent pig, it must be provided by full-bore valves, the bends must not be more than 3 times their radius, there must be enough gas transported in the pipeline so that the intelligent pig can properly be pushed into the line. A great effort has been made by all Gas Companies in order to adapt the characteristics of older pipelines in order to make them piggable, as far as possible.

Sometimes, however, this is simply not possible; in these cases, the only viable option is to use methods which from the external of a pipeline, can give information on the conditions of its metal. In the beginning of 70ies, an extensive use of over the ditch cold applied tapes was made. This type of coating, in particular, is mostly prone to coating disbondment and relevant corrosions in areas where the metal can be reached by the electrolyte, but not by the CP current, due to the so-called shield effect. A similar problem may be present in pipelines coated with 2 or 3 Layers PE. Usually, the single spool was properly coated in the factory but the field joints, usually coated with thermo-shrinkable sleeves, were applied over the ditch. Their application, especially on large diameter pipelines, was sometimes not proper and the adhesion of the wrap to the metal resulted quite poor. The subsequent laying phase most of the times determined the formation of wrinkles on the sleeve, typically at 4 – 19 o'clock around the pipeline.

These typical defects on pipelines buried in the 70ies are very dangerous for pipeline integrity.

They can give rise to corrosions due to the presence of SRB (Sulphate Reducing Bacteria). If the conditions exist (presence of mechanical stress, local conditions of pH around the neutral value), this type of coating defect can even give rise to Stress Corrosion Cracking.

Another typical corrosion phenomenon, usually appearing on very well coated pipelines, has been recognized in the last 30 years, the a.c. corrosion. This type of corrosion has been very deeply studied at national and international level. Some specific Working Groups have been launched in CEOCOR and numerous papers have been presented, showing the results of these studies. In 2001 CEOCOR has published a booklet whose title is "AC Corrosion on Cathodic Protected Pipelines" which is the compendium of the knowledge at those times. Even today, this booklet has confirmed its full validity.

Due to practical examination of many of these corrosion types, it has been possible to characterise their conditions of occurrence and make real field tests in order to discover these corrosions in time (e.g. before pipe wall perforation), even when the intelligent pig could not be used.
Analogously, an important problem for pipeline integrity can be the mechanical damage of an existing pipeline in agricultural areas, where the mechanical machines can reach noticeable depths (e.g. heavy Tractors, Rippers, Trimmers etc.). Due to the laws existing at the time of laying of some pipelines, and to the works over the pipeline way, the pipe burying depth can result sometimes less than 50 – 60 cm. This fact can determine some scratches on the metal of the pipe, and the consequent so-called "delayed fracture".
Initially only very small cracks appear on the metal which, due to the oxygen developed by the Cathodic Protection process, they may increase and determine very dangerous cracks, especially if longitudinal ones.
Summarizing, the following main phenomena must be prevented on a pipeline:
- Coating damages (coating faults)
- Disbondment of coating
- Mechanical damages on the pipeline steel
- Lack of cathodic protection

The following scheme, presented at IGU - International Gas Union in 1996 - Milan, resumes the origin of the main corrosion phenomena on a pipeline:

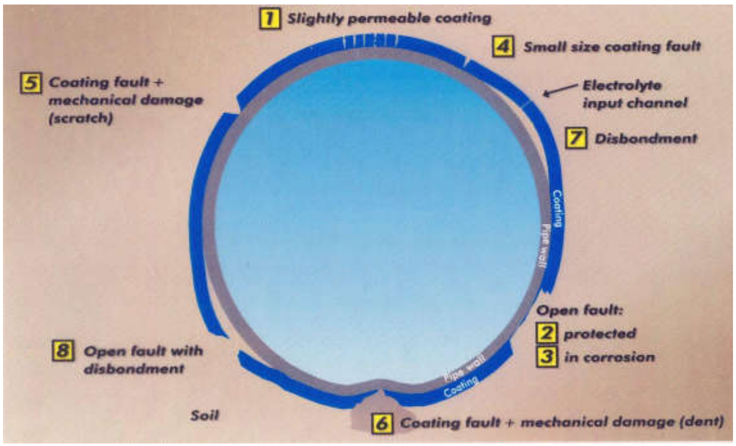



**Fig. 1 – Schematic characterisation of main coating fault features**

In practice, any coating fault can represent a risk for pipeline integrity. For each of these type of faults we can expect the following consequences:
1) This is the normal condition of a pipeline as the coating always has a certain porosity;
2) Presence of coating faults: these are usually cathodically protected by a sufficient CP current density;
3) If the current density is not enough, the metal on this area can be corroding.
4) Small coating faults on very well coated pipelines, in case of interference by a.c. current, may produce a.c. corrosion;
5) This type of fault in the upper surface of the pipeline is mainly produced by mechanical machines working over the pipeline after it's laying;
6) In this case the coating fault is derived by stones/hard rocks present in the ditch; also a dent may result, according to the weight/metal surface ratio;
7) This is the mechanical disbondment of the coating, often due to a poor quality of its application (e.g. inadequate surface cleaning, inappropriate coating materials, etc.).
   In these cases, if enough electrolyte (water, soil) enters the void area between coating and metal of the pipeline, it may be corroded due to the presence of anaerobic bacteria;

8) An open fault in the coating can be accompanied by a disbondment around the fault, sometimes determined by a too high current density provided by the cathodic protection system (usually referred to as “cathodic disbondment”).

The corresponding electrochemical parameters of the above said faults have been characterized in the following way:

| N. | Coating Fault Feature | ELECTROCHEMICAL CHARACTERISATION | | |
|---|---|---|---|---|
| | | Rp (*) | Cdl (**) | Ri (***) |
| 1 | Slightly permeable coating | *Very High* | *Very Low* | *Very High* |
| 2 | Open Fault (cathodically protected) | *High* | *Low* | *Low* |
| 3 | Open Fault (in corrosion conditions) | *Low / Very Low* | *High* | *Low* |
| 4 | Open, small/very small Fault (a.c. corrosion conditions) | *Medium / Low* | *Medium / Low* | *Low / Very Low* |
| 5 & 6 | Coating Fault + mechanical damage | *High* | *Low* | *Low* |
| 7 | Shielded Fault (in corrosion conditions) | *Low* | *Medium / High* | *High* |
| 8 | Open Fault together with coating disbondment | *Medium / Low* | *Medium / High* | *Low* |

Where:
(*) Rp – Polarization Resistance (inversely proportional to the Corrosion Rate)
(**) Cdl – Double Layer Capacitance
(***) Ri – IR Drop

**Table 1 – Electrochemical comparison between various types of coating fault features**

## 2. – Coating faults – Localisation, Cathodic Protection, Corrosion

The Coating Faults occurring during the pipeline laying phase are usually not considered a big problem, as the Cathodic Protection current just serves to protect these faults from corrosion. Nevertheless, if coating faults are too many or too large, or resulting in particular positions/conditions they can represent a great risk for pipeline integrity.
Some examples:

- A coating fault resulting nearby an insulating joint can produce large electrical interferences and sometimes may hinder the correct working conditions of a whole CP System, especially in Stray Current Areas;
- If small coating faults are present in a well coated pipeline, in the presence of a.c. interference can represent a risk for a.c. corrosion;
- Small coating faults determined by a mechanical machine (e.g. excavator) after pipe-laying, they can be accompanied by mechanical scratches which can determine cracks which will develop in large cracks due to the hydrogen developed by the cathodic protection process;
- Where coating faults expose large metal areas to the electrolyte, these could not be cathodically protected. The normal CP measurements could not be able to discover these areas not protected (e.g. when the Test Posts are too far from these faults).

For this reason, it is essential to verify the presence and repair coating faults on buried pipelines. A number of techniques have been developed for locating coating faults such as the following:

- Pearson
- CIPS (Close Interval Potential Survey)
- DCVG (Direct Current Voltage Gradient)
- Electromagnetic Current Attenuation
- Extrapolation Method

The above said techniques are not equivalent: according to the specific situation and scope, each technique has its own specific application. According to our experiences, in the following, the particular use of some of these techniques is described.

## 2.1. – Coating insulation and mechanical impacts on a pipeline

A deep study was made in the $90^{ies}$ to verify the capability of a System properly developed to monitor any possible mechanical impact on a pipeline.
This system was studied particularly in SNAM by using some equipment developed in the Research Laboratories which were by that time held in ENIRICERCHE, the research Company of the ENI Group. The study was made during a 3 years period, also by reproducing real mechanical impacts on real pipelines; it allowed to develop this unique technique, devoted to continuously monitor the isolation condition of a well defined extent of pipeline, and to alert for possible mechanical impacts on the same section of pipe.
Usually, a section of pipe (e.g. 5 to 30 km length) is cathodically protected by one only CPS (Cathodic Protection Station), or 2 CPS placed at its extremities.

To this extent of pipe, a variable CP current (square wave modulation) is imposed in such a way that the relevant values of $V_{on}$ and $V_{off}$ are detected, thus revealing its coating condition response.

$$\mathbf{Ris = (V_{on} - V_{off})} * S / I$$

where:
I = cathodic protection current
S = overall exposed surface of the pipeline

After due calibration on a pipeline in the real field, the amplitude of modulation (ON/OFF values) can be tuned in such a way that not the total current is interrupted, but only a small percentage of it. The useful intensity of the modulation after numerous tests was considered to be in the range between 0,5 and 5% of the total CP current applied to the pipeline for its Cathodic Protection, but this mainly depends on the general quality of the coating. A data logger continuously records the data and calculates the overall Insulation Resistance of the pipeline so that any deviation can give rise to automatic alarms to the Operating Centre. In case of a mechanical impact due to a machine, the corresponding signals are very peculiar and can be easily recognised and characterised via software. Over time, the insulation conditions value of the pipeline under control is rather constant and only subjected to seasonal variations. If a sudden variation happens, the system automatically gives rise to an alarm. The relevant Patent was filed in 1991 and issued in 1993. Even though the system was working properly, no real application has been made afterwards. On the contrary, such a system could profitably be used on pipelines in remote areas where the risk of mechanical impact is greater (e.g. insufficient burying depth) or the type of cultivation implies the use of means working quite in depth in the soil (e.g. Rippers).

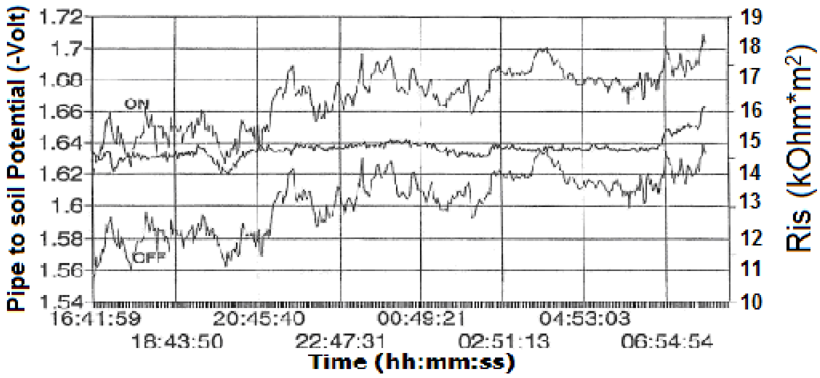



**Fig. 2 – Continuous Monitoring of the Isolation Resistance of a Pipeline**

As it can be observed in the graph, while the variation of Von and Voff potentials during time appear quite large, the insulation resistance calculated continuously with the Remote Monitoring System remains around 15 KΩ*m$^2$.
If applied to a Water Pipeline, a coating insulation variation due to a water leak will be clearly and immediately discovered with this type of monitoring, giving rise to automatic alarms.

## 2.2. – Coating disbondment

In a similar way as in the above par. 2.1., a study has been made in the Research Laboratories to verify if it was possible to detect the presence of corrosions occurring under disbonded coatings. An international Patent was applied on "Monitoring and locating Defects in and detachments of the protective covering of underground or immersed metal structures or pipelines" in 1995.
The method for monitoring the state of, and for locating any detachment of, the protective covering of immersed or buried pipelines or other metal structures subjected to cathodic protection with constant current, on the basis of the overall electrical resistance offered by the pipeline/covering/ground system, consisting of applying local sinusoidal wave excitation currents of different frequencies to the pipeline and measuring the corresponding voltage responses, then comparing the measured responses of the system to determine, on the basis of response differences or coincidences at the various frequencies, whether within the portion under consideration there is detachment with corrosion underway or whether there is a simple covering decay. The analysis of Bode and Nyquist diagrams allowed to extract the overall insulation conditions of a buried, cathodically protected pipeline.

The results of the study were positive, even though the process for the examination of a small section of pipeline was quite complicate and very long.
The system was based on the application of low/very low frequencies on the pipeline under study as the CP current is usually applied.

## 2.3. – Microbial corrosion

In real pipelines, the use of intelligent PIGS revealed that some important corrosions had been occurred under disbondments of very good quality coatings. This phenomenon was worrying as some corrosion found had a growing rate of about 2 mm/year. Laboratory

tests demonstrated that, while the normal speed of a Corrosion due to Microbial Bacteria is around 0,8 mm/year, in special conditions this speed can be much greater. In particular, when the electrolyte (water) is alternatively present or not over the metallic surface, the corrosion rate can noticeably increase and reach around 2 mm/year.
In these cases the following remedial actions were necessary:

- First of all to run intelligent pigs for locating any corrosion spot;
- Increase the Pig Inspection frequency (once a year instead of every 2 years)
- Localize areas where the phenomenon of varying water table is more consistent,
- Improve local tests and site excavations in these particular areas.

In these particular pipelines the Transverse Gradient Technique was used for localize possible spots where these disbondments could be present. In order to highlight these positions, as the Shrinkable Sleeves were acting as a screen towards the C.P. current, it was necessary to increase the CP Current normally used for its Cathodic Protection 3 or 4 times more. In this way the peaks (they have a high Ri, as the Table 1 at Item 7- shows) due to the little amount of current going in these spots could be detected, revealing that these sleeves were disbonded and allowed the income of electrolyte towards the metal of the pipeline.

## 2.4. – Stress Corrosion Cracking

In particular conditions, a pipeline can suffer the so-called Stress Corrosion Cracking phenomenon (SCC). Two main types of SCC have been recognised:

- Low pH SCC
- Near Neutral SCC

In order the Stress Corrosion Cracking Process can take place, some peculiar conditions must be contemporaneously present in the pipeline:

- Mechanical stress
- Presence of $CO_2$
- Lack of cathodic protection (low or near-neutral pH)

The mechanical stress on a pipeline is generally due to the following effects:

- Transverse stress, due to pressure variation of the transported fluid
- Transverse or longitudinal Stress due to soil movement, landslides and similar.

Experience on gas pipelines in Europe have shown that the stress on a gas pipe can mainly be due to soil subsidence or landslides. Where the pipeline is mechanically stressed, its coating is usually damaged and, as a result, some areas may exist where the coating is disbonded. These disbonded areas, if the soil contains sufficient carbon dioxide, can give rise to the so-called phenomenon of Low pH Stress Corrosion Cracking if also a mechanical stress exist.
The near-Neutral SCC phenomenon is more often found downstream the Compressor (Gas) or Pumping (Oil) Stations, where the fluid temperature is more than 50°C. In this case, the temperature is induced by the compression/pumping action, while the stress is caused by the mechanical deformation of the pipeline steel, due to its temperature variations.
A large Low pH Stress Corrosion Cracking phenomenon happened in the 80ies in the Trans-Canadian pipeline. This pipeline was mainly coated with cold applied tapes, then prone to coating disbondment, while the mechanical stress was induced by the large variation of the gas pressure during pipeline operation. As the Mechanical Stress was axial, the cracks were longitudinal and sometimes very long, being the mechanical properties of the steel quite poor (no crack stop longitudinally).

Some significant experiences were made on a few pipelines in Italy. Where the pipeway was known as being in a landslide area, the pipelines were generally monitored by using specific ***strain gauge.*** These ***sensor*** devices were monitored either by a telecommunication system or periodically verified on site. When the stress accumulated over the pipeline was too high, excavations were made in the critical areas of the pipeline in order to release any mechanical stress (e.g. excavating the constraint area along the pipeline upstream a landslide).
The peculiar case study which we happened to witness was on a 16" gas pipeline. The pipeway area was known as being a clear landslide, about 1500 m long. In this area some years before a transverse crack happened, causing a small gas leak: as a result, a tree was completely frozen nearby the leak. Our study started by reproducing in the laboratory the stress conditions on a piece of the same steel of the pipe, introducing as a media the soil and water found in the position where the pipeline was laid. This area was also studied by geologists, who ascertained the presence of a particular shape of the soil rocks such as to maintain raining water for a certain time. In fact, as soon as a rain happened, water was springing out from the soil.
This water, due to the specific sediment existing in these rocks, was sparkling water (presence of Carbon Dioxide). When the specimen in the laboratory was used together with this type of electrolyte, the cracks were perfectly reproduced.

The second step was to examine the entire hill along the pipeline in order to localise possible areas where the coating was damaged and the metal, due to the shield effect, was not properly protected by the CP current so that its pH could have been quite low.
The excavations, made in the positions accurately chosen, showed the presence of numerous cracks, some of them half the thickness of the pipe wall.
A further study was made by comparing the results of an intelligent PIG inspection along this section with the real existing cracks still in their position (before the complete excavations).
It is quite interesting to notice that the final results of the intelligent PIG did not signal the presence of the cracks. This was due to the fact that the Data resulting from the Intelligent PIG inspection were normally depurated via software from the "**background noise**" ; this fact hided the small mechanical faults.
We asked for the ROUGH DATA recorded by the intelligent PIG and verified that these small cracks were hidden due to the software elaboration. They were in fact visible in the raw data: a slight difference could be noticed between the signal of the crack and other small mechanical defects.

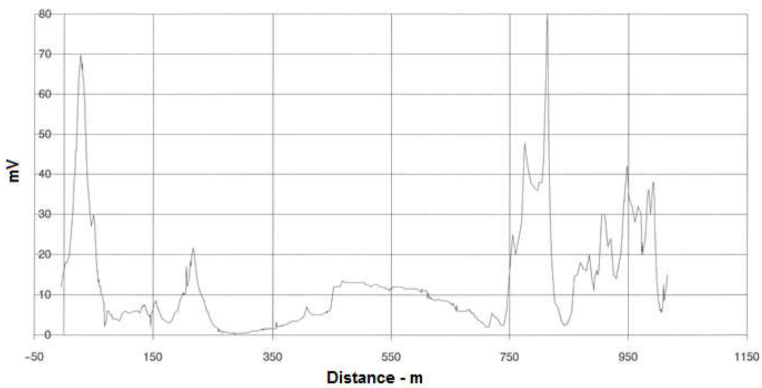



**Fig. 3 – Results of Transverse Gradients Technique along the landslide hill**

### 2.5. – Poor/very poor coating insulation

This is a rather quick method through which no specific faults are found, but the C.P. currents required by different sections of the pipe can be measured from above soil, without contacting the pipeline. It is a relatively recent, quite low cost technique, which allows a quick localization of sections having the poorest coating conditions. Once these sections have been identified, other techniques (such as the transverse gradients) can be applied on them to precisely locate coating faults. Typically, the distance between various measurements is 500 m, so that in a few days many km of pipelines can be covered.
Some interesting statistics were elaborated by analysing the results of more than 6.000 km of surveys performed. Each coating type has been characterized by its "Reference Attenuation Value", in mdB/m$^2$.

| TYPE OF COATING | Reference Attenuation Value (mdB/m$^2$) |
|---|---|
| **Bitumen** | 3,68 |
| **Cold appllied Tapes** | 2,68 |
| **Bitumen + Tapes** | 2,32 |
| **Two Layers PE** | 0,83 |
| **Three Layers PE** | 0,64 |

**Table 2 – Reference Attenuation Values for various types of coatings**

The graph of Attenuation Values resulting along the complete pipeline will highlight the sections having its worst conditions. According to our experience, in those sections where the measured value exceeds the "Reference Value", a more accurate location of coating faults must be performed by using the "Transverse Gradients Technique". The ECA technique allows then to better define the worst conditions of the coating along an entire pipeline in an economic and quick way and to invest most of the energies to those areas which deserve more attention.

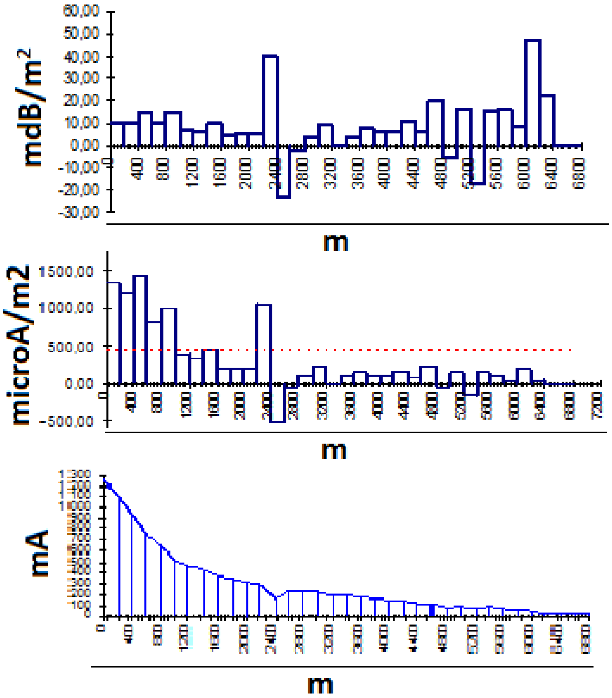



**Fig. 4 – Typical results with the Electromagnetic Current Attenuation Method**

As the graph in Fig. 4 shows, in this case only a few measurements (1-2 hours work) were needed to localize the worst conditions of the coating along ca 7,0 km of pipeline.

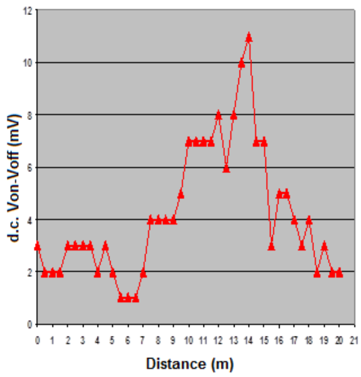
## 2.6. – Presence of a.c. interference

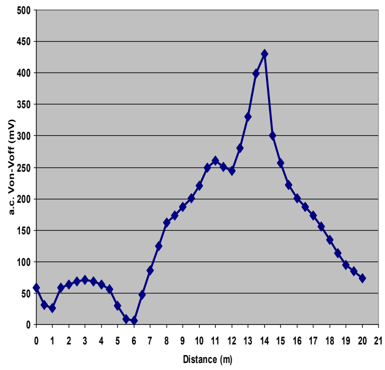
When a pipeline is influenced by a.c. voltage, its coating must be controlled in order to find out if small/very small coating faults are present in the area interfered and verify if any a.c. corrosion phenomenon is taking place.
An important experimental phase was devoted to a.c. corrosion in Riyadh (Saudi Arabia), where ISPROMA realised in 2005 a Training and Research Centre for Cathodic Protection. This field was used to reproduce quite all the possible coating fault cases, including the ones which could be corroded by a.c. and quite all the situation which can be found on a real pipeline (shorted casings, different pipe burying depths, a.c. and d.c. interferences etc.).
In order to reproduce the conditions for a.c. corrosion, a specific AC Feeder was installed and used for two main scopes:

a) To reproduce a.c. interference on the pipelines in such a way that corrosion could occur on the Coupons (these were prepared and installed for this scope);
b) To locate the worst conditions of a.c. interference that is where, within the various reproduced faults (ad hoc coupons), the corrosion could be the worst.

The various measurements and analyses allowed us to conclude the following:
When corrosion is taking place on a pipeline, a survey made with a.c. current gives much better and precise results than the traditional d.c. methods.

This can easily be explained having a look at Table 1 – Item : a corroding surface has a much lower Rp, then a much lower electrical impedance.
The measurements performed along the section of pipeline where corroding coupons were present clearly demonstrated that the IR Drops measured on these with a.c. were much greater than the ones measured with d.c. current.



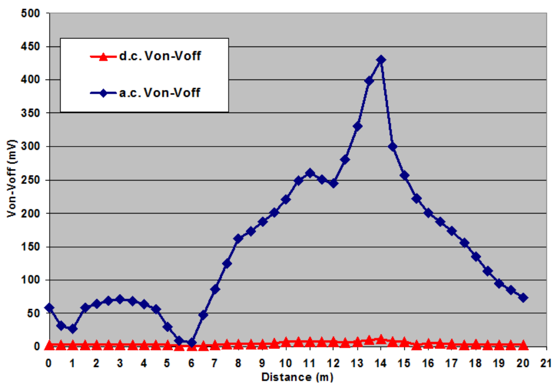



**Fig. 5 - Transverse Gradients with a.c. and d.c. (Von-Voff)**

It is quite clear that the IR drops measured with a.c. current is much greater than the ones measured with d.c. current. The exact position of the coupons can very well be distinguished at m 8, 11 and 14 where they were installed.
In this case, the a.c. current was artificially injected into the Section 3 of the network in the Training Centre. This result has been further verified and confirmed in the real field, on a gas pipeline influenced by a.c. interference. The following Figure illustrates the results.

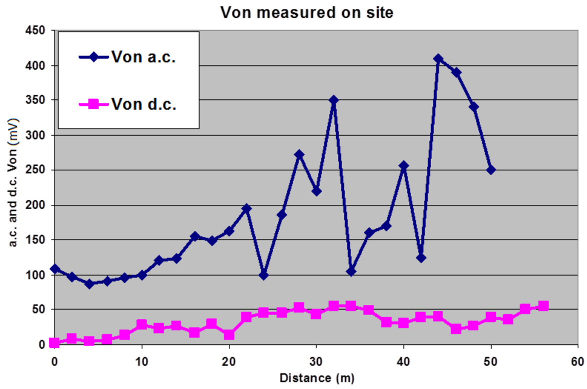



**Fig. 6 - Transverse Gradients in a real pipeline interfered by an Electricity Power line**

## 3 – GPS Mapping System

The use of a geo-positioning systems, such as LK2 *GPSforPipe* to precisely locate, trace and archive any particular point along a pipeline during its laying phase, in connection with a Geographical Information System - GIS, will allow to have, from the very beginning, a clear picture of all points of interest especially those peculiar for the Integrity of Pipelines. This application also serves to pinpoint in a similar way the poles of public lightings, e.g. after their examination from the corrosion point of view. Any specific spot will be pin-pointed on GIS Maps with annex photographs and relevant significant data (repairs, substitutions, special pieces etc.).
The System is composed by the following 3 Key elements:


**Fig 5 – The S8 GNSS GPS Equipment with accurate and quick satellite fixing**

**Fig. 7 - A Tablet with the specific application, including a camera and a Bar Code Reader**

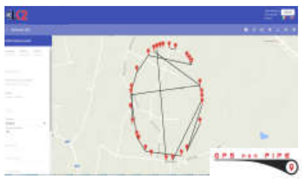


**Fig. 8 - A Management Solution based on the WEB Platform: [www.gpsforpipe.com](http://www.gpsforpipe.com)**

A rugged Tablet, suitable for utilization in the field even in hard working conditions, allows quickly and easily collecting and managing all the information needed. Not only the geospatial coordinates are detected (in a simple and guided way, in order to avoid human mistakes), but also a wide number of details can be selected and handled: a **geodatabase is created to store, collect and visualize the physical location of pipelines, casings, wells and any significant spatial data**. Non-spatial information such as leases, date of installation and pipe material or equipment can be added to attribute data, either by reading its bar code on a label, or adding them manually later on.

This is an extremely useful tool to better understand when and, above all, **exactly where** pipelines need maintenance or repair. Definition queries can be set up to differentiate pipelines with specific attribute data and other useful analytic information. For example, a comparison is possible among various pipelines according to their type in specific locations, or in relationship with certain type of damages (such as particular coating damages, coating faults, disbondment of coatings, presence of shrinking sleeves etc.) along the pipe including the lot number / product used during pipeline laying phase.

After years from pipeline laying, operators will be able to easily track any point on them, thanks to a '*guide-me-there*' tool, which gives directions to go exactly on the selected position, with a centimetric precision, tracing with no mistake the key elements, even years after laying: a technical solution which allows costs reduction as well as saving time and money, limiting the environmental impact of the operation when an intervention on the pipeline is unavoidable. A similar application, named Gecomet®, has been developed in the field of corrosion monitoring of lamppost: all the metallic poles are identified by GPS coordinates and graphically represented on google maps (or similar web background). All the measured parameters are collected with a portable device (tablet) and sent via GSM to a Central Server Database. Each lamppost is featured on maps with a different colour according to the corrosion damage level.

## 4 – Conclusions

Some important lessons have been learned in the past years from the results of the various techniques adopted to verify the conditions of Integrity of buried pipelines, especially those transporting gas and oil. We would like, as a conclusion, to highlight the most meaningful ones.

Our large experience in the field by using quite all the types of survey's techniques, allows us to state the following: where unpiggable pipelines exist, the only viable option to verify their integrity from the corrosion point of view is the use of Specialised Electrical Surveys.

- Pipelines installed in the 60$^{ies}$-70$^{ies}$, having a poor/very poor insulation condition can be profitably verified by performing specialized electrical surveys; the ECA method allows to quickly assess the status of coating conditions along the whole pipeline in a very short time;
- Electrical Surveys can be used as a precious tool to make a priority ranking for unpiggable pipelines in order to adapt and make them piggable;
- On similar pipelines which are not piggable (same coating type, same year of installation, same type of soil etc.), these electrical surveys can be used to compare the results in parallel with the ones obtained on similar pipelines which have been pigged, gaining important knowledge about its integrity.

Mainly for pipelines which cannot be inspected, such as those having:

- too short radius bends;
- not full bore valves;
- different pipeline diameters;
- insufficient gas flow for pig inspection,

Specialised Electrical Surveys are an exceptional and fundamental tool devoted to maintain Pipeline Integrity; they specifically allow to:

- thoroughly assess coating conditions just after the pipe-laying phase of new pipelines improving the overall quality of coating insulation thus adopting a quality control of operators;
- localise possible mechanical damages occurred on the pipe either in the laying phase or during operation;
- localize areas where the installation of Test Points is mostly recommended (e.g. the installation of Test Point which are meaningful – the so-called "Characteristic or Selected Test Points" - of the CP System functionality in case of "Remote Control");
- make general analyses and statistics;
- compare the coating and cathodic protection conditions among different pipelines having the same type of coating or between different sections of the same pipeline.

The results of Specialised Electrical Surveys can generally be considered a "PERMANENT FOOTPRINT" of the conditions of a pipeline coating, then it is a long-term investment.

The results can in fact be used for the entire lifetime of a pipeline unless specific circumstances take place such as:

- third party intervention on the pipeline route;
- new construction work on the pipeline;
- new parallelism with electrified railways or High Voltage electricity power lines.

In these cases, a new Survey must be performed in the sections interested so that any new faults or damages or problems can be immediately discovered by simply comparing existing survey results with the new ones.

## BIBLIOGRAPHY

[1] – IGU - International Gas Union – June,1994 – Milan – Fault location on pipeline Coatings

[2] – CEOCOR – Guidelines for measurement techniques in cathodic protection (1997)

[3] – EN - TS 15280, "Evaluation of a.c. corrosion likelihood of buried pipelines - Application to cathodically protected pipelines" – 2006

[4] – M. Büchler, F. Stalder, H.-G. Schöneich, A new electrochemical of a.c. corrosion, CEOCOR Conference, Dresden, June 2004

[5] – AC Corrosion on Cathodically Protected Pipelines Guidelines for risk assessment and mitigation measures – CEOCOR - Dec. 2001

[6] – R. Cigna, O. Fumei, Training centre for cathodic protection, CEOCOR Conference, Dresden, June 2004

[7] – O. Fumei, R. Cigna, L. Di Biase, M. Abutaleb, Research & Training Centre for Corrosion and Cathodic Protection, CEOCOR Conference, Mondorf Les Bains, Luxembourg, June 2006

[8] - Effect of Cathodic Protection Levels and defect geometry on the a.c. corrosion on pipelines – CEOCOR Conference 2007 MALAGA, SPAIN
M. Büchler, C.-H. Voûte, and H.-G. Schöneich*

[9] – L. Di Biase, R. Cigna, O. Fumei,- A new technique for locating coating faults on buried metallic pipelines –II World Congress on Corrosion in the Military – Naples, Sept. 2007

[10] – CIGRE Technical Brochure N° 95 published in 1995 "Guide on the Influence of High Voltage A.C. Power Systems on Metallic Pipelines"

[11] – CIGRE - A.C. Corrosion on Metallic Pipelines due to Interference from A.C. Power Lines – Phenomena, Modelling and Countermeasures - 2006

[12] – AC induced corrosion on onshore pipelines, a case history. Roger Ellis Shell UK – 2001

[13] – Proof-of-Concept Development of Disbonded Coating Cathodic Protection Monitoring Coupon, 20-9216 Oliver C. Moghissi, Darrell S. Dunn, Narasi Sridhar – 2000

[14] – Predicting Pipeline Corrosion under Disbonded Coatings with the Influence of Slow Flow Underneath - Fengmei Song* and Narasi Sridhar Mechanical and Materials Engineering Southwest Research Institute - San Antonio, TX U.S.A. – 2008