TECHNICAL PRESENTATION

PIPELINE LEAKAGE and SHOCK DETECTION SYSTEM
L D S

PROCO
Process + Control

11, Avenue Philippe Auguste
75011 - PARIS
Tel : + 33 1 53 27 19 19
Fax : + 33 1 53 27 19 10
E-mail : proco@proco-france.com

April 2003

TABLE OF CONTENTS

Introduction

This **Technical Presentation**, made in cooperation with Metravib RDS, gives detailed **system specification**, **various application fields** as well **actual operational** and **monitored reference results.**

The LDS **L**eak and Impact / Shock **D**etection **S**ystem can be **installed on existing or new, above ground, underground pipelines and subsea pipelines.**

- It can **detec**t leakages and shocks on **any liquid or gas pipelines**, of what ever media.
- In installing approx every 15 km one sensor on a pipeline, the leakage can be detected with a **precision** in the area of **approx 100 m** along the pipeline, **holes/cracks of minimum 5 mm** openings and all in real-time purveyance from one - or for operator conveniences several - control rooms.
- A **reference** pipeline LDS **detection system** of approx. **450 km**, carrying **ethylene** in France, is now for two years in **successful industrial operation** in the **TotalFinaElf Group** at Atochem.

Based on this important reference it can clearly be stated that this **system is fully proven and good for industrial and reliable operation**. TotalFinaElf will make a principle decision -and publications- to install this LDS system in a somewhat regular way in the group throughout the world.

The Pipeline LDS Leakage and Shock Detection System is based on:

- **acoustic detection by specific sensors installed on the pipeline**
- **leakage and/or shock location detection by GPS system by time difference**
- **a specifically developed computer system analysing the noise as well as the time and thereby indicating the location and the size of the leakage and/or shock and its hole/crack.**

The main advantages and merits of this acoustic detection system are summarized hereunder :

- Impact leakage or shock detection and localization
- Direct detection
- Possible operation with different fluids (any gas, any liquid)
- Long range detection and localization capabilities
  (up to 50 Km between two sensors in some cases)
- Excellent accuracy for leakage localization
- Very quick, real time detection
- Detection of small diameter leakages (minimum 5 mm)
- Easy installation of the leakage detection system
- Use of anti explosion certified sensors
- Low maintenance.

In the present Technical Presentation are described various alternatives of equipment and/or system parts.

This new and efficient detection system has been proven to be very reliable, particularly in the Total Fina Elf Group. An approx. 450 km ethylene pipeline (installed in France) is successfully secured for since the beginning of 2002.

I. TYPICAL FUNCTIONAL DESCRIPTION AND SPECIFICATION FOR LEAK AND SHOCK DETECTION SYSTEM

I.1 – GENERAL PRESENTATION OF THE SYSTEM

This new and proven LDS detection system takes advantage of the experiences obtained in various leakage localization detection activities (in critical areas, using acoustic techniques) and in the classified defence sector such as: shooting detection, noise identification techniques, adaptive learning methods and new signal processing methods.

The TotalFinaElf Group is successfully operating this detection system on a 450 km ethylene pipeline in France. It is considered fully viable, tested and proven in the chemical industrial operation environment.

The leakage and shock detection service is operating on-line and in real time to detect shocks or leakages by permanent pipeline monitoring.

The best strategy for any pipeline operator is to either prevent or limit leaks before they happen. Leak prevention will help to avoid:

- production loss,
- costly pollution clean up,
- severe accident and
- unfavourable media exposure.

Leak detection on fuel, gas and chemical pipelines is now considered as a serious issue by pipeline or pipe network operators.

Loss of production, pollution cost and risk of severe environmental accidents caused by leakages are risks absolutely to be avoided by oil, gas and chemical pipeline operators.

Water distribution operators are mainly concerned by lost of production caused by leak.
The strategy to avoid leaks varies from one pipeline operator to another depending on the fluid transported, the type of pipeline and the environment. In some cases all appropriate actions are taken to avoid leaks but it is impossible to achieve a zero risk !

The risk of leaks is increasing as operators try to extend existing pipeline operation time and installed new pipelines in more and more severe environmental conditions (Deep and very deep water, Arctic area).

Conventional techniques such as pressure/flow measurements are limited in sensitivity, detection time, localization ability and fluid type and therefore not efficient.

The presented LDS acoustic system provides the necessary combination of range, sensitivity, detection time and low false-alarm rates.

The LDS shock detection and localization function is unique because it gives the operator a first alarm which may prevent a future leak. Impacts from excavators, fire guns, drill machines, or other means can be detected easily.

This LDS system has been intensively tested on water distribution networks, oil & gas pipelines and pipelines for chemical products, all either liquid or gaseous. This leakage detection system is configured with either :

- hydrophone sensors which are intrusive to the pipeline (sensor mounting on a T-branch on the pipeline),
- or with accelerometer sensors which are not intrusive to the pipeline (sensor mounting outside on the pipeline).

The sensors and the related instruments are packaged for long-term low maintenance operation. The sensor sensibility can be improved with intrusive acoustic pressure sensors.

I.2 – PRINCIPLE FUNCTIONING OF THE SYSTEM

Any leakages on pipelines generate sources of noise, its amplitude and frequency spectrum depending on the fluid type, the leakage flow size and geometry.

Leakage or shock noise propagates and travels in the pipeline for a very long distance. The noise attenuation with length depends on the fluid conveyed, the pipeline type and geometry, its environment and the frequency spectrum of the leakage itself.

At any point of the pipeline, the leakage or shock noise creates a pressure fluctuation, which can be measured by specific acoustic and vibration sensors installed on the pipeline.

With an appropriate data processing technique, the noise radiated is extracted from the global ambient noise in the pipeline.

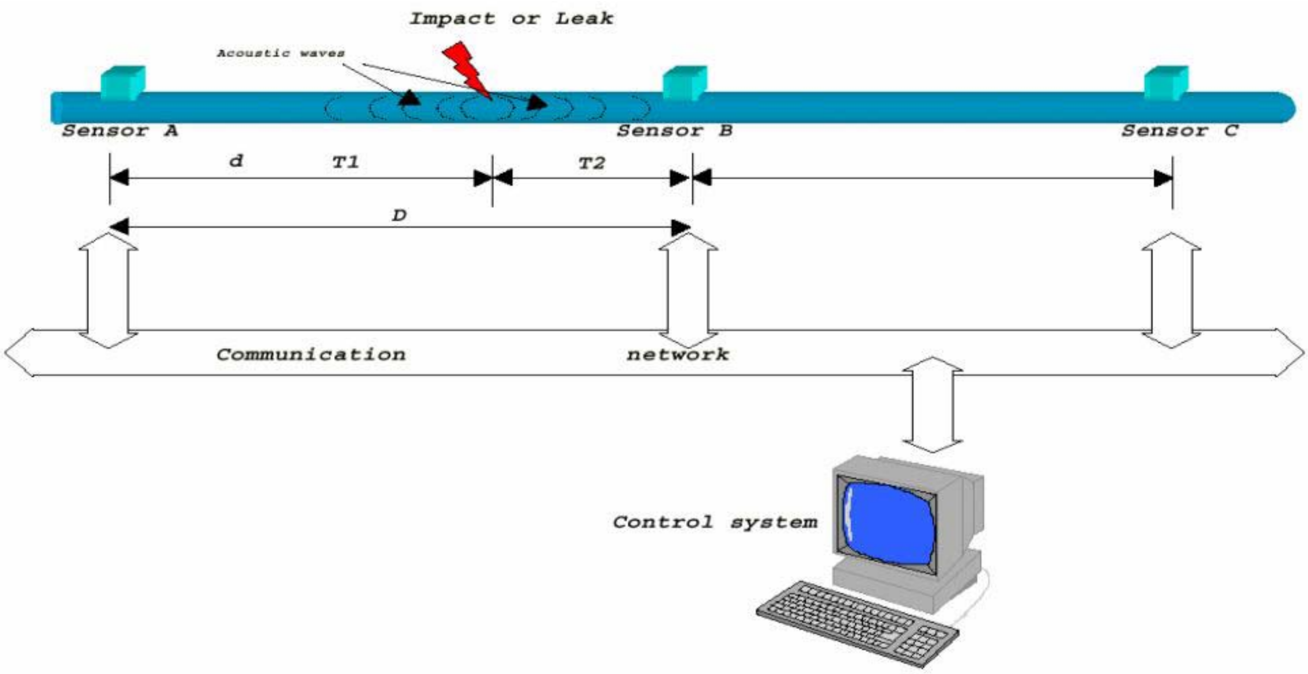
Programmed analyses are applied to the signal and leakage alarms as they are received by the Central Supervisory Control Room and thereby activated.

Accurate leakage or shock localization is possible by installing sensors all along the pipeline and to be monitored in a continue, on-line and real time mode.

By determining the velocity of sound propagating and travelling inside the pipeline and using the exact distance between the sensors, the leakage position can be accurately computed with the analytic following formula:

$$d = \frac{D - Vt}{2}$$

with : d : distance of noise from sensor
D: overall distance between the 2 close sensors
V: sound velocity inside the pipeline
t: transit time difference for noise to reach sensors = T2-T1.



Several sensors must be installed on the pipeline to monitor a long length of pipeline. Typically, the distance between sensors is around 15 km.

The leakage or shock detection and its localization principle are identical. An unexpected event such as hammer, anchor, excavator, drill or fire gun shock on the pipeline, explosion or ground movement create an impact source, which radiates in the pipeline. As well as the leakage noise, this transient impact can be remotely detected and located. The shock will be well identified, as it is a very energetic and short pulse. The amplitude and length of this pulse will depend on the type of shock itself.

A shock and a leakage are well distinguishable. The shock is transient. A leakage can occur suddenly but is continuous. Shock can be prior to a leak. Shock detected will give pre-alarm to the operator.

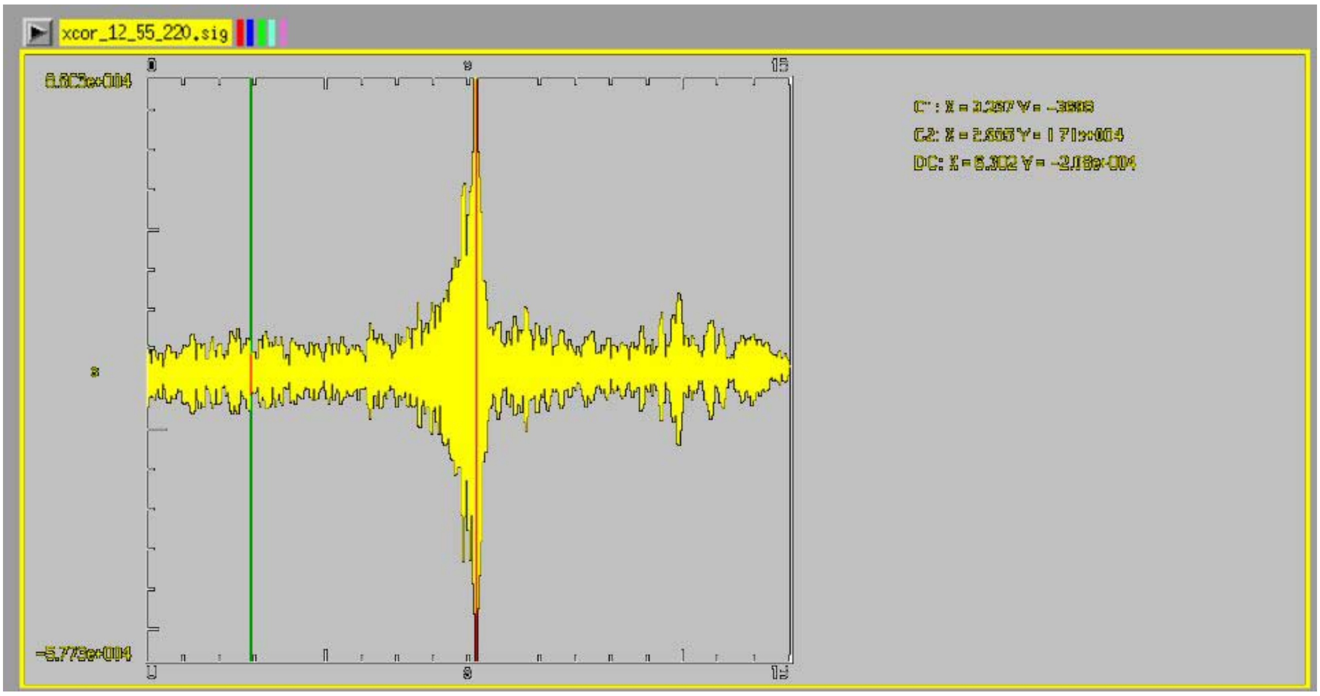
In order to localise leak and shock, the proposed Central Control System will be programmed with input parameters such as accurate distance between sensor, sound speed (measured or calculated).

Once a leak or impact is localised, the operator will dispatch a team to the site at the identified zone in order to protect the zone and repair the pipeline. The given localisation output is the distance d between the leak or the shock and one of the sensors.

The localisation methods employed in the detection system are the acoustic cross-correlations.

After impact or leak detection at one sensor N, the system will store the noise signal measured at N, N+1 and N-1 at the same time (using the GPS for time synchronisation). The noise signal will be transferred to the Central Control System through the communication network.

Then the Central Control System computes the correlation between N and N-1 and between N and N+1 and locates the event. Typical cross-correlation is shown hereunder:



The cross-correlation function is significative when a coherent source of noise (a leak or an impact) is present in the segment. The method is well operating when there is also a non coherent back ground noise such as flow noise. However, when coherent noise such as valve noise or pump noise are present, a specific signal treatment method must be applied. The detection system can be programmed to adopt one of the following signal treatment :

- Real time cross-correlation,
- Frequency filtering,

- Noise substraction,

- Wave selection using two or three sensors closely together.

The Data Collector Panels (DCP) are programmed from the proposed Central Control System through the communication network.

Upon request, via a specific, optional telephone modem, the Central Control Systems well as each DCP can be monitored and programmed from anywhere in the world through the telephone modem and the local communication network. Therefore, the detection system maintenance can be made through the communication network.

The LDS detection system can also be reprogrammed in case of future changes in the pipeline network.

Position of the cross-correlation peak gives directly the location of the event using the analytic formula given above.

Localisation accuracy depends on three factors :

- Accuracy of the speed of sound (which can be measured or calculated),

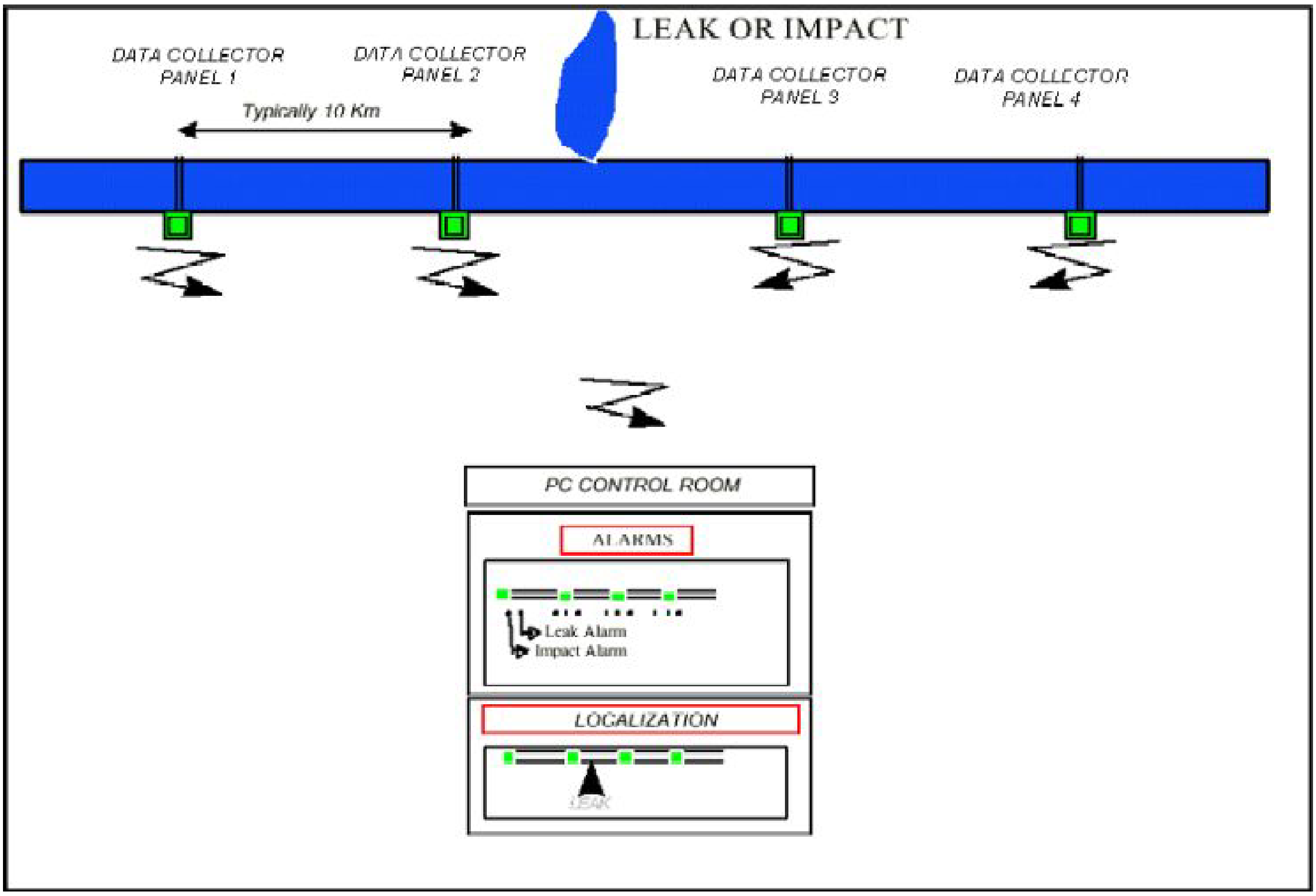
- Accuracy of the linear distance between sensors,

- Accuracy of a 'universal' time inside the detection system by using the satellite GPS (Global Positioning System), of which its use is free of charge.

Typical global accuracy is around 1% of the distance between the sensors. This accuracy can be improved as the system is used by the operator, by increasing accuracy of the speed of sound.

I.3 – SYSTEM DESCRIPTION

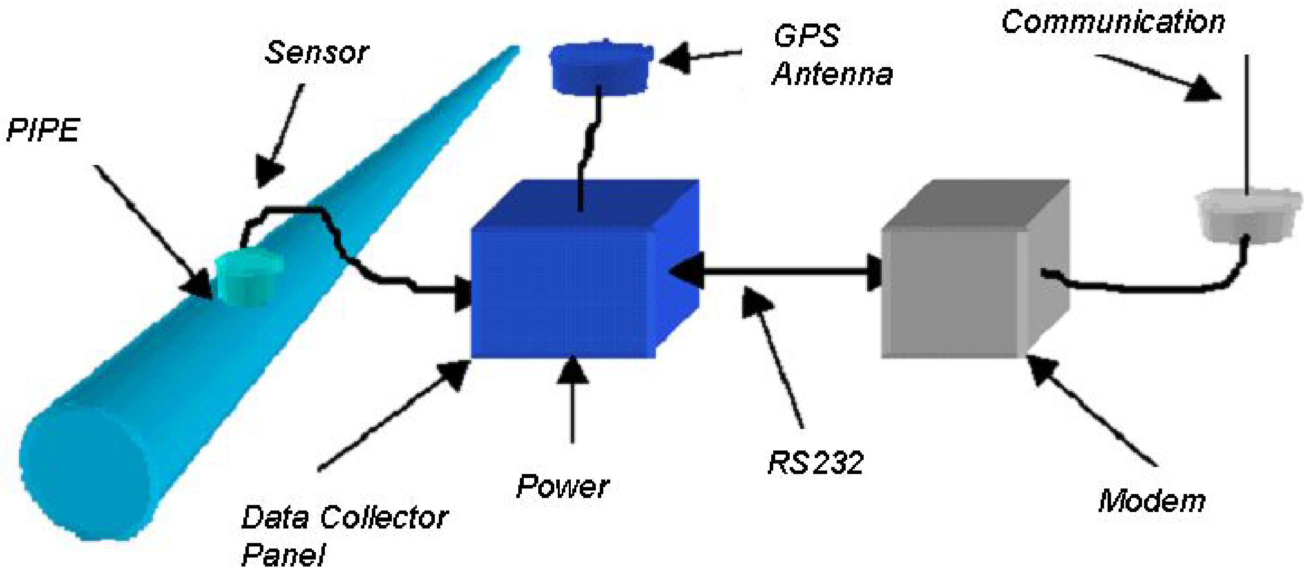
A schematic description of the acoustic leakage detection system is shown in the block diagram below.



The system consists of a defined number of Data Collector Panels directly installed on the pipeline and a Central Supervisory System installed in a control room displaying the results. Minimum leakage size to be detected, energy or telecommunication network available, internal noise source location and economics are some of the parameters taken into account to design the leakage detection system.

Typical arrangement of the

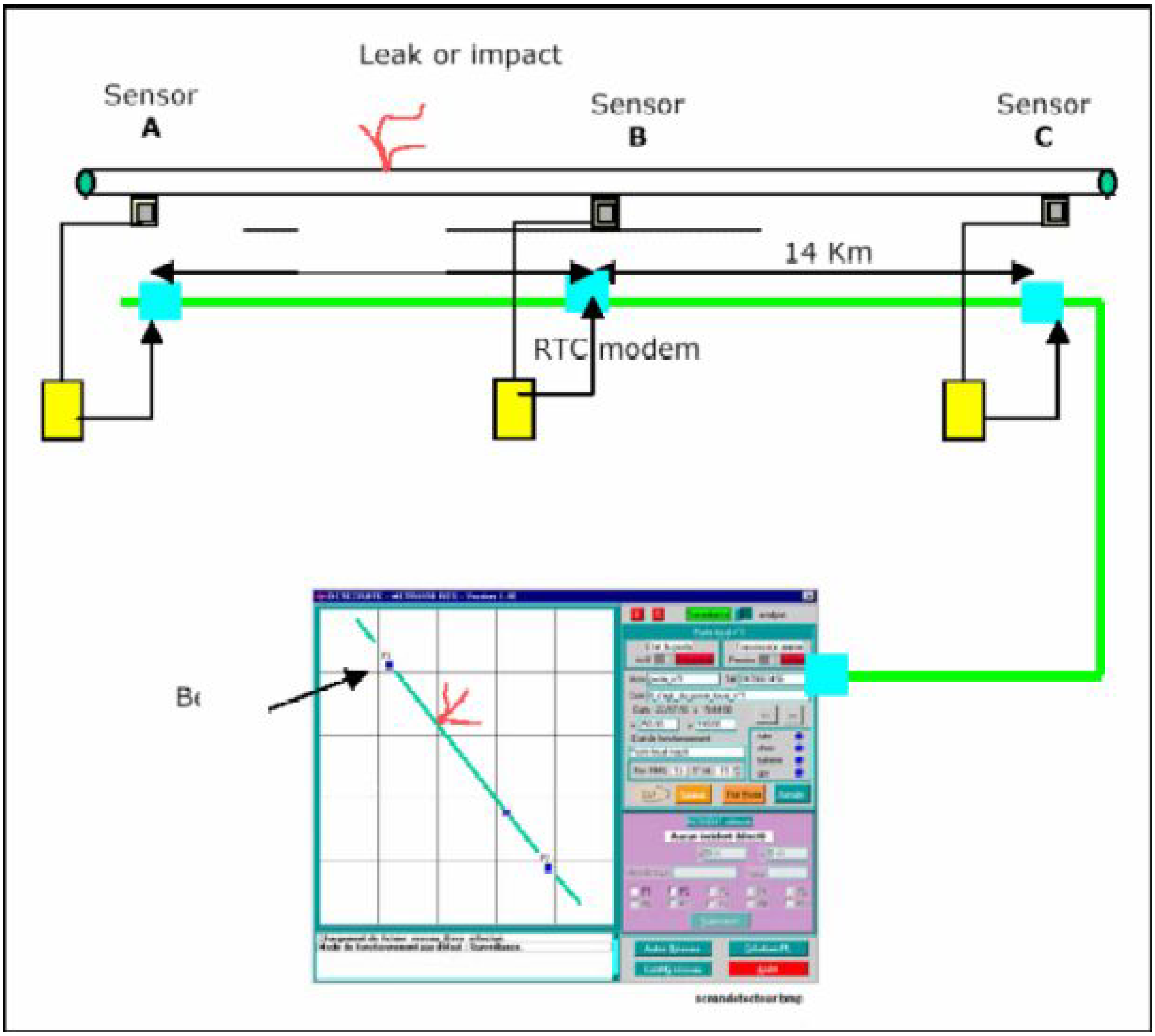
Acoustic Sensor and the Data Collector Panel



Typical arrangement

The main components of the Leakage and Shock Detection System are described hereafter.

An architecture of the proposed LDS is shown here under:



Regarding the sensor and due to the minimal leak size to detect, it is recommended to use the CPA20 type sensor with a very high sensibility, which is also explosion proof.

CPA20 hydrophone measures directly acoustic noise fluctuation in the fluid which propagates at long distance in the pipeline at the speed of sound (around 1000m/s). Each hydrophone must be installed on a non flowing T connected to the pipeline. This T must be equipped with a (manual) ball valve to allow dismounting of the sensor for installation and repair. CPA20 is supplied with a DN25 PN100 ISO RTJ flange and a dedicated protected cable for connection with the Data Collector Panel / Beacon.

I.3.1 – SENSOR : HYDROPHONE

The acoustic pressure transducer (hydro sensor) requires a threaded fitting (typically flange 1") for installation on a horizontal, non flowing T-branch connected to the pipeline. The sensible part (actual acoustic and detection) of the sensor is in contact with the fluid. The sensor is an explosion proof certified acoustic pressure sensor:

CPA20 - 300 Bar - Eex Hydrophone

H100 – Drinking water hydrophone

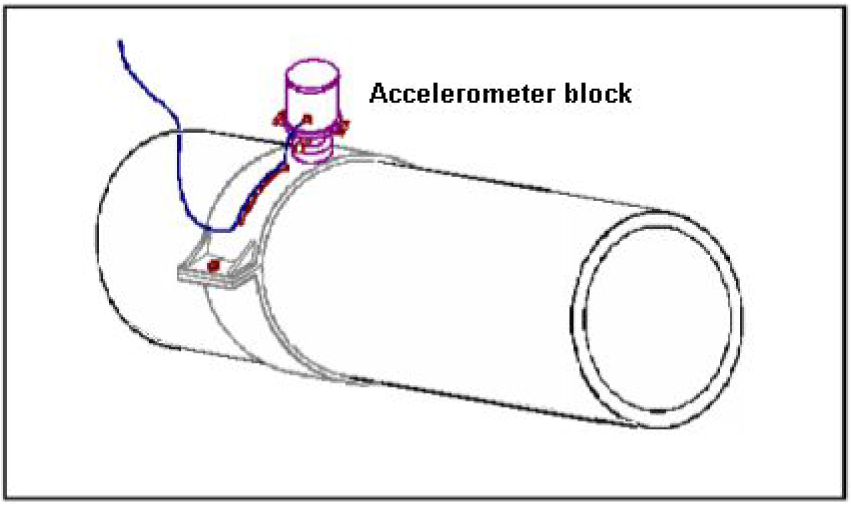
Hydrophone Sensors

Type	H100	H70	CPA20
Fluid	Water	Oil, gas, chemical	Oil, gas, chemical
Sensitivity dB ref 1V/microPa	-194	-201	-216
Pressure limit Bar	10	70	300
Size mm	L=75 D=35	L=75, I=40, H=60	L=75 D=35
Material	Silicone RTV11+Stainless steel 316	polyurethane stainless steel316	Stainless steel316
Cable length m	10	<300	<300
Certification (explosion proof)	No	Yes EN 50014 & EN50020	Yes EN 50014 & EN50020

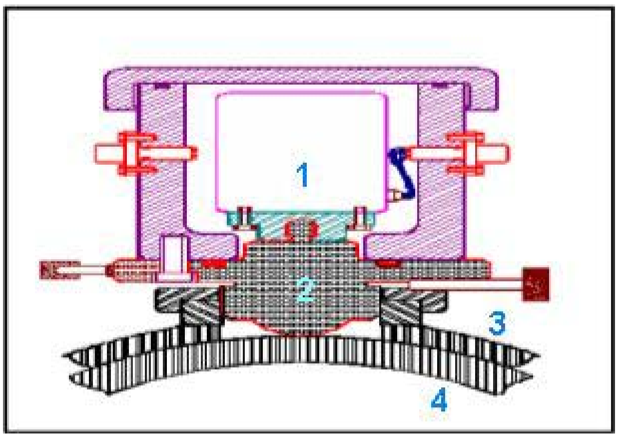
The hydrophone sensor is to be installed on a horizontal T-branch (pipe tap), flange and a manual ball valve (1" dia.) for installation / maintenance.

I.3.2– SENSOR : ACCELEROMETER

When acoustic pressure sensor installation in direct contact with the fluid (Hydrophone) is not possible or not allowed, high sensitivity Accelerometers are used. Each Accelerometer when used could be integrated in a block with collars, installed over the coating of the existing pipeline (see diagram below).



As an example, the detail of an Accelerometer block is shown here below.



1- Accelerometer
2- Interface module
3- Collar around the pipe
4- Pipeline

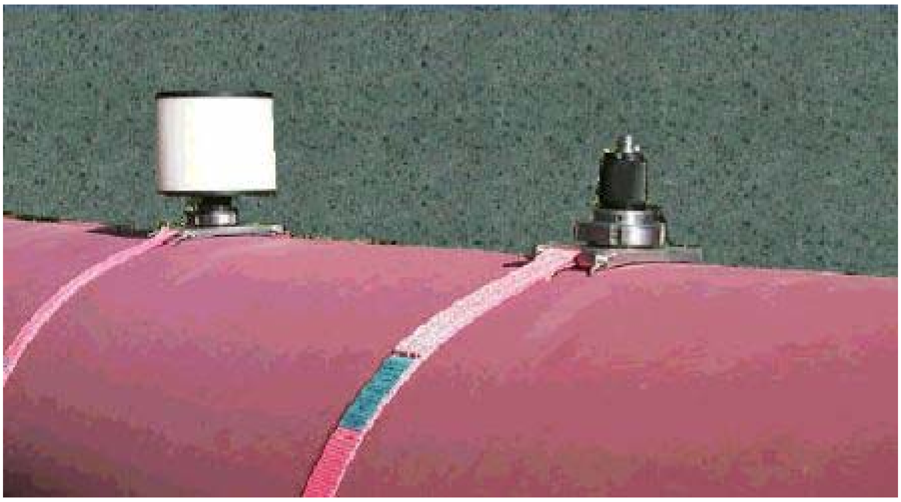
The Accelerometer sensor is most suitably installed on existing local posts on which no openings of the pipelines are existing or not desirable to be made.

The special design of the Accelerometer block ensures a good acoustic coupling between the sensor and the metal. To guarantee good transmission of reception signals, the contact ball of the interface module must be in direct contact with the pipe

wall. An area of the coating of approximately 50 mm in diameter must be removed at the location of each future Accelerometer block.
The interface module is made of a plastic component. After installation, the space between the module and the pipe wall is filled with grease to avoid future corrosion.

All instrumentation is mounted in waterproof panels and is coupled by waterproof connectors.

Pictures of Accelerometers clamped on pipelines are shown hereunder:



I.3.3 – DATA COLLECTOR PANEL

The Data Collector Panel is an electronic panel which treats and analyses the noise spectre of the sensor.

The Data Collector Panel functions are:

- Automatic detection of leakages and impacts/shocks
- Acoustic filtering
- Signal recording
- Communication connection to the Central Supervisory Control System
- Sensor conditioning
- Low consumption
- GPS Satellite Universal time synchronization.

Data Collector Panels have been designed with very low energy consumption components (a few Watts per Data Collector Panel).

Different types of power energy arrangements are possible:

- Regular power source (single phase 220Vac-50 Hz or 110Vac-60 Hz or 12Vdc)
- Plus integrated batteries (12 V each) for electric power back up in case of a power failure.

I.3.4 – CENTRAL SUPERVISORY CONTROL SYSTEM

This man-machine interface of the Leak and Shock Detection System is implemented through a GUI (Graphic User Interface).

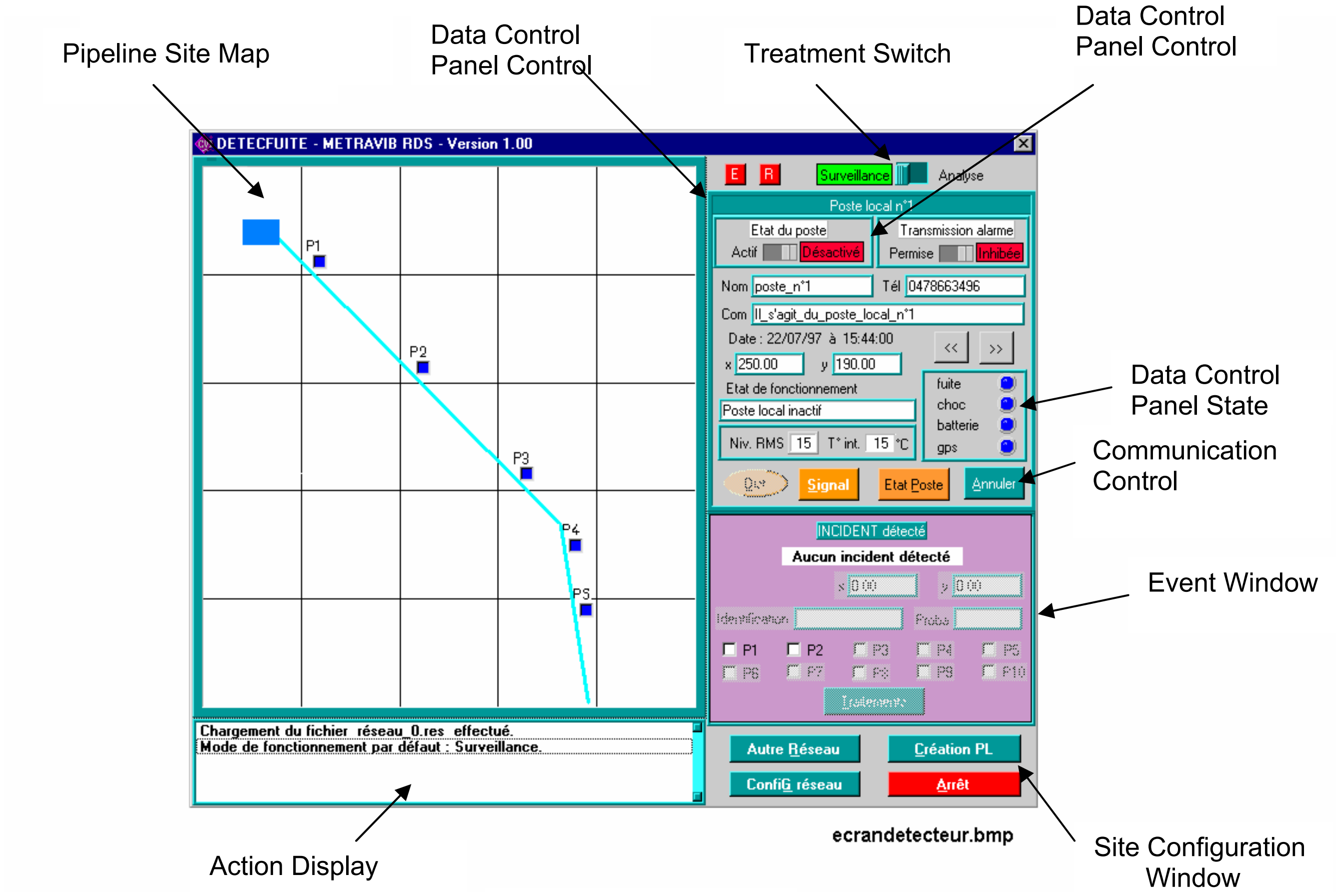
The Central Supervisory Control System uses a common personal computer (typically a PC Pentium) running specifically developed and dedicated software and hardware.

The PC is to be installed in an air conditioned control room and is connected to each Data Collector Panel along the Pipeline through either an existing, operational telecommunication network or a new dedicated radio or optical fiber telecommunication network.

The Central Control System includes a screen. The power requirements in the control room are typically single phase, 220V-50 Hz or 110V-60 Hz on an appropriate uninterrupted Power Supply (UPS).

The Central Supervisory Control System has the following functions:

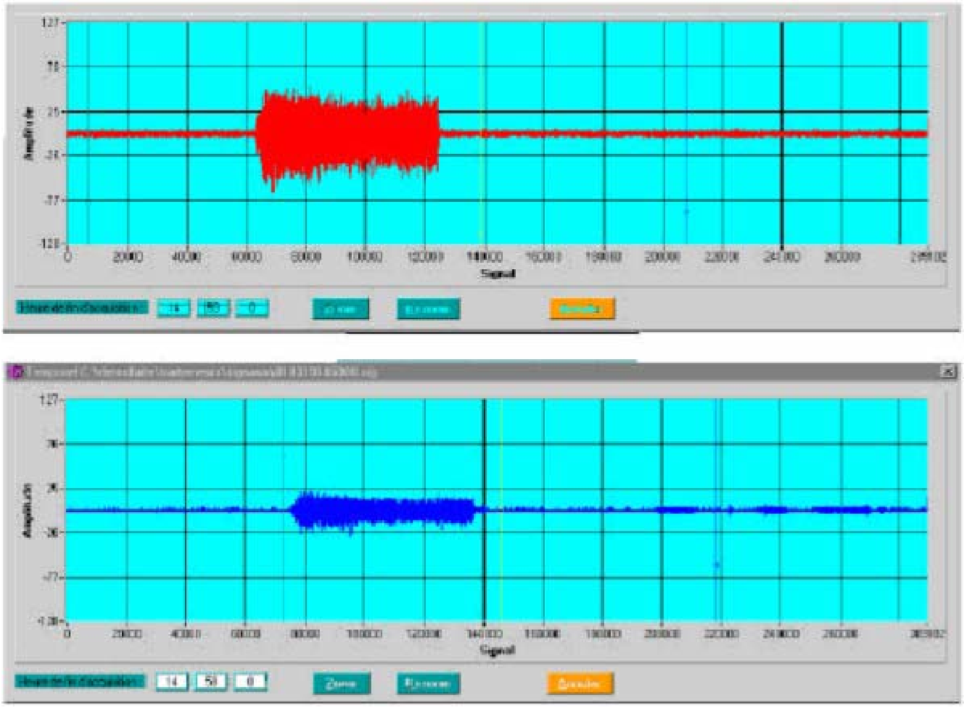
- Set up the data collector panel parameters,
- Periodically test each data collector panel,
- Display the alarms sent by the data collector panels (leakage and shock alarms),
- Connect to data collector panels and recover the noise signal,
- Display and reproduce the noise signals (the operator is able to visualize and listen to the noise measured by each data collector panel),
- Accurately calculate and display the leakage or the shock location,
- Store signals, exact time and type of alarms,



Main PC Window

Analog signal window:

Typical Noise Spectre on a PC Screen



The communication network between the Data Collector Panel and the Central Control System PC control room can be of various types:

- Regular telephone network – by cables
- Cellular phone network (integrated in our beacons) if available
- Satellite phone network
- Optical fiber network
- Electric cables
- Or radio for portable applications.

The required modem will be installed inside the Data Collector Panel to exchange the data with the Central Supervisory Control System.

PROCO

I.4 – EQUIPMENT SPECIFICATION

The acoustic and shock detection system is consisting of the following equipment and supplies

HYDROPHONE SENSOR: CPA 20

Characteristics	Specification	Comments
Size	Diameter 125mm length 200mm	
Operating temperature	-20°C to + 50°C	
Operating pressure	150 bar maximum	
Required connection	To Data Collector Panel	
Testing pressure	300 bar maximum	Hydraulic testing pressure
Maximum cable length	300 m maximum	At sensor side, cable is protected by 3m stainless steel flexible sleeve
Eex	Yes	Eex-dIIB T6
Installation on pipeline	Flange DN25 ISO PN100 type 11-J (or class 600-RTJ)	
Protection	IP67	
Weight	3,7 Kg	Without cable
Installation requirements	Shelter for protection from rain, wind, direct sun	
Number	one every ~15 km	
Installation area	on a pipeline flange	
Branche diameter	>25mm	
Distance to main pipeline	<2 m	

DATA COLLECTOR PANEL (DCP) PL 100
or BEACON

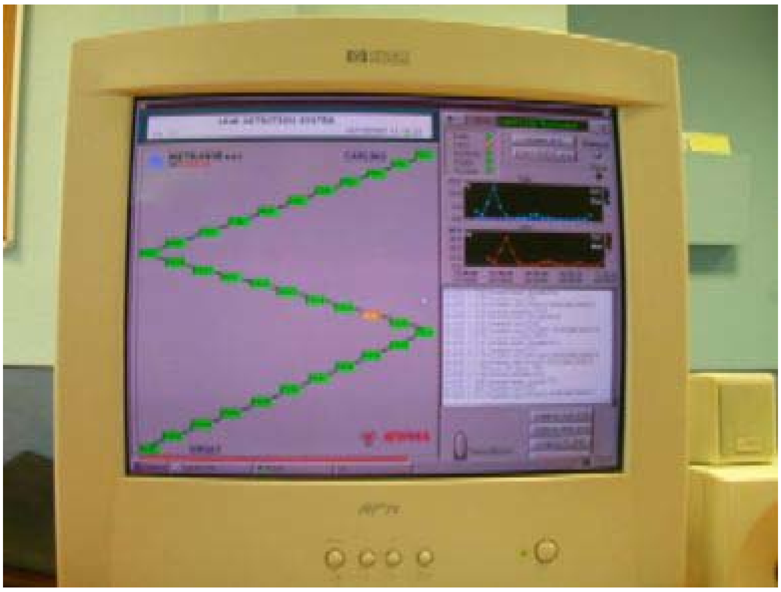
Characteristics	Specification	Comments
Size	500 x 300 x 130	mm
Support	By 4 lugs: diameter 10mm Piercing 4 holes on 32x260mm, M8	
Weight	7 Kg	
Connections	- Power (outside network) - Sensor - Telecommunication network - GPS antenna - Earth lug (for Eex)	
Power source	Power regulator package and 12V DC back up battery	
Consumption	Approx. 3,5 W	
Operating temperature	-20°C to + 50°C	
Ambient temperature	-20°C to + 50°C	
Humidity	0 to 100%	
Number	1 DCP per Sensor	hydrophone sensor
Communica-tion network	Bi-directional, 1200 bit/s minimum	DCP is adaptable to any kind of network (Radio, satellite, GSM, optical fiber, RTC)
Communica-tion type	RS232, asynchronous, duplex, without galvanic isolation	No RTS, CTS

Protection	IP54.	
Installation requirements	GPS antenna. Shelter for protection from rain, wind, direct sun	
Distance DCP /GPS	12 meters maximum	
Installation zone	Safety zone	
GPS antenna	« Bullet » type installed on pole in safety zone. In direct view to satellites	
CEM	EN 61000-4-5	

COMPUTER OF THE CENTRAL SUPERVISORY CONTROL SYSTEM

Characteristics	Specification	Comments
Size	Office computer	Typically: PC Pentium III
Installation zone	Safety zone	
Power source	110 to 220V AC 50 to 60 Hz	
Consumption	100W	
Installation requirement	Air conditioned room	
Operating temperature	+10°C to +45°C	
Required connections	- to power source. - to telecommunication network	

Typical Central Control System Screen Window



II. TYPICAL FUNCTIONAL DESCRIPTION OF THE COMMUNICATION NETWORK

- **OPTICAL FIBER NETWORK**
- **RADIO COMMUNICATION NETWORK**
- **CONNECTION WITH EXISTING TELECOMMUNICATION NETWORK**

II.1 – GENERAL

An efficient, secure communication system between the Acoustic Sensors/Data Collector Panels along the Pipeline and the Supervisory Control System is necessary. Such communication networks can be :

- Optical Fiber Network (along the Pipeline)
- Public/Private Telecommunication Network
- Radio Telecommunication Network

The communication system possibilities have to be investigated case by case.

In certain cases the proposed detection system can also convey and treat other data/information than the detection data. Such other data can be valve opened/closed or electric motor or instrumentation controls or other controls.

The presented telecommunication networks are professionally secured and their efficiency and resistance to crises events are fundamental.

Connection with an existing (or new) public telecommunication network can also be made.

II.2 - OPTICAL FIBER NETWORK COMMUNICATION

If the pipeline is equipped with an optical fiber network, the necessary communication for the detection system can be made through such a network. This is certainly the most economical communication solution.

II.3 – SYSTEM ARCHITECTURE FOR RADIO COMMUNICATION

- Exclusive radio frequencies within the concerned geographic zone.
- Radio infrastructure with dedicated architecture for the operator.
- High MTBF of the professional units.

Its architecture excludes the recourse to existent telecommunication systems (fix, mobile or satellite) of which the availability would depend on external factors not controllable by the operator.

The proposed radio network allows:

- Transmit data to the local post
- Communication in phonic mode between the Central Supervisory Control System and the local Data Collector Panels (phonic mode: alternate).

The network is built on the principal of arterial serial highway by fix liaison point by point (radiorelay) type hertz beam 1,4 GHz input of 320 kbit/s. Each local relay serves by a liaison-celled distribution a cell covering 7 to 15 terminal modems installed at the local post.

NB: To minimise costs, the relays could be installed on existing tower structures (such as mobile phone towers).

II.4 – CHOICE OF RADIO FREQUENCES

In the domain of radio between fixed points, the government administration reserves normally the waves of 1,4 Ghz for the connection of efficient long distances and without meteorological limitations (more than 100Km of flat area).

These connections allow a high capacity level between the local posts.

II.5 – DISTRIBUTION OF RADIO COMMUNICATION

For the distribution network of radiorelays between the data collector panels, various solutions are possible depending on the functionalities and the authorisations: the frequencies of the band semi-duplex 35/40Mhz are recommended for low inputs.

The choice allows the following advantages:

- Important radio distance

- Redundancy of the distribution connection. The local posts can communicate with 2 relays:
  - One in normal mode
  - The other as emergency (example: after lightning striking of one relay)

- Easy operation.

The regular and cyclic questioning of the local posts by the PC of the Control Room will be done in different ways including by an additional independent phonic way.

II.6 – SECURITY AND EFFICIENCY OF THE RADIO NETWORK

All mechanical equipment and materials (such as pylons, antennas, radio bays, panels and cabling) are widely and currently used in other existing service networks and assure security and efficiency.

In the local posts, the radio modem will be made by integrated 12V batteries with holding system in case of power cut.

The radio frequencies allow to filter noise sources due to exceptional propagation or environmental, industrial noises.

All equipment and relays are identical to allow inter changeability and simplified spare part stocks.

The arterial highway hertz beam is a closed network allowing communications in case of failure of a relay.

II.7 – CONNECTION WITH AND USE OF EXISTING TELEPHONE NETWORK

The existing public and operational telephone network is to be professionally secured and its efficiency and resistance to crises events are fundamental.

This network is operational and available all the time during the leakage and shock detection operations.

Any interruption of this network is also interrupting the leakage and shock detection operation since the Central Supervisory Control System will not receive any information from the Data Collector Panels.

Each Data Collector Panel is equipped with one unit Remote Terminal Unit (RTU) and one CPU card to communicate with the Central Supervisory Control System.

III. SYSTEM MERITS, ADVANTAGES AND RELIABILTY

III.1 - ADVANTAGES AND MERITS

The LDS Leakage and Shock Detection System has proved to be in successful industrial pipeline operation for Leakage and Shock Detection and their localization. Very fast and reliable leakage or shock alarms are given to operators who are able to communicate with the Data Collector Panel for signal visualization or listening. A combination of GPS synchronized Data Collector Panels and specific acoustic software installed in a Central Control System allow a very accurate and fast leakage and shock localization (in an area of approx. 0,5%-1% of distance between the sensors).

The Data Collector Panels equipped with packaged non-intrusive accelerometer sensors or very sensible intrusive acoustic pressure sensors offer a flexible set up and easy installation.

Applications are various:

- Permanent leakage monitoring for water, oil & gas pipelines and pipe networks
- Permanent shock monitoring (construction works, accidents, explosion, terrorism, river crossing, boat anchors …)
- Monitoring on offshore pipelines,
- Long range leakage localization
- Temporary shock monitoring during civil works close to pipelines.

The main advantages and merits of this acoustic detection system are summarized hereunder :

- Impact leakage or shock detection and localization

- Direct detection

- Possible detection with different fluids (any gas, any liquid)

- Long range detection and localization capabilities
  (up to 50 Km between two sensors in some cases)

- Very long pipeline length of upto several thousand kilometres for one system

- Excellent accuracy for leakage localization
  (Approx. 100 m area of the detected leak / shock on a distance of approx.
  15 km between two sensors)

- Very quick, real time detection

- Detection of small diameter leakages or cracks (minimum 5 mm)

- Easy installation of the leakage detection system

- Use of anti explosion, certified sensors

- Low maintenance time and cost.

III.2 – MAINTENANCE AND SYSTEM LIFETIME

There are no moving parts in the system, except those in the PC. Therefore the required maintenance is limited to regular instrumentation adjustments and system tuning.

In case of a specific sensor maintenance/cleaning operation, any hydrosensor can easily be dismantled by closing the manual ball valve in front of the hydrosensor. This can be done without stopping / closing the pipeline operation.

The minimum system lifetime is equal to those of properly operated PCs.

III.3 – RELIAIBLITY, REQUIRED SPARE PARTS

Hydrophone CPA 20 Sensors:

no moving parts

very reliable

certified for pipeline pressure

electrical certified for mounting in Zone 1.

For example: The Reference Ethylene 450 Km Pipeline of the Total Fina Elf Group is equipped with 31 sensors: only one sensor for the complete pipeline is recommended as commissioning and operational spare part.

Data Collector Panels:

local mounting in a closed panel, automatic restart after power shut down, remote programmation from the Central Supervisory Control System through the telenetwork communication system.

For example: The Reference Ethylene 450 Km Pipeline of the Total Fina Elf Group is equipped with 31 data collector panels: only one panel is recommended as commissioning and operational spare part.

Central Supervisor Control System:

Software remotely maintainable.

No spare parts required other than those for normal PCs.

Automatic restart after electric power shut down.

IV. SYSTEM PERFORMANCES

The Leakage and Shock Detection System is a proven technology which is reliable and successful for leakage and shock detection and its localization. Very fast and reliable real time leakage or shock alarms are given to operators who are able to communicate with the data collector panel for signal visualization or listening.

The combination of GPS synchronized Data Collector Panels and the specific acoustic software installed in a Central Supervisory Control System allows a very accurate and fast localization of leakages and shocks.

This system provides with a leakage and shock localisation precision in an area of approx. 100 m along each controlled pipeline section with hole and crack detections of:

<u>Example</u>: minimum 5 mm diameter at 600 psi JP 4 flow pressure, all valves between the acoustic sensors opened.

Any leakages from pipe holes or cracks, which occurred before the commissioning of the LDS system can in principle be detected. Specific leak research detection can be made depending on flow pressure, effluent media and pipeline configuration.

V. SCOPE OF SUPPLY

BD : means Basic Design **DD** : means Detail Design **SUP**: means Supply

V.1 - PRINCIPLE OF DIVISION OF SCOPE OF SUPPLIES

Description	PROCO			BUYER			REMARKS
	BD	DD	SUP	BD	DD	SUP	
Acoustic Detection System							
Hydrophone CPA or Accelerometer	0	0	0				
Pipe tap (horizontal)+ Flange + Manual Ball valve 1" dia.	0				0	0	
Cable earthing at both ends (2x each)	0	0	0				
Data Collector Panel	0	0	0				
GPS Receiver System	0	0	0				
GPS Antenna fixed on Shelter and Lightning protection with its earthing	0	0	0				
Cabling the Data Collector Panels to:							
- electric power cables and connections to electric power network	0	0	0				
- telephone cables and connections to existing telenetwork	0	0	0				
Power regulation package and back up Battery 12V	0				0	0	
Communication Network							
Remote Terminal Unit (RTU) and CPU Card (in all cases)	0	0	0				
Antenna radio modem with directive coupler (for radio)	0	0	0				
Network Engineering to connect with existing telecommunication network	0	0					
Central Supervisory Control System							
Hardware and System Software	0	0	0				
UPS	0	0	0				
Shelter for each Data Collector Panel	0				0	0	
Any Civil Engineering + works	0				0	0	
Erection, Commissioning, Tests	0				0	0	
Supervision during Engineering and during Erection, Test, Commissioning and Training			0				

The above Buyer-parts can also be taken over by PROCO.

V.2 – EXCLUSIONS

The following supplies and services are excluded from PROCO's scope of supply:

- Subsoil investigation, seismic factor definition, site levelling, compacting and piling
- Civil works, foundations works, buildings construction works, piping works, drainage works, wiring works, water supply works, painting works, instrumentation works, material for civil, foundation, building architectural, safety guards
- Anchor bolts, shims, plates and all parts to be embedded in foundations
- Any piping, supports, fixations, racks, insulation
- Simple parts: trench covers, handrails, ladders, walkways, etc.
- Protection in accordance with local safety regulations not specified
- Workshop and maintenance services, maintenance equipment
- Any electrical power connections and protections with the national grid
- Electrical cables (except those specified), cables trays, racks and electrical erection material
- Pulpit, cabinet, etc. for lighting, building, utilities, others than those specified

- Lighting including emergency lights

- Closed circuit interphone / telephone / television system other than those specified herein

- Fire detecting / alarm / fighting system

- Lighting protections, other than those specified herein

- Transport insurance from PROCO's workshop to SITE, unloading, storage and guardianship of the equipment at SITE (including cranes and operators)

- The necessary tools, machinery, equipment and materials (including embedded ducts and pipes), maintenance and consumable materials for the civil, architectural, mechanical, electrical work, such as excavators, welders, overhead and movable cranes, lifting / mobile devices

- Mechanical and electrical installation: materials, man power and equipment and tools for their execution (including for start up, commissioning and ACCEPTANCE TESTS)

- Supervision service Man/days exceeding the Man/day- period indicated in this SPECIFICATION

- Office for supervisors, telephone / fax / e-mail on site, toilets, showers etc.

- Consumables materials, any utilities, raw materials and operators for all test runs.

- The supplied special tools for the commissioning and test works will remain PROCO's property.

- Import, federal/provincial, road and local taxes and duties

- Local licences, permits and fees, including Environmental, Security and Operation Permit

- Any other supplies, services, taxes, etc. not expressly indicated in this SPECIFICATION and / or supplies and services required by local authorities beyond this SPECIFICATION.

VI. REFERENCES

REFERENCES LDS

The most interesting and significant reference proving its industrial viability is the 2001-reference at the TotalFinaElf Group:

- **ATOFINA approx. 450 Km Ethylene pipeline in 2001.**
  31 units CPA20 hydrosensors and 31 units data collector panels are installed. The Leakage Detection System Central Control is installed in the Pipeline Control Room, located at Viriat / France. The communication network is by Radio and, as back-up, by public telecommunication network.

CLIENT	Year	OD Pipe, material	Distance between sensors	Fluid	Pressure	Leak size	Distance between measured Leaks and Sensor ▲	Operation	Contact
T O A Z TogliattiAzot Russia Ammonia Export Terminal Russian Black Sea	Ordered 2003 Operat. 2004	450 mm low carbon steel, above ground	5 000 m	Liquid and Gaseous Ammonia	Various	Leak and Shock/Impact Detection		Permanent Pipelines: 2x Pipes each 5 000 m	
SPSE France Sté. Pipeline Sud-Européenne	Ordered 2003 Operat. End 2003	1'000 mm dia carbon steel, buried pipes	Approx. 15 KM	Crude Oil	5-8 bar	Leak And Shock/Impact Detetion		Permanent Pilot Project: 40 KM Total Pipeline: 800 KM	
ATOFINA France (TotalFina Elf Group)	**2001**	**200 mm, steel**	**Approx. 15 Km between each Sensor**	**Ethylene**	**50 to 90 Bar**	**Total Pipeline length: 450 Km**		**Permanent Leak and Impact Monitoring**	**Mr Grenier 33-4-72396964**

CLIENT	Year	OD Pipe, material	Distance between sensors	Fluid	Pressure	Leak size	Distance between measured Leaks and Sensor	Operation	Contact
TOTALFIN AELF Raffinerie de La Mède France	2002	80 mm, steel	7 813 m	Propane	15.7 Bar	No leak detected, Punctual Test of Impacts		No leak verification	Mr Leroy 33-4 42785000
TOTAL Nigeria Lagos Airport	1997 & 2001	400 mm, steel	500 m	Air	2 Bar	2 mm	350 m	Punctual Leak localisation Service	TOTAL OUTREM ER Mr POURIEL 33-1-41352636
ELF ATOCHEM France	2000	200 mm, steel	20 000 m	Ethylene	82 Bar	Test Leaks of 5 & 10mm, plus Impact Testing (see Test Data)	7 500 and 12 500m	Pilot Leak & Impact Test to confirm LDS System viability	Mr Lambotte 33-1-49008459
C G E (Water Utility Operator) Lyon France	1999	400 mm, Cast Iron	1 300 m, 815 m	Water	6 Bar	Impacts and Leaks 20 & 50 mm	500 m	Punctual Leak & Impact test	CGE Lyon Mr Blanc 33-4-72693090

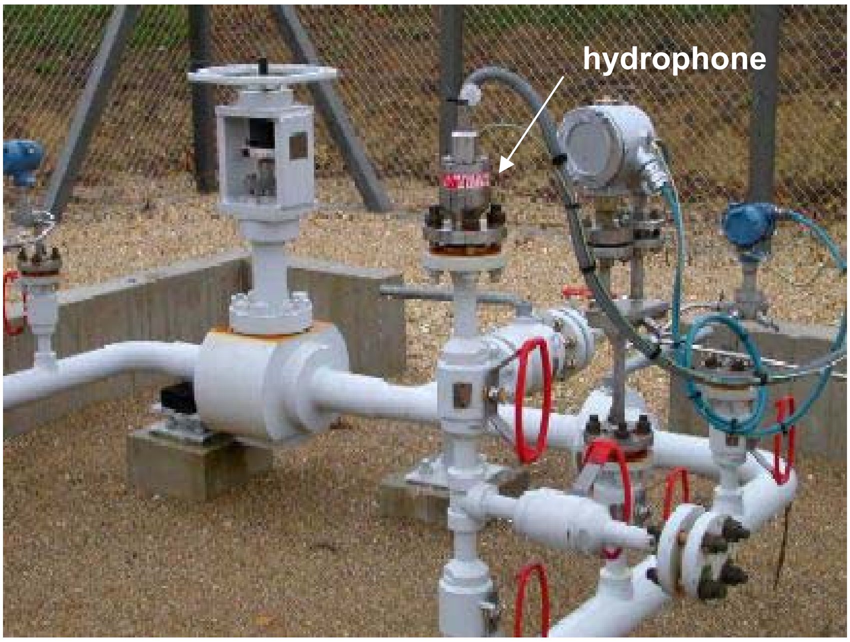
CLIENT	Year	OD Pipe, material	Distance between sensors	Fluid	Pressure	Leak size	Distance between measured Leaks and Sensor ▲	Operation	Contact
Gaz de France France	1998	400 mm, steel	15 000 m	Gas	70 Bar	50 mm with Hydrophone, 80 mm avec Accelerometers , plus Impacts	4 700 m and 9 600m	Leak and Impact test	GDF Marseilles Mr Blanc 33-4-91283320
TOTAL Liban Beyrouth Airport	1997	14 ", steel	485 m	Air	6 Bar	2 leaks	9 & 32 m	<u>Punctual</u> Leak localisation Service	TOTAL OUTREMER Mr POURIEL 33-1-41352636
ELF Norway	1996	300 mm, steel	5 000 m	Gas	45 Bar	4 mm	1700 m	Leak test	
COFLEXIP France	1993	150 mm, flexible	800 m	Air	1 Bar	1/8 "	800 m	Leak test	
SNEAP France	1990	100 mm, steel	1 300 m	Light oil	12 Bar	1 "	1300 m	Leak test	
SNGSO France	1988	300 mm, steel	19 000 m	Gas	50 Bar	1/4 "	10000 m	Leak test	
CGE France	1987	1000 mm	400 m	Water	10 Bar	20 M3/H	250 m	Leak test	
Pont a Mousson France	1986	200 mm, steel	800 m	Water 90°C	8 Bar	1/4 "	500 m	Leak test	

▲ actually measured leakages.

Reference ATOFINA (TotalFinaElf) : approx. 450 km Ethylene Pipeline in VIRIAT / France

One of the operational 31 Valve Stand Areas, showing (as installed in each valve stand area) :

- Installed **Hydrosensor CPA20 on a T-form flange** and



- Pipeline Instrumentation Control Panel in the Valve Stand Area with an incorporated **Data Collector Panel** and mounted **GPS Antenna** :

Reference ATOFINA (TotalFinaElf) : 20 km Ethylene Pipeline in VIRIAT / France

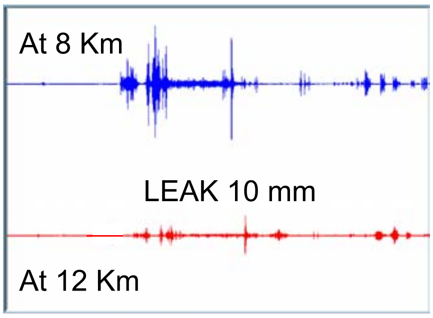
Pilot Leak and Shock Testing :
Pipeline length tested : 20 Km
Pipe Diameter : 200 mm
Pipe Material : Steel
Test Pressure : 80 Bar
Sensors used : Hydrophones CPA20 as presented hereabove.

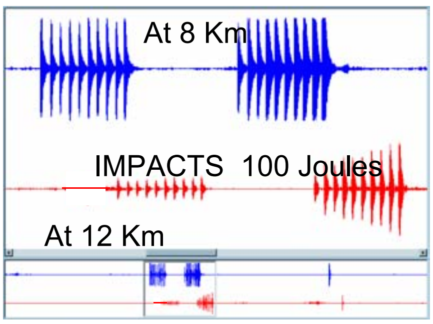
Leakes were created, tested and successfully monitored at 7 500 meters and 12 500 meters from the Sensors.

Testing and monitoring of a 10 mm Ethylene leak.

This **leak pilot test** was created for response and monitoring checking to fully test the **LDS performances**.

The **satisfactory results** have let to the **decision to equip the 450 KM Ethylene pipeline** with the proposed LDS system.





5 km ammonia pipeline, used to convey ammonia from a storage facility to a sea tanker filling point and operated by JSC "Togliattiazot" at Volna, Temryuk district, Krasnodar territory, Russia.

Pipeline length:	5,8 km
Pipe diameter:	400 mm
Pipe material:	low-temperature steel
Sensors:	Hydrophones CPA20

The architecture of this LDS system, installed on the pipeline of an ammonia export terminal, differs from the standard installation because the small distances between sensors enables to organize a centralized data collection: the GPS synchronization is not needed, sensors are directly connected to the Central Supervisory Control System through an analog cable or optical fibre link. Thus, the signals are continuously being analyzed by the Central Supervisory Control System which does not wait anymore for alarms to be sent by any DCP. Such an architecture enhances availability and accuracy of the monitoring.

With the authorization of the operator – JSC "Togliattizot", interested companies can visit the installation. A leak and/or shock test on the ammonia pipeline, showing all the functionalities of the LDS and its industrial viability, can be organized.

VII. COMPARISON WITH OTHER DETECTION TECHNIQUES

Other leak detection systems have been developed before the LDS acoustic detection technology was on the market. One of these other systems is the quasi static **pressure and flow control** technique which uses pressure and flow sensors to characterize the pressure and flow gap along the pipeline. These measurements must be associated with a mathematical model to describe the pressure and flow profile in the pipeline when a leak is happening. The central unit performs a comparison between model prediction and measurements to identify and analyze an irregular flow fall or pressure fall.

This pressure and flow control method is proposed by several vendors worldwide. Some of these systems are implemented for permanent monitoring in sensitive areas.
This method has several limitations compared to the proposed LDS acoustic detection technology.

Another leak detection method is based on the measuring of pressure transient peak caused by rarefaction waves only and instantly at a leak occurring. As far as the method detects a kind of "hammer effect", the energy levels are much higher than the energies that are characteristic of the acoustic phenomenon analyzed by the LDS. The LDS acoustic sensors are far more sensitive than the pressure sensors used in the described method.

The comparison table herebelow shows very clearly the advantages of the proposed LDS system.

	Flow / Pressure Control	Acoustic Detection Crosscorelator Portable	***Acoustic Detection LDS - Permanent Monitoring***
Detection System	Fix	Portable, light, sensors attached with cross-correlator	*Fix, industrial heavy duty sensors. High noise sensibility level and Ex-proof*
Detection of:	Leak	Leak	*Leak + Impact / Shock*
Detectable Leak Size	Large Leak or Full Pipeline Break	Variable	*Very Small Leaks*
Localization Accuracy	Typically 2 to 50 KM depending on measuring distances	Variable	*Very precise: typically 0.5 to 1 % between two sensors*
Kind of Control	Monitoring when flowing only	Mobil Patrols with portable registering devices	*Permanent monitoring*
Response Time	Very slow, depending on leak size	Not permanent	*Around 30 seconds, depending on local communication network*
False Alarms	Frequent	Not permanent	*Very few*
Mounting on Pipeline	Easy	Provisionally, not permanent	*Very easy and cost effective*
Fluid	Liquid only	Liquid only	*Liquid & Gas*
Distance between Sensors	Variable	Typically 500 meters	*Typically 10 to 15 Km*
Pipeline	Pipeline (no network)	Typically in urbane pipe networks	*Any Pipeline and Pipe Network*
Merits		Application in urban, short pipeline sections	*Application on Pipelines with Sensor distances of 10 Km to 15 Km. Upto hundreds of kilometers length with one control system*

VIII. CONCLUSIONS

The presented **Leak Detection System (LDS)** has proved to be successful and reliable for **Leak and Shock detection and localization** in punctual and in permanent industrial pipeline operations over years.

Very fast and reliable leak or shock alarms are given to operators who are able to communicate with the Data Collector Panel (Beacon) for signal visualization or listening. A combination of GPS synchronized Data Collector Panels (Beacons) and specific acoustic software installed in a PC control system allows a very accurate and fast leak and shock localization: **location accuracy: 0,5% to 1%** depending on the distance between the sensors.

The presented LDS system has:

- quick response time
- low false alarm rate
- good location accuracy
- down to 5 mm leak hole precision.

The Data Collector Panels (Beacons) equipped with packaged non intrusive accelerometer or very sensible intrusive acoustic pressure sensors offer a **flexible setup, easy installation and lowest possible maintenance.**

LDS applications are various :

- Leaks permanent monitoring for water, oil & gas pipelines and pipe networks
- Shocks permanent monitoring (explosion, terrorism, river crossing, boat anchors monitoring on offshore pipelines)
- Long range leak localization
- Temporary shock monitoring during civil works close to pipelines.

IX. YOUR CONTACT

Günther PRÜCHER

PROCO Process + Control SAS

11, Avenue Philippe Auguste

75011 PARIS (France)

Tel : + 33 1 53 27 19 11

Fax : + 33 1 53 27 19 10

Email : prucher@proco-france.com

X - REQUIRED BASIC DATA OF PIPELINE

The pipeline on which the proposed Leakage and Shock Detection System is to be installed, has the following characteristics:

- Pipeline:	New or Existing
- Pipeline length:	to be given by Operator
- Pipeline diameter:	to be given by Operator
- Pipeline wall thickness:	to be given by Operator
- Pipeline grade:	by Operator
- Pipeline coating:	by Operator
- Pipeline history and incidences:	date installed ?? → by Operator
- Pipeline protection:	Cathodic ?? -→ by Operator
- Pipeline conveys:	Product (liquid or gaseous) by Operator
- Flow velocity:	minimum: → by Operator maximum: -→ by Operator
- Flow pressure:	minimum: → by Operator (minimum 20 kg/cm^2 for leak detection functionality) maximum: → by Operator
- Number of pump stations:	to be completed by Operator – estimated average every 30km
- Number of valve stands:	to be completed by Operator – estimated average every 5km.

This preliminary proposal requires technical clarifications of the existing pipeline and its existing control system.

The following main questions need to be clarified with the Operator:

- Pipeline location
- Do you need an existing leak localized
- If yes, what is the leak flow size
- If yes, are you able to stop the production and pressurize the pipeline with gas (air or nitrogen)
- Do you need a permanent leak monitoring
- Do you need a shock monitoring
- Is it a pipe network ? If yes how many branches
- Pipeline layout and profile
- Distances between each pump station
- Distances between each valve stand
- Possible/requested type of communication network between the local posts:
  - telephone network (by cables)
  - cellular phone network
  - fiber optic network
  - electrical cables
  - radio for portable applications.

- Choice of type of noise sensor to be installed of either:
  - Hydrophone (installed on existing pipeline openings), or
  - Accelerometer (installed externally in the pipeline).

- Pipeline environment (buried, coating, subsea...)
- Type of external noise sources
- Type of internal noise sources
- Type of communication network available
- Type and location of energy available
- Are the process conditions varying with time. How.

- Are existing threaded fittings available for acoustic pressure transducers instrumentation. Where.
- Other useful information.

The pipeline is operated as follows:

Example:

- all valve operations (on-off) are made manually on site after specific telephone requests

or

- the pipeline is operated with SCADA with the following software/hardware functionalities : (please fill in).

Main reasons of leakages of the (existing) Pipe Line have been experienced in the past as follows:

Example:

- pipe weld cracks (mainly due to welding defaults)

and / or

- pipe / stone frictions from vibrations (road traffic), causing over the time pipe holes.

As a precondition for the good functioning of the detection system, the existing telecommunication network between the Sensors/Data Collector Panels and the Central Supervisory Control System (by cables) is operational at all times of the leakage detection.