A.C. CORROSION, A MINOR CORROSION PROBLEM WITHIN MANY OTHERS FOR MAINTAINING PIPELINE INTEGRITY

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ABSTRACT

Maintaining the integrity of pipelines, especially Gas and Oil ones, is a must for owners and operators of pipeline networks.

Safety, economical, strategic and legal reasons lead Gas & Oil Operators to continuously improve their Integrity Management System.

The capability of localizing and predicting possible pipeline failures is nowadays much more feasible and reliable than in previous decades, it is just a matter of managing the risk by using proper investments and human resources in the proper way.

Methods for Integrity Assessment are nowadays well known:

- Pressure Tests;
- Inline Inspections;
- Predictive assessment (e.g. the “Direct Assessment Method”).

It is well known that, even if Smart Pigs are able to carefully localize corrosions, the simple fact that they can only work once the corrosion damage has already happened, make the method a little bit “a post-mortem” intervention. And, what about the non-piggable pipelines ?

It is much wiser, of course, to localize, repair and take the remedial actions to avoid the insurgency of corrosions on buried pipelines before their appearance, but this is a little bit more difficult task.

Based on many years of field experiences and specific tests, this paper tries to approach the difficult task of managing the risk of corrosion on buried pipelines, in a preventative way, with a particular regard to a.c. corrosion, a “small” problem, but susceptible of high consequences, localizing it’s insurgency in a very early stage.

Keywords: coating faults, a.c. corrosion, intelligent pig

FOREWORD

A pipeline is usually designed to withstand the operational stresses associated with the transportation of the product; it must also be protected as far as possible from damages and degradation during its operational life.
It is, however, generally acknowledged that such preventative measures do not provide complete protection against post-construction damages, which are most commonly due to:
- third-party interference;
- corrosion;
- soil movement;
- material and construction defects.

Damages due to third-party interference is the most common service problem and is usually the result of earth-moving operations such as plowing, digging, and boring in close proximity of the pipeline causing damages such as dents, gouges, scratches.
Corrosion is an electrochemical process occurring at the pipe wall in contact with the surrounding environment which eventually causes a reduction in wall thickness.
The primary form of corrosion protection is, of course, the application of an external coating combined with a proper cathodic protection system. Experience shows, however, that corrosion may occur where the coating is disbonded, preventing cathodic protection current from reaching the steel exposed to the environment. Another risk, usually under-evaluated, is the one associated with small/very small coating defects which may give rise to a.c. corrosion, when a.c. interference is present.
The majority of pipeline operators, have adopted a pipeline-protection and condition-monitoring strategy aimed at ensuring the fitness-for-purpose of its gas-transmission network in the most safe and cost-effective way.
The condition-monitoring tools commonly used are:
- cathodic protection monitoring;
- electrical surveys;
- visual inspections by walking along and flying over the pipeline;
- control of soil settlement;
- excavation for coating inspections;
- metallurgical investigation for pipe steel and weld-metal decay;
- intelligent pig inspections.

All of these techniques, integrated in a unique plan and reviewed by expert staff within the company, should cope with the majority of risk on operating pipelines.
Nevertheless, none of the above said techniques is able to highlight the risk of a.c. corrosion.
In order to ascertain if an a.c. corrosion risk exist on a pipeline, a specific approach to this problem must be adopted:
- is a.c. corrosion a risk for my pipelines ?
- how can it be verified ?
- how can it be avoided ?

The present paper is mainly focused on the peculiar aspect of a.c. corrosion and its prevention, by following some consequent steps:

a) mechanical and electrochemical characterisation of the faults prone to a.c. corrosion;
b) localisation of sections in the network where a.c. interference is present;
c) localisation of small/very small coating faults and their a.c. corrosion risk;
d) reduction of a.c. induced voltage to safety values.

1 – Characterisation of coating faults at risk of a.c. corrosion

If a pipeline network is to be verified about the risk of a.c. corrosion, a census is necessary to verify which of the pipelines and which section of them may be at risk.
A general choice can be made according to the coating type susceptibility to a.c. corrosion.
A general assessment can be made by having a look to small thickness coatings (e.g. cold applied tapes, polyurethane coatings), especially in rocky soils.
It can be very useful to use some statistical data taken from previous experiences.
One of the main European Gas Company has performed some years ago an intensive program for verifying the coating conditions on its new laid pipelines, obtaining the following results:

a) The number and types of faults which can be detected is tied to the type of coating, the pipe diameter and the soil characteristics;

b) Most of the coating faults have been found on small diameter pipelines, due to their smaller coating thickness; for this reason a decision process has been derived in order to increase the coating thickness for small diameter pipelines (< 16” diameter);

c) Statistical analysis of the results of the surveys performed on more than 2.500 km of pipelines showed that a mean value of one coating fault every 1400 m has been found on modern coatings (three layers polyethylene coating);

d) Other statistical data of interest are as follows:
    - About 50% of the faults were found on rocky soils;
    - Quite 50% of the faults were due to backfilling operations during pipe lying;
    - More than 57% of the faults were found on the upper surface of the pipe (9 o'clock - 3 o'clock position), confirming the results of the previous point:
    - More than 70% of the damages were holes or tearings on the coating caused ***by the action of small stones which had perforated the coating;***
    - Numerically, the majority of coating damages were found on the principal coating, but percentually the faults were more frequent on special fittings and bends, generally coated with thermosetting resin.

The following figure illustrates the mechanical, general characterisation of main coating faults which can be found on a buried pipeline.

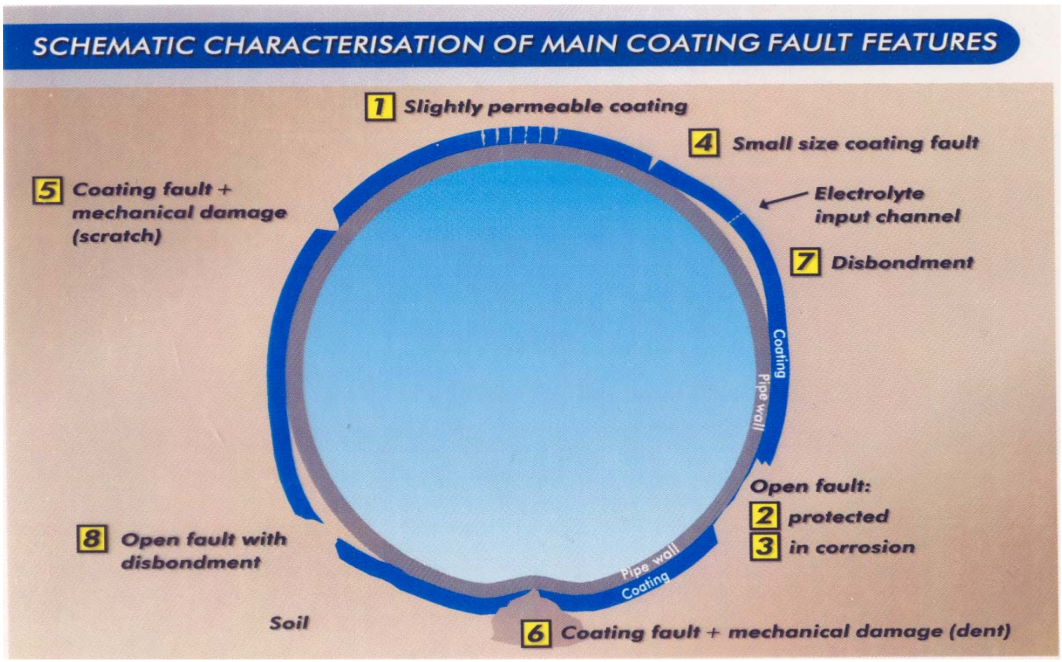

Fig. 1 – Mechanical characterisation of coating fault features

In a very general way, the corresponding electrochemical characterisation of these coating fault features can be represented as follows:

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 = Polarisation Resistance -** **Cdl = Capacitance of the Double Lwyer –** **Ri = IR drop**

Table 1 – Comparison of electrochemical characteristics among various types of coating fault on buried, cathodically protected pipelines

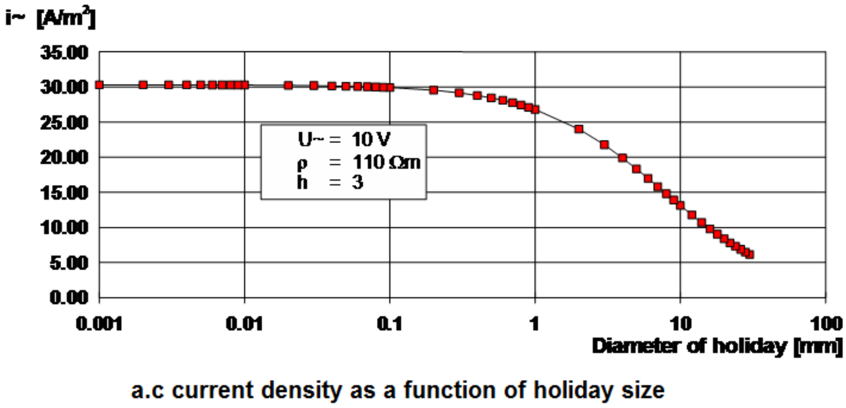

Figure 2 – AC current density as a function of the holiday size [5]

When a.c. corrosion is a risk, the a.c. current density exchanged between the bare metal of a coating fault and the soil is considerably higher, especially on small/very small coating faults. After an "initiation time", the so-called "spread resistance" of a coating fault whose bare metal is prone to a.c. corrosion will dramatically decrease so that both d.c. and a.c. currents will considerably increase.

2 - Features that intelligent pig cannot detect

Just a few types of corrosion may not be easily discovered by intelligent pigs. These can be restricted to the following:

- Alternating current corrosion
- Cracks due to Stress Corrosion

Corrosions due to alternating current are characterized by the following features:

- Small/very small coating defects;
- Concentrated and very small lack of metal, at least in the initial phases;
- Cathodic protection apparently working properly, with values within the limits foreseen by the international standards (e.g. V_{off} more negative than -0,85 Volt)

Real field tests have demonstrated that in these cases, as the missing metallic material percentage of the total thickness is very small, intelligent pig cannot distinguish a real corrosion due to a.c. from the general noise which is usually (and voluntarily) not taken into consideration by the software elaborating the data. These softwares are quite powerful and sophisticated, but a base limit must be fixed to cut out the basic "noise" from the signals elaboration.
Cracks due to Stress Corrosion in a pipeline are the result of peculiar and often very localized coating conditions (tent effect, the presence of non-adhering coating which hinders the current to reach the bare metal), the presence of mechanical stress and particular environmental conditions (i.e. presence of CO_2).
According to the direction of the mechanical stress, cracks can grow either longitudinally or transversally to the axis of the pipeline.
These cracks, especially the longitudinal ones, cannot be distinguished by performing a "normal" intelligent pig inspection. In fact, the sensors of intelligent pigs are usually

placed longitudinally to the axis of the pipe and this peculiar disposition hinders to detect longitudinal variations of the magnetic field.
Special intelligent pigs can be used, which are designed for detecting cracks, especially the longitudinal ones, having the magnets detecting circumferential variations of the magnetic field around the pipe.

3 – Detection of small coating faults along a pipeline

In the presence of small/very small coating faults, a higher concentration of a.c. current occurs. This fact helps a lot in finding these faults at a very early stage, just after the pipe laying, if proper coating fault surveys are performed.
Our studies in a Training Field some years ago allowed to verify the following:
N. 3 a.c. corrosion coupons (1 cm^2) were installed at 3 m from each other along a cathodically protected pipeline, at the distances of 8, 11 and 14 m.

Fig. 3 – a.c. corrosion coupon

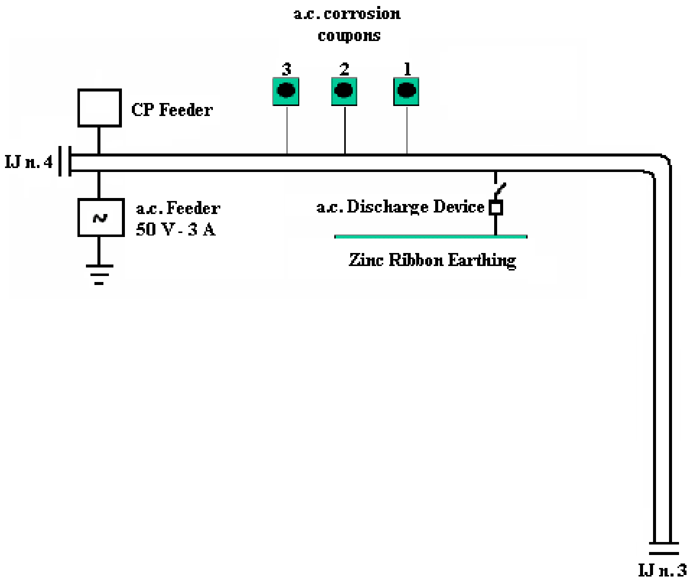

Fig. 4 – Installation of a.c. corrosion coupons

This section of pipeline could be either fed by a d.c. Cathodic Protection Feeder and from an a.c. Generator.
This Section was fed with 3 A d.c. current , then with 3 A with a.c. current. The transverse gradients gave rise to the following results:

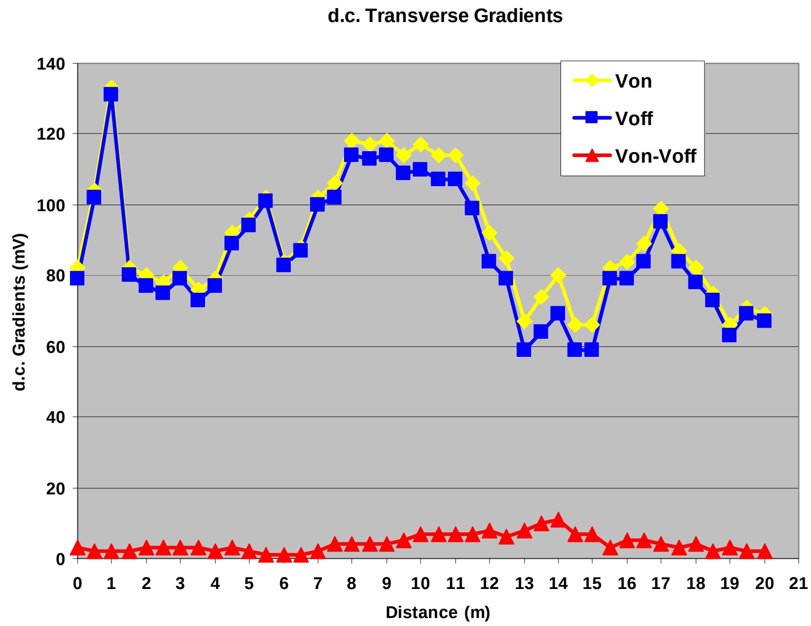

Fig. 5 – d.c. transverse gradients

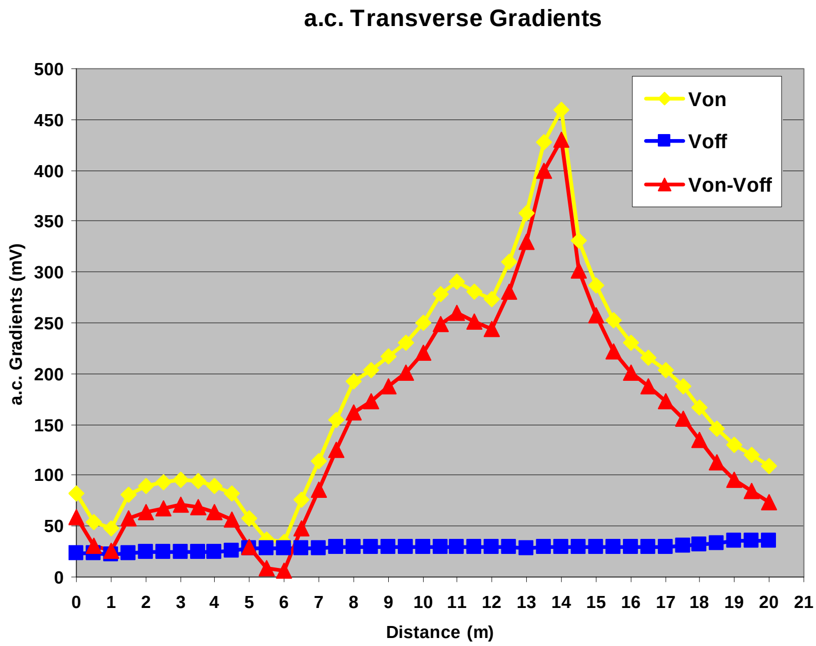

Fig. 6 – a.c. Transverse Gradients

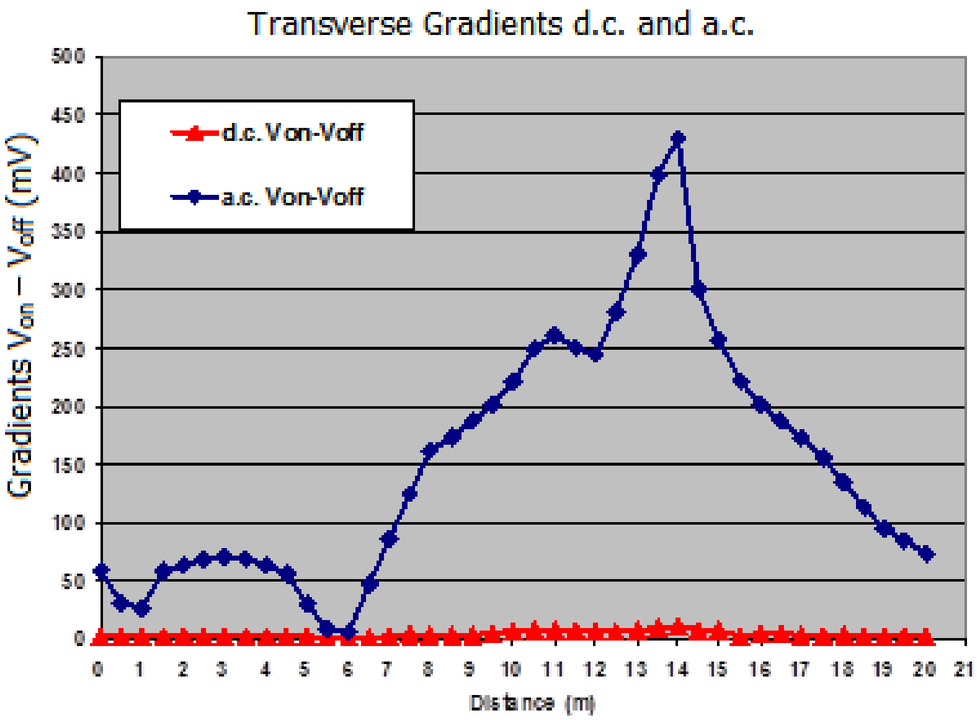

Fig. 7 – d.c. and a.c. Transverse Gradients

Superposing the results of the two graphs, it is quite clear that the IR drops measured with a.c. current (blue graph) shows values much higher (more than 10 times greater) than the ones measured with d.c. current (red graph).
The exact position of the coupons can much clearly be distinguished at m 8, 11 and 14 where they have been installed, when using an a.c. signal.

This type of measurements were performed in a real field, in Italy, obtaining the following results:

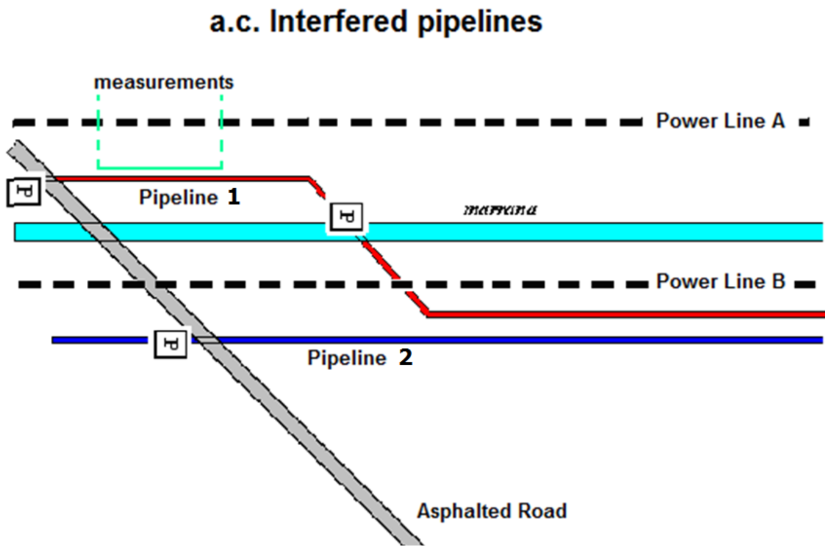

Fig. 8 – Pipeline interfered by a.c.

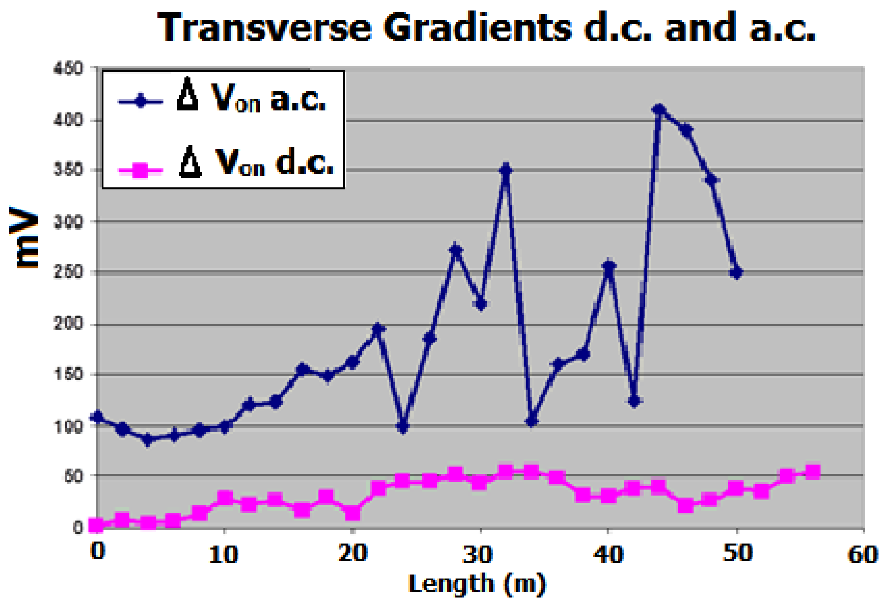

Fig. 9 – Transverse Gradients d.c. and a.c. – Real Field

Since in the Transverse Gradient Technique the IR drops are proportional to the current flowing in the soil, it is evident that a certain amount of a.c. current is being discharged through the pipeline. It is also evident that there are coating faults in the area investigated.

From these results, two main points of interest can be foreseen when the location of coating faults is performed on pipeline by using an a.c. signal:

- The response in terms of IR drops is much greater if compared to d.c. signals;

- a.c. interfered pipelines where small coating faults could be affected by huge a.c. current density, thus exposing them to a.c. corrosion, can be much easier localised.

The main advantages of this method are:

- clearer identification of coating faults;
- identification of potential corrosion conditions before corrosion problems occur.

4 – A general approach for preventing a.c. corrosion

In order to make a priority list, by using proper maps it is possible to localize the parallelisms between pipelines and electricity power lines, or train rails fed by a.c. where more attention should be paid. Once chosen these sections, an a.c. Voltage measurement $\mathbf{V_{on}}$ campaign is to be organised to localise which of the pipelines has a greater a.c. induced voltage. As a.c. interference may be variable, according to the charge on the electricity lines (or lines feeding a.c. fed trains), it would be wiser to use recorder instrumentation. A coating fault location is to be made on these sections by using the A.C.V.G. Technique (Alternating Current Voltage Gradient). In principle, there is no need to feed the pipeline with a.c. current, as the a.c. interference is already present. The highest peaks of a.c. Transverse Gradients and their shape will highlight the position of coating faults at most risk of a.c. corrosion. Some excavations in the more meaningful points will confirm the correctness and the reliability of the results.

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