



## Design Guide

### UNDERGROUND PIPELINES Liquid Leak Detection System

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## 1. INTRODUCTION

TTK has developed a sense cable suitable for detecting liquid hydrocarbon leaks: FG-OD.

This sense cable allows detection of small quantities of liquid coming into contact with the sense cable. FG-OD sense cable is addressable, re-usable and can detect multiple leaks over long-line systems. FG-OD cables are designed to be connected to TTK's FG-NET Touch Screen Digital Panel.

FG-OD is ATEX / IECEx approved for Zone 0. Coupled with FG-NET, FG-OD provides fully mapped, multiple simultaneous leak location across the network of protection cables together with an advanced alert, alarm and logging system.

The intent of this document is to provide design guidelines of the leak detection system on underground pipelines.


## 2. SENSE CABLE: FG-OD



### 4.1 General Features

- Reusable
- Detect any abnormal presence of liquid hydrocarbon / non-conductive solvent along the entire length of the sense cable.
- Multiple leak detection and localization, as well as cable break faults (one per sense cable), thanks to Independent Digital Addressing Microchip.
- Able to monitor at the same time, on a single digital unit :
  - liquid hydrocarbon / non-conductive solvent sense cables, plus
  - water / acid or base sense cables
- Fastest response time on the market
- System may be tested during Testing& Commissioning
- Insensitive to humidity, Pressure and Pollutions
- Pre-connected (water tight connection IP 68)
- Suitable for hazardous areas : LCIE certified Ex ia IIB T4 Ga (ATEX "Zone 0")

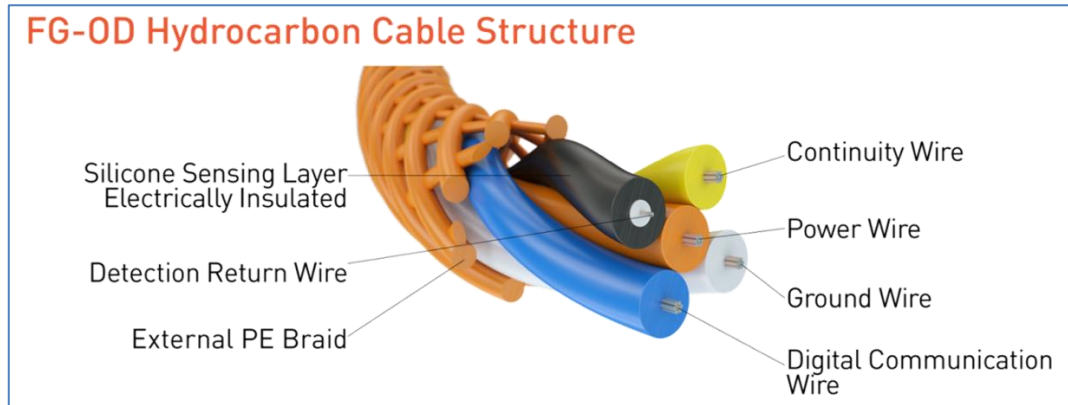
#### IECEx / ATEX marking:

TTK - Type : FG-OD  
CE 0081  II 1 G  
Ex ia IIB T4 Ga  
LCIE 13 ATEX 3082X  
IECEx LCIE 13.0072X

-30°C < T < +100°C



## 4.2 Sense Cable Structure



- Microchip embedded in each FG-OD sense cable  
→ Independent digital transmission of unique address to the Alarm Panel

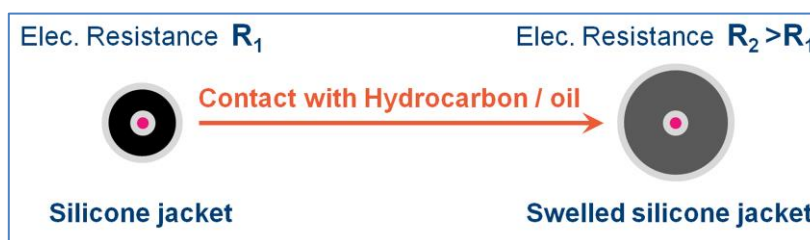


- Three different models available, in function of the required sensitivity :
  - **FG-OD** : standard sensitivity
  - **FG-ODC** : enhanced sensitivity
  - **FG-ODR** : reduced sensitivity – adapted for applications with residual hydrocarbon presence – in particular in vapor phase - in the installation environment
- Sensor standard lengths - including pre-fitted plug-socket connectors
  - 3m → FG-OD3 , FG-ODC3, FG-ODR3
  - 7m → FG-OD7 , FG-ODC7, FG-ODR7
  - 12m → FG-OD12 , FG-ODC12, FG-ODR12
  - 20m → FG-OD20 , FG-ODR20
- Customized lengths up to 20m per sense cable



## 4.3 Detection Principle

- Silicone element containing Carbon Black particles
  - Electrical conduction
  - Ability to absorb hydrocarbons, oils or solvents (insoluble in water)
- In case of contact with hydrocarbon / oil
  - Silicone element absorbs the product and its volume increases locally
    - Distance of Carbon Black particles increases
    - Electrical resistance of the silicone element increases



*Effect on silicone sensing layer after contact with hydrocarbon / oil*

## 4.4 Performance

- Typical detection times for TTK sense cable :

PRODUCT \ SENSE CABLE MODEL	FG-ODC	FG-OD	FG-ODR
Gasoline	1-2 minutes (*)	3-6 minutes (*)	20-30 minutes (*)
Jet Fuel & Kerosene	4-10 minutes (*)	10-20 minutes (*)	2-4 hours (*)
Diesel Oil	7-12 minutes (*)	15-30 minutes (*)	3-6 hours (*)
WTI Crude Oil	20-35 minutes (*)	-	-

(\*) depending on temperature, leak conditions and composition

- Accurate leak location (accuracy : sense cable address)
- True multi-leak system: multiple alarms on the sense cable string (one alarm per sense cable)
- Maintenance free :
  - ☐ No calibration required, circuit spot test advised once per year
  - ☐ Cable cleaning required only in case of contamination
- Reliable detection : insensitive to water, dirt, external loads (pressure)
- Cable reuse after leak detection, following cleaning with appropriate solvent
  - Possibility to perform leak detection tests under real conditions

### 3. DIGITAL ALARM UNIT: FG-NET-LL

The FG-NET digital unit is designed to be used with all TTK digital sense cables, for water, bases, acid and hydrocarbon leak detection.

In the event of a fault on the sense cables (leak or cable break):

Primary responses from the FG-NET:

- An audible alarm is triggered and a relay is activated.
- The touch screen of the panel displays the location of the leak (for oil leaks : cable section concerned) and details of the fault (the type of fault leak or cable break), including the time and date the fault is registered.
- Optional – integrated maps of the leak detection installation highlighting the location of the fault, available on the touch screen display of FG-NET.

Secondary advanced responses:

- Report to the BMS via a JBUS/MODBUS protocol. The FG-NET can drive dynamic drawings on the host BMS.
- Send email alerts and SNMP traps to a LAN-connected BMS, via a standard Ethernet connection.

#### General Features:

- Full Addressable, Digital and Secured Panel
- Monitor Up to 1000 Sense Cables
- Touch Screen Interface
- Efficient and Reliable locating of Faults (Leak, Cable Break)
- Cable Ejection Feature
- Up to 5000 Events Log
- Interactive Mapping
- TCP/IP & JBUS/Modbus Connection
- Web Interface: to remotely view, configure and control FG-NET on a connected computer

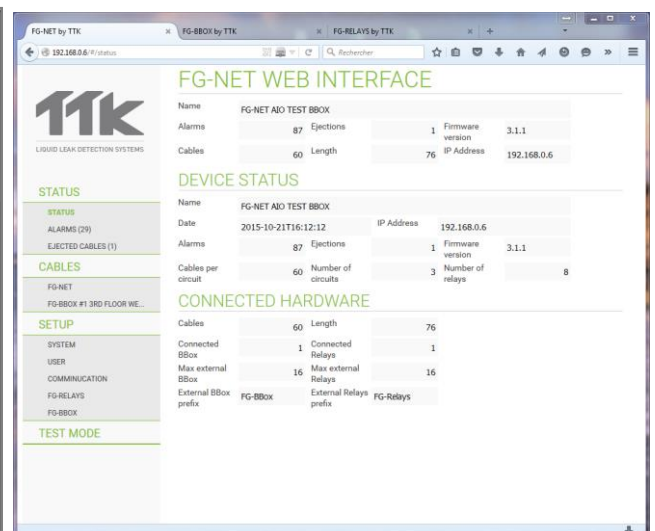
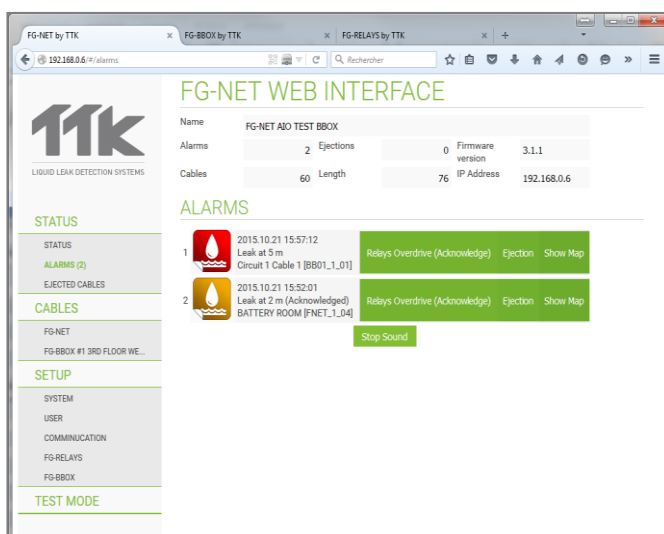
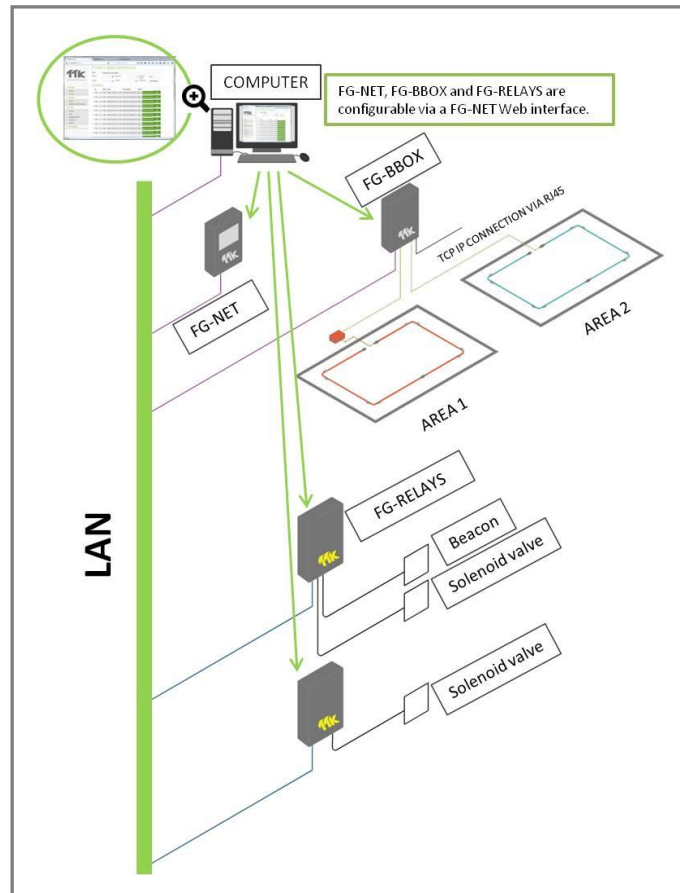


The FG-NET-LL digital unit can be fully configured via its touch screen. It can be also viewed, configured and controlled remotely on a connected computer via FG-NET Web Interface.

The FG-BBOX and FG-RELAYS are external devices of FG-NET-LL. They are monitored by FG-NET-LL via a standard Ethernet network. They can be configured and their real-time status can be viewed via the interface.

## FG-NET - WEB INTERFACE

To remotely view, configure and control FG-NET on a connected computer (via TCP/IP) :



### 4. SYSTEM DESCRIPTION

Liquid Leak Detection System provided by TTK is a complete monitoring system based on FG-OD sense cables and including monitoring units FG-NET-LL and satellite devices FG-BBOX-LL.

The FG-OD sense cables are usually installed along the entire length of the pipeline to be monitored.

The sense cable system is split in several circuits, depending on the pipeline length / architecture.

Each circuit can carry up to 40 individual sense cables.

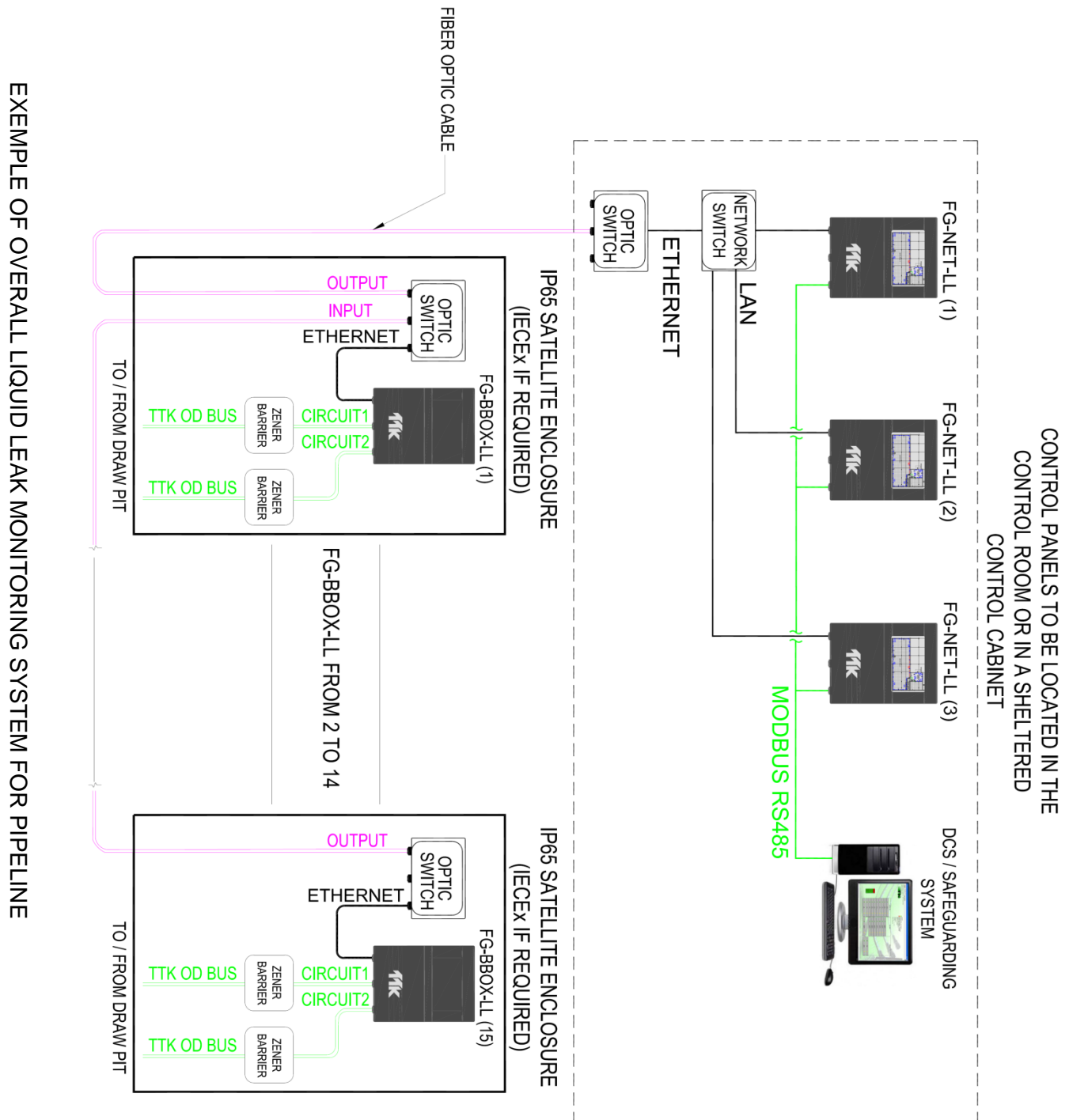
Each single sense cable has a standard length of 3m, 7m, 12m or 20m.

The different sense cable circuits are connected to satellite devices FG-BBOX-LL, each device carrying two circuits.

FG-BBOX-LL satellite devices will be connected to FG-NET-LL monitoring units via a digital communication (Ethernet) network which includes fiber optic switches and fiber optic cables, as indicated in the figure below.

FG-NET-LL monitoring units will be located in a sheltered area (typically the Control Room), while the different FG-BBOX-LL units will be located along the pipeline – placed inside satellite enclosures.

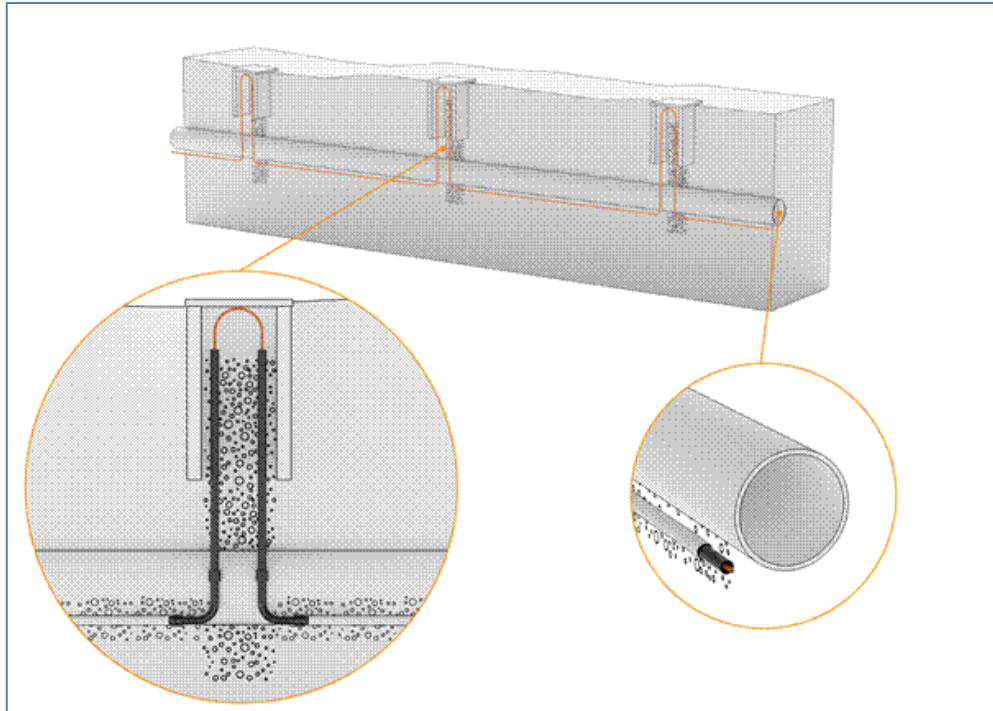




The sense cables will follow the pipeline on his entire routing – including road and pipeline crossings.

For underground sections, the sense cable is inserted in a PVC slotted conduit placed at the same level as fuel pipe bottom, as shown in the following pictures.

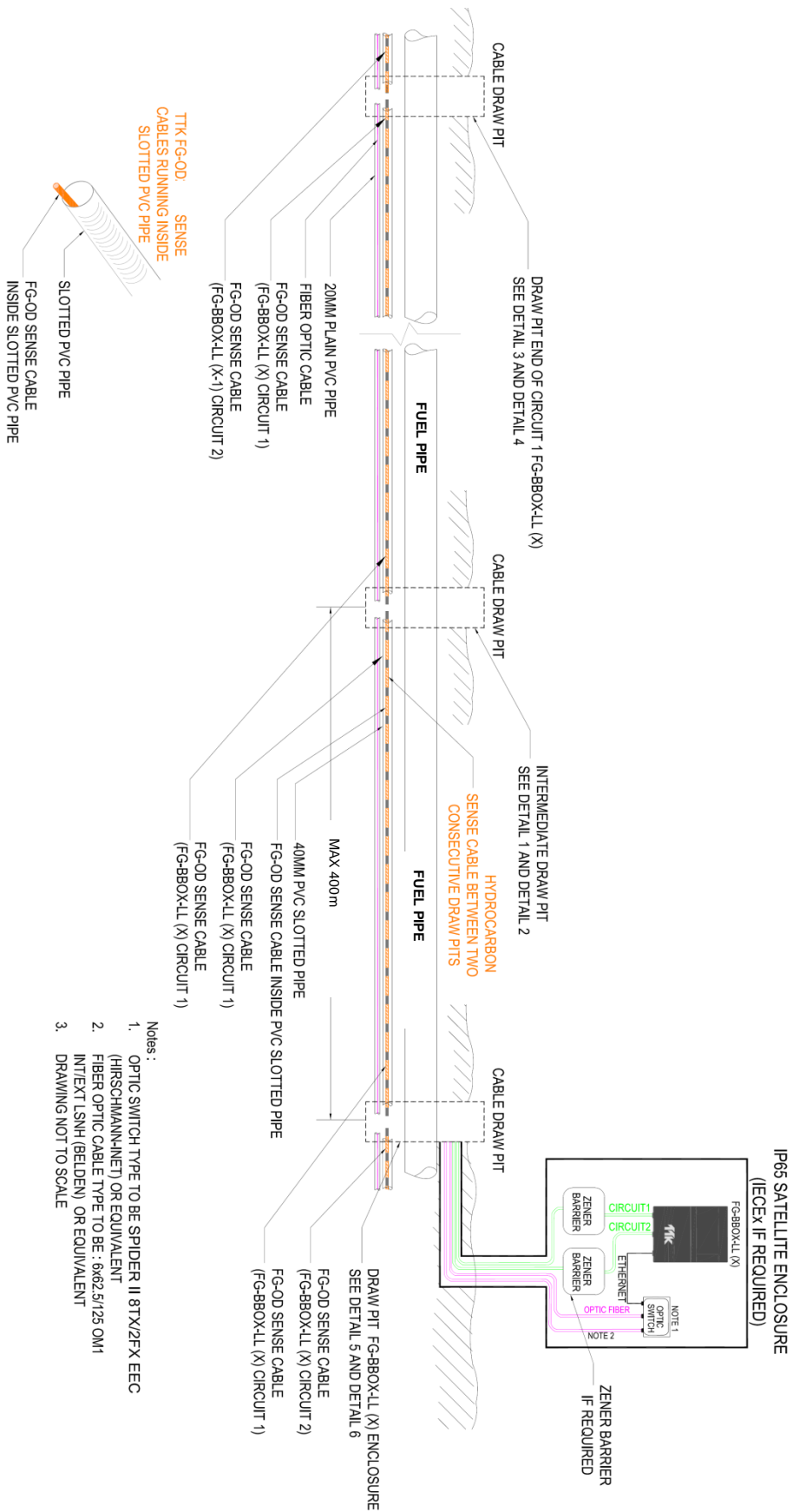
The cable will be accessible via draw-pits, located along the pipeline.

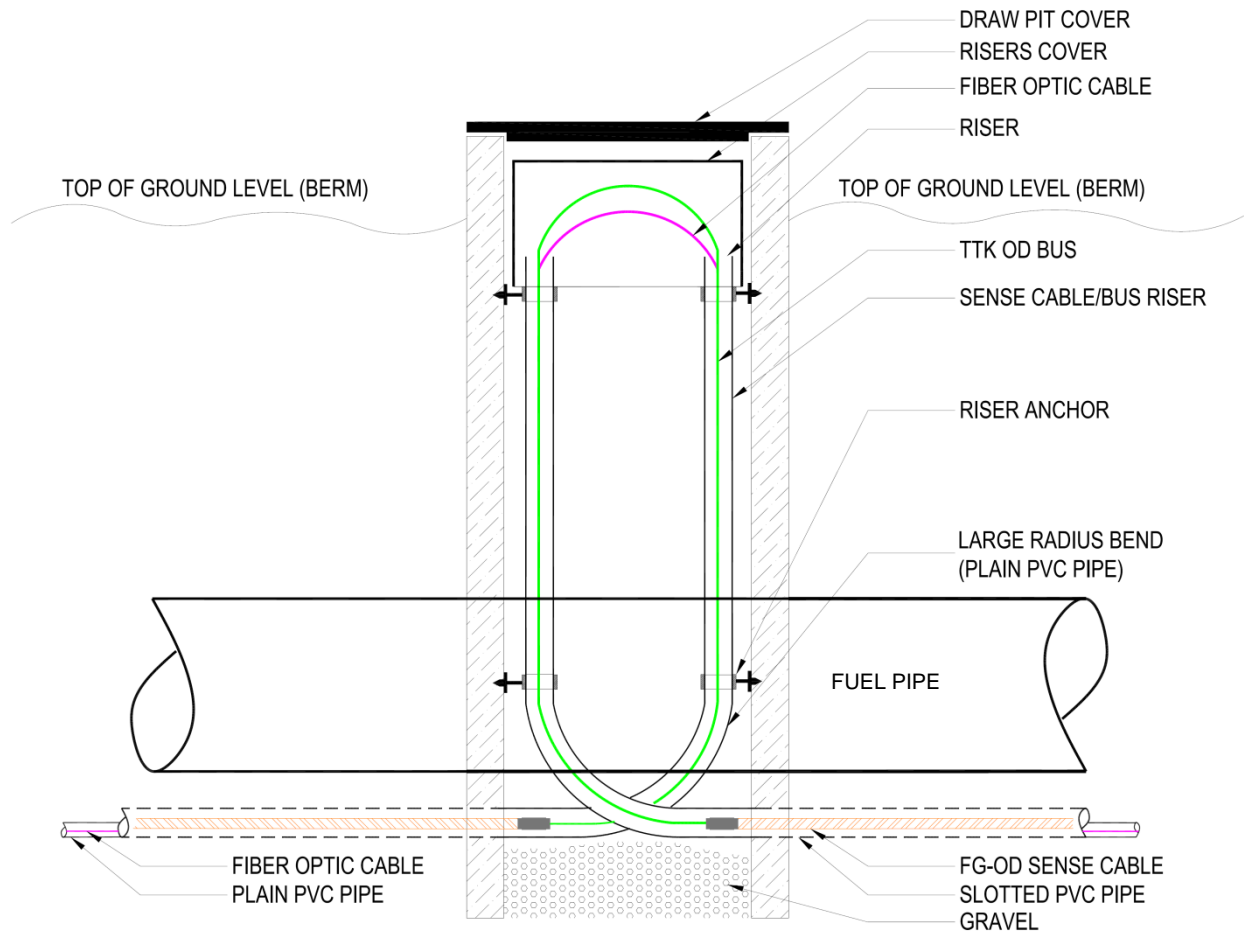


The distance between two adjacent draw-pits shall not exceed 400m.

The system general layout (sense cable installation) on site is illustrated in the following figures.

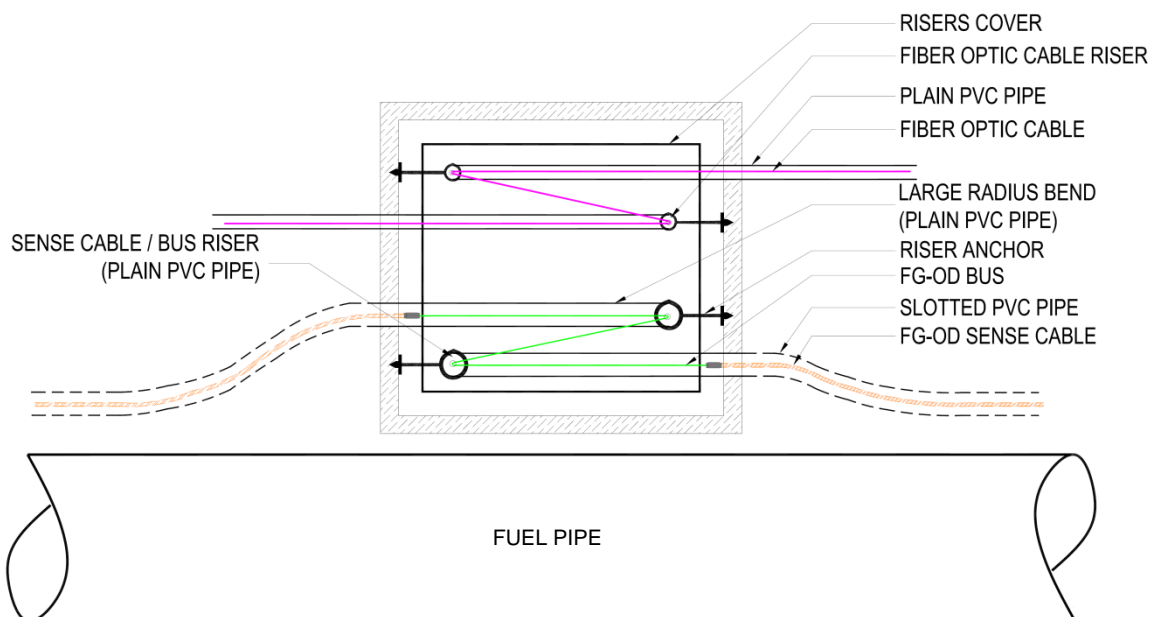
## TYPICAL INSTALLATION OF SENSE CABLE MONITORING SYSTEM ALL ALONG THE FUEL HYDRANT NETWORK





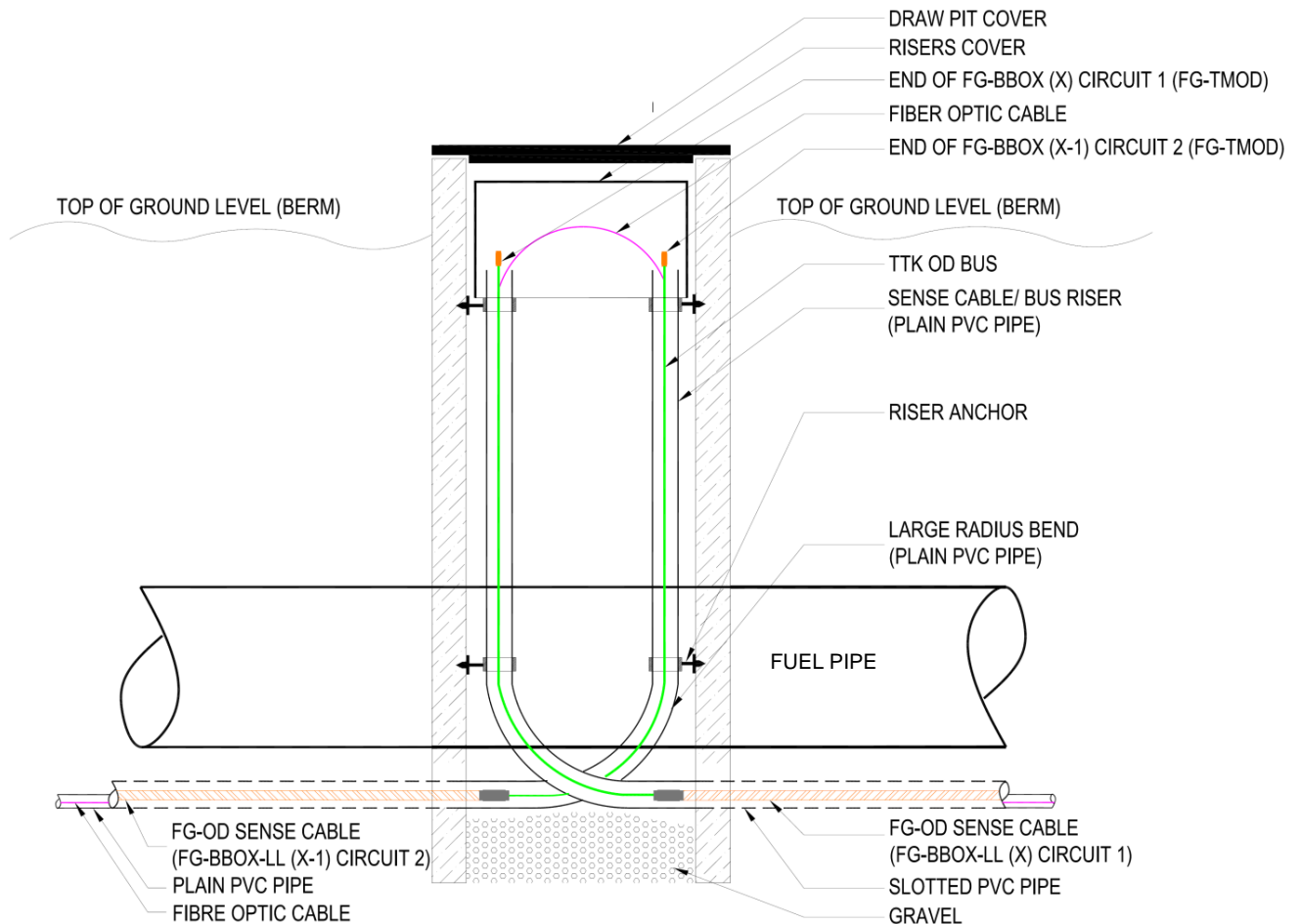
DETAIL 1 : INTERMEDIATE DRAW PIT - SECTION "AA"

NOTE : DRAWING NOT TO SCALE



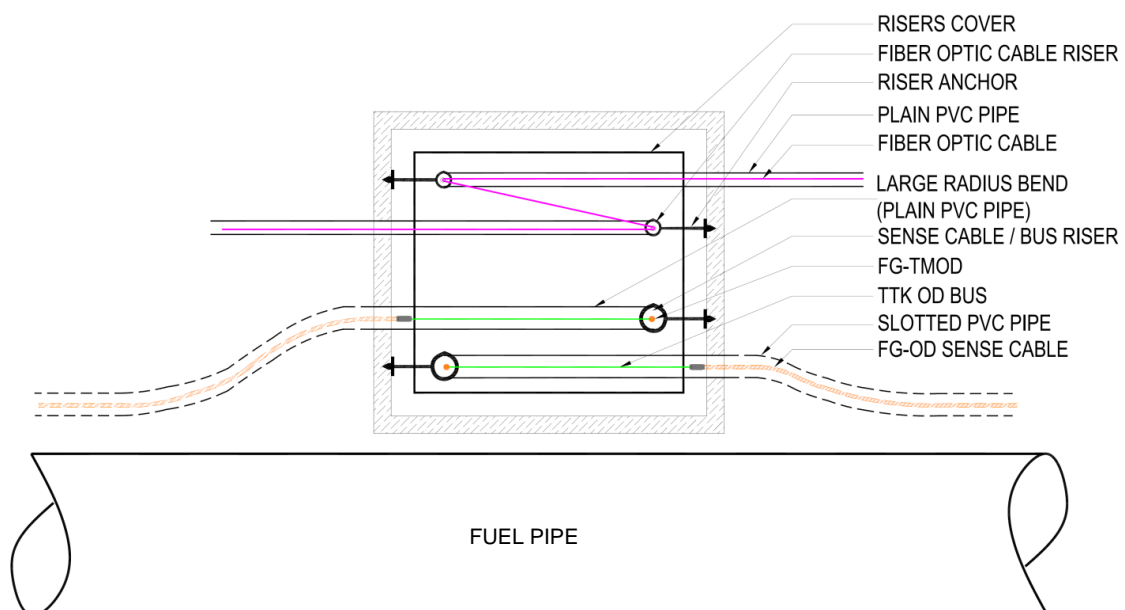
DETAIL 2 : INTERMEDIATE DRAW PIT - SECTION "BB"

NOTE : DRAWING NOT TO SCALE



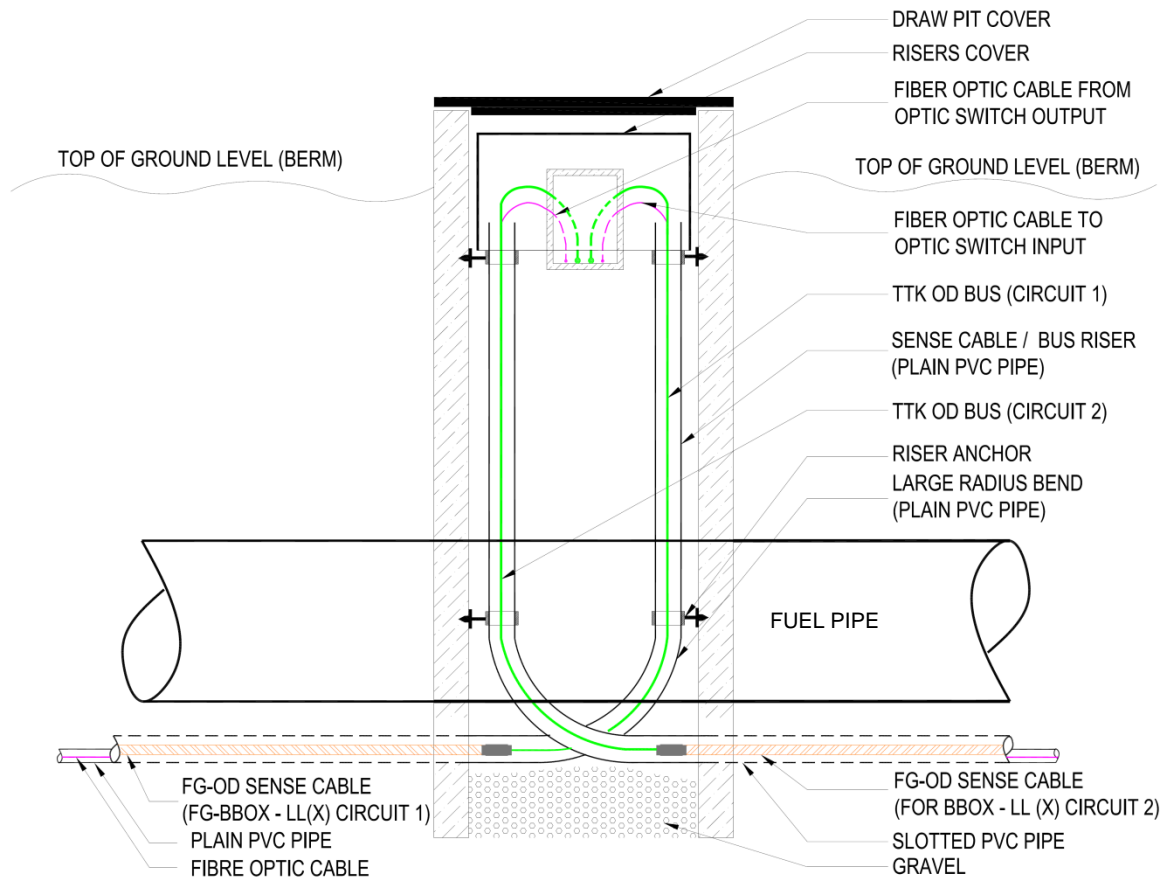
DETAIL 3 : FG-BBOX (X) END OF CIRCUIT 1 DRAW PIT - SECTION "AA"

NOTE : DRAWING NOT TO SCALE



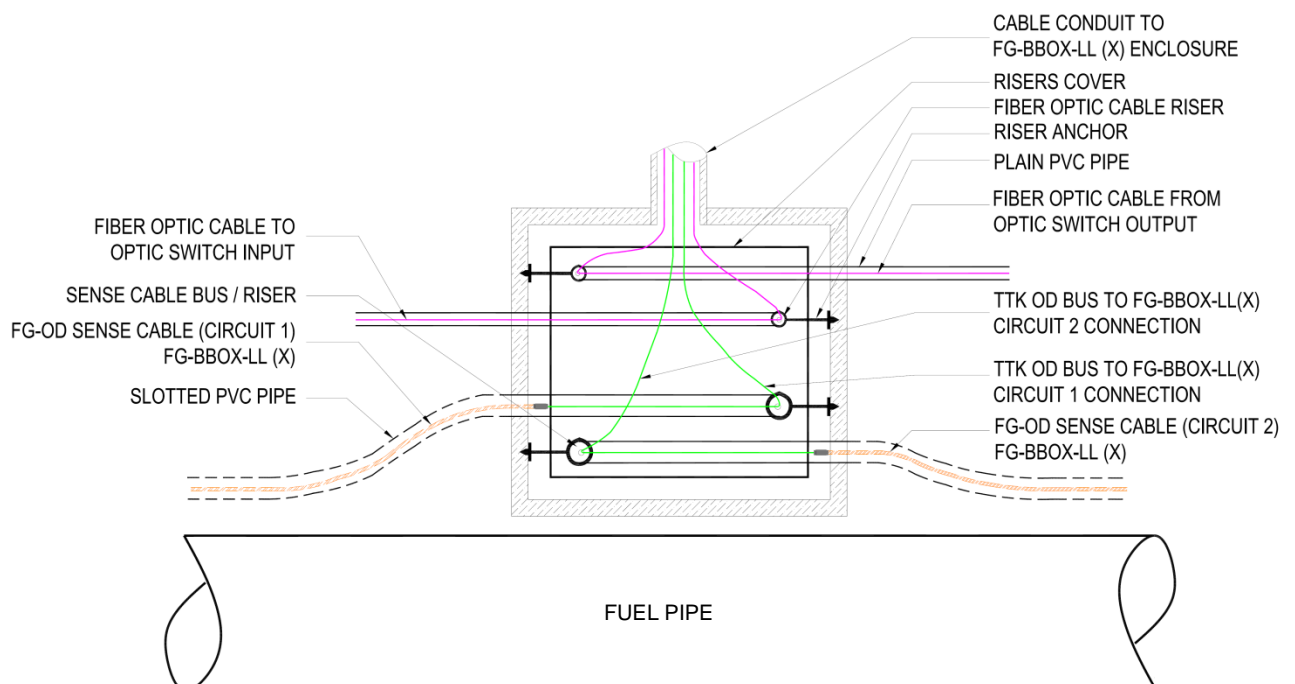
DETAIL 4 : END OF FG-BBOX (X) CIRCUIT 1 DRAW PIT - SECTION "BB"

NOTE : DRAWING NOT TO SCALE



DETAIL 5 : FG-BBOX (X) ENCLOSURE DRAW PIT - SECTION "AA"

NOTE : DRAWING NOT TO SCALE



DETAIL 6 : FG-BBOX (X) ENCLOSURE DRAW PIT - SECTION "BB"

NOTE : DRAWING NOT TO SCALE

### 5. MATERIAL AND INSTALLATION

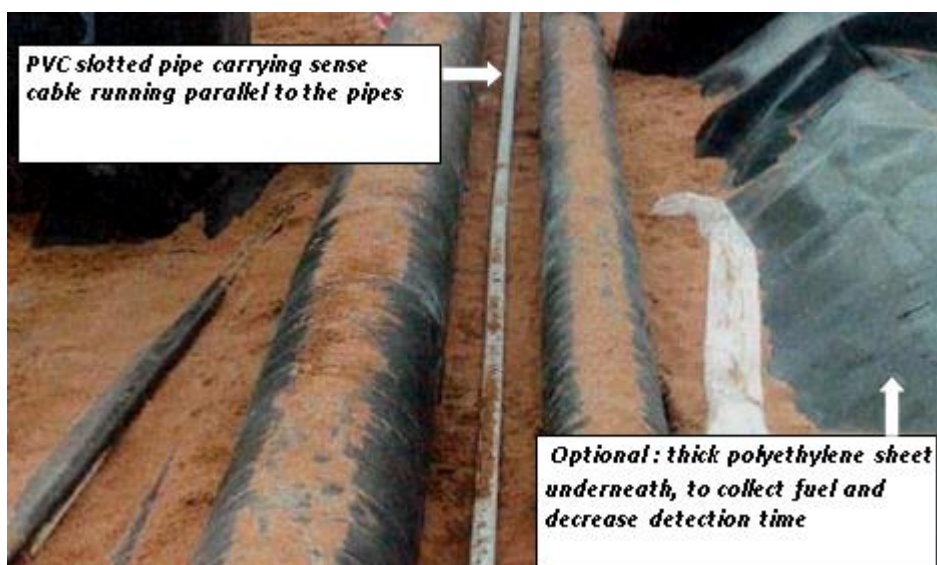
On a Fuel Hydrant System, the sense cable will be installed mostly in buried conditions.

On some parts of the system (e.g. around / close to the storage tanks), the sense cable could be installed in aerial conditions.

The buried installation will be performed according to the following general requirements :

- Sensors run through dedicated plastic slotted pipes to allow sensor maintenance (cleaning after leak detection or replacement in case of damage)
- Filtering fabric sleeve installed around the slotted pipe
- Connectors accessible in junction boxes at grade or in manholes, valve pits or other locations
- Plastic pipe risers installed to reach a level close to grade, making the cable serviceable or replaceable in the field

#### Example of slotted pipe installation



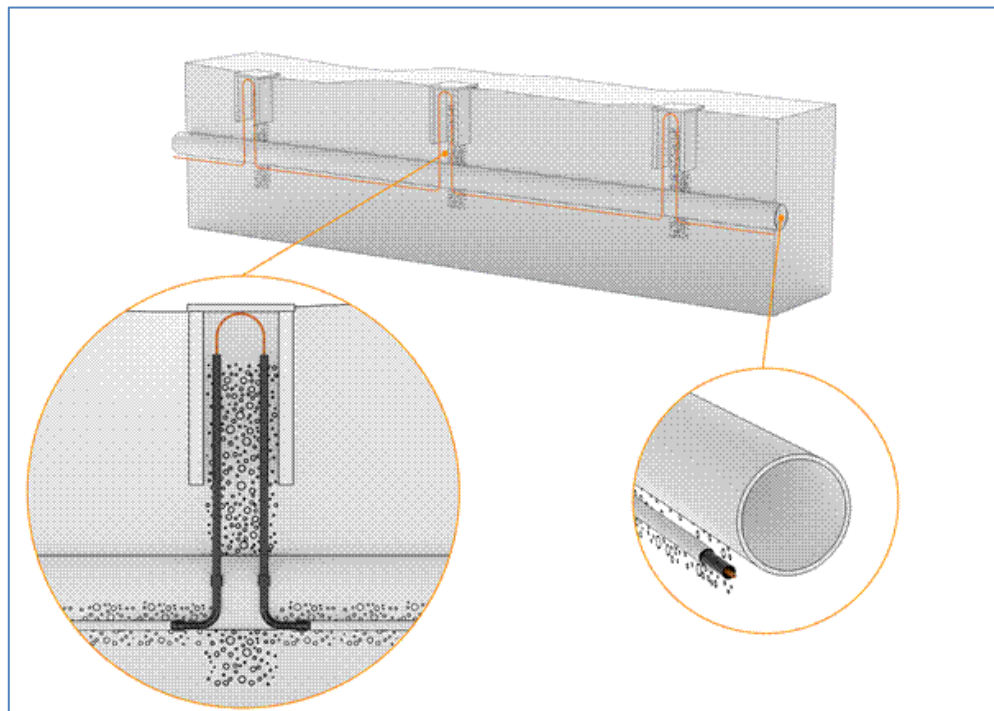
## Example of installation of long radius elbows and risers



It is not required for the draw-pit chambers to reach the pipeline level: usually the chambers will be filled with gravel - plus concrete at the top level - , while leaving the top of the risers accessible.

Generally, a draw-pit chamber height between 400mm and 700mm is sufficient to allow access to the sense cables from grade level.

## Draw-pits along the Pipeline



## 5.1 Material

- **FG-OD : Sense Cable**

Refer to Section 2

On jet fuel main lines (long line application), TTK recommends using direct embedded connections:

1. sensing elements with direct embedded connections in between two consecutive sense cable sections ("LL" feature) – an element length of 20m is deemed appropriate for long line applications, however it is alternatively possible to use 12m, 7m, or even 3m if required,
2. each detection string is formed by "x" adjacent sense cable sections,
3. Disconnectable, plug-socket connectors pre-installed at each string end.



The FG-OD most appropriate reference will be determined depending on project constraints and specifications.

- **FG-CLOD : "OD Bus 8771" Leader Cable 3.5 m**

This jumper cable, provided with pre-installed socket connector, will be used to interconnect the FG-BBOX-LL outlet of circuit 1 or circuit 2 to the sense cable circuit (FG-OD strings).



- **FG-NOD7 : "OD Bus 8771" Jumper Cable 7 m With Connectors**

This jumper cable will be used to interconnect the different sense cable strings forming one circuit.



- **FG-NET-LL : Digital Alarm Unit**

Refer to Section 3

- **FG-BBOX-LL : Satellite Device (if required)**

For monitoring of long pipelines (> 6 km), satellite devices (FG-BBOX-LL), to be connected to FG-NET-LL monitoring unit, are required.

Each FG-BBOX-LL has two circuits, each able to carry up to 99x FG-OD sense cable sections.



The different FG-BBOX-LL required by the project application will form a network which communicates with the FG-NET unit via Ethernet protocol.

- **FG-TMOD : End Plug**

End plug will have to be connected at the end of each sensing circuit – typically to the connector of the jumper cable connected with the last sense cable section of the circuit.



- **ZENER BARRIER**

If the monitored area is classified as explosive, zener barrier will have to be provided on each of the circuits - upstream sense cables.

The zener barriers will be installed as shown on the project scheme.



- **FG-SLPIPE50 : HDPE Slotted Flexible Conduit in 50m roll pre-fitted with filtering sleeve**

The sense cables will be inserted into slotted conduit, allowing for easy cable installation and maintenance whenever required (e.g. cleaning after leak detection or replacement in case of damage).



HDPE slotted flexible pipe is provided in 50m length and have an external nominal diameter of 50mm (40mm internal diameter).

It is pre-fitted with filtering fabric sleeve, in order to prevent:

1. obstruction of the pipe slots
2. sand ingress inside the conduit

The flexibility of the slotted conduit allows to curve the conduit as required – in particular, at risers (inside the draw-pits) – advised curvature  $R > 0.5$  m.

Each 50m conduit roll is provided with one connector, to allow easy jointing of consecutive conduit sections :



- **FG-PUL : Pulling Connector**

Pulling connector, provided with a pulling ring, will have to be connected at one end of the sense cable string for allowing its insertion inside the PVC slotted pipe.

Plug pulling connectors and socket pulling connectors are available – depending on the end of the sense cable string to be pulled.



The pulling ring will host one end of the pulling tape which is initially installed in the slotted PVC pipe.

- **FG-PULTAPE : Pulling Tape**

High strength measuring and flat woven pulling tape will have to be installed inside the slotted PVC pipes during site construction. Connected at the pulling connector ring, It will allow sense cable string to be inserted inside the PVC slotted pipe.





Pulling tape presents the following features:

- moisture resistant, made from 100% polyester for low absorption of moisture
- resistant to conduit cutting during cable pulling (burn-through)
- low elongation for safety and accuracy
- provided with a with sequential meterage printed marking for easy locating

Pulling tape has a width of 12mm and is available in spools of 900m length.

- **Draw-pit sealing kit**

Wherever required, draw-pit can be equipped with a sealing chamber, allowing :

1. to prevent accidental leakage on the outside ground from coming into contact with the buried sensor cable - in place to detect leaks from buried pipelines, not other sources of contamination
2. to easily accommodate any excess detection cable length - which will advantageously be wound into a ring and placed between the risers and the top (waterproof) of the risers chamber.

Not providing water-tightness on the risers may result in leak detection alarm, whenever rain water would carry some accidentally spilled hydrocarbons e.g. during maintenance (valves, pumps, etc).

The riser chamber also avoids entrance of sand and debris carried by rain water, which may potentially result in plugging pipe slots from inside the pipes.

The cover of the riser chamber is fitted with an elastomeric “O-ring” gasket.

The pit bottom and the riser chamber bottom are sealed using a concrete layer :

- 150 mm to 300 mm height is required.

The top of the risers shall be :

- 50 mm – 100 mm distance above the concrete layer
- 150 mm – 300 mm distance from the riser chamber cover



An anchor steel bar, penetrating through the pit wall and the riser chamber, will be embedded inside the concrete layer and ensure the pit does not displace with time.

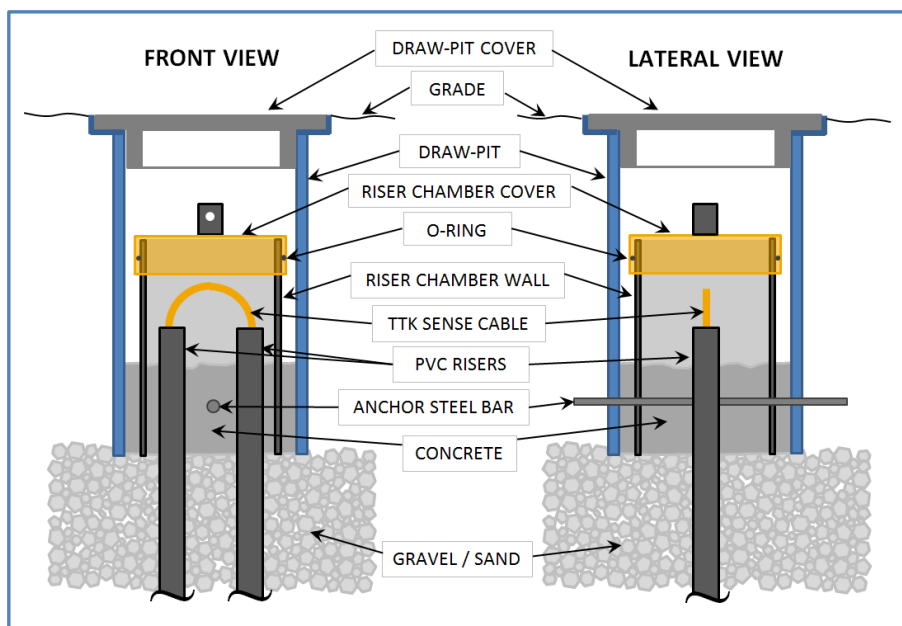
A handling pommel, provided with a 9mm hole, is fitted on the riser chamber cover so that it will be easy to turn and / or pull the cover to open the chamber, whenever required.

The riser chamber and cover are in PVC, and hence insensitive to corrosion over time.

The diameter of the riser chamber is either 200mm or 400mm, depending on the draw pit size (9" or 18").

The standard sealing kit for draw-pits includes:

- a sealing chamber for 9" draw-pit
- two "risers": plain PVC pipe, in length of 0.5m
- two clamps 40-60mm - 9mm rack: to fix the perforated flexible duct on the plain PVC pipe.



## • ES-OD Tags : Identification Labels

Identification label will be provided in each draw-pit (see below) to identify the liquid leak detection circuit.

Identification labels are available in packs of 40 units each.



## **NOT INCLUDED IN TTK SCOPE OF SUPPLY :**

Besides TTK accessories listed above, the following references, available on the market, will have to be provided - TTK advises the Installer to directly procure them.

- **Bus (Jumper) Cable**

Appropriate length of the cable specified below is required to interconnect :

- the beginning of the sensing string (connected with the leader cable FG-CLOD) to the monitoring panel
- sensing strings located on the same circuit but at different locations.

Cable specification :

- Instrumentation tray cable, 250V to 300V
- Three stranded copper wires - one triad – 18 AWG min. ( $S=0.82\text{mm}^2$ ) plus drain 22 AWG
- Overall aluminium shield
- Stainless steel armoring – if required by End User or local norms / standards
- PVC insulation/jacket, oil resistant (aliphatic hydrocarbons), UV resistant
- Examples of acceptable market references :

Non armored :

- BELDEN : 8770
- France : 01IT 09 EG SF - following NF M 87-202 standard

Armored :

- BELDEN : 1 (or 6, or 7) - 5 - 1036A
- France : 01IT 09 EG FA - following NF M 87-202 standard

Examples of acceptable bus cable structure - armored



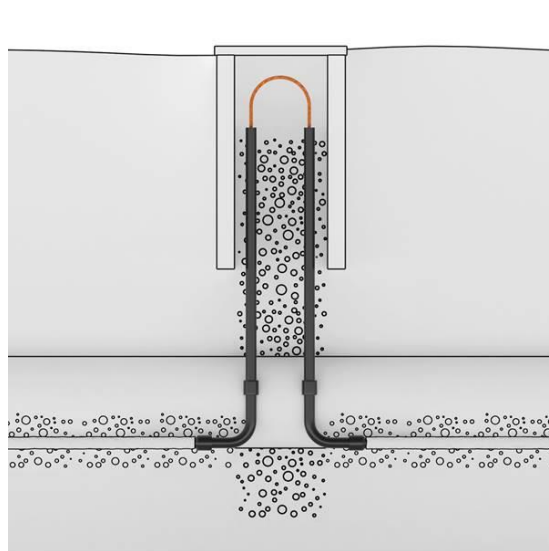
- **Draw Pits**

Each of the sense cable strings will be accessible via a draw pit, from which the string will be inserted inside the slotted conduits.

The distance between two consecutive draw pits shall not exceed 400 m.

Gravel to be provided at draw pit bottom, to ensure proper pit drainage – min. gravel bed height = 250mm

TYPICAL DRAW-PIT – SECTION VIEW



- **Communication Network**

On a TTK liquid leak detection system, the communication between FG-BBOX-LL satellite device(s) and FG-NET-LL control unit(s) can be ensured using different type of links, depending on the project constraints: fiber optic cable or wireless.

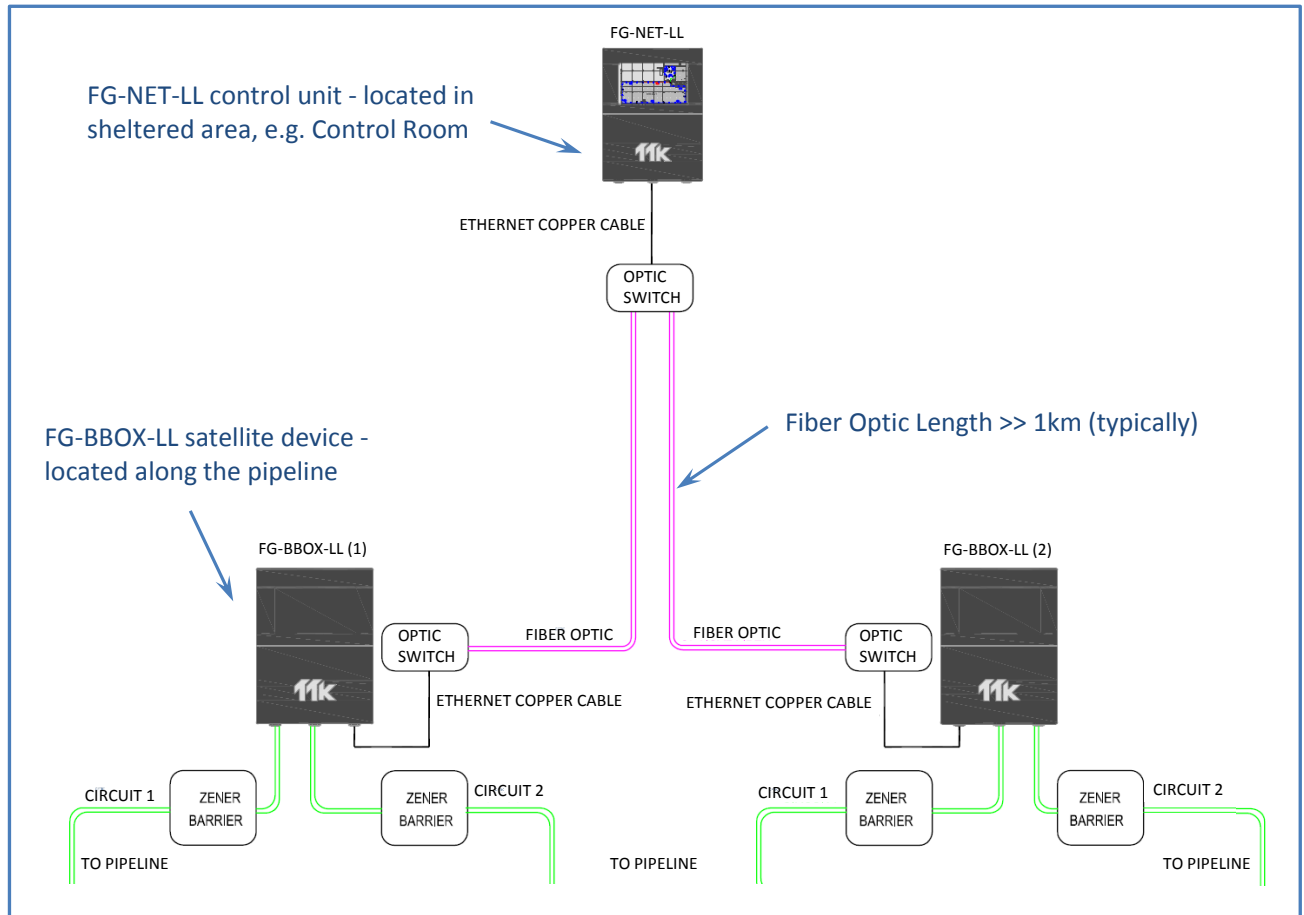
In case **fiber optic cable link is used**, external optical switch(es) to convert the electronic signal from the Ethernet copper port of FG-BBOX-LL / FG-NET-LL units into optic signal, is (are) required.

With fiber optic cable, long distances can be covered – up to about 20 km between optical switches (amplifiers). Using optic cable(s) would allow minimizing the jumper cable (“OD Bus 8771”) length, since in this case the FG-BBOX-LL device(s) are placed close to the monitored area.



An example of a simple installation using optic switches is indicated in the picture below.

## Fiber Optic-based communication network: architecture example



Fiber optic network material will have to be compliant to the following specifications :

- Fiber optic cable to be type : FO 6 x 62.5/125 OM1 - INT/EXT LSNH (by BELDEN) or equivalent
- Optic switch to be type : SPIDER II 8TX/2FX EEC (by HIRSCHMANN-INET), IGT-1205AT (by PLANET) or equivalent

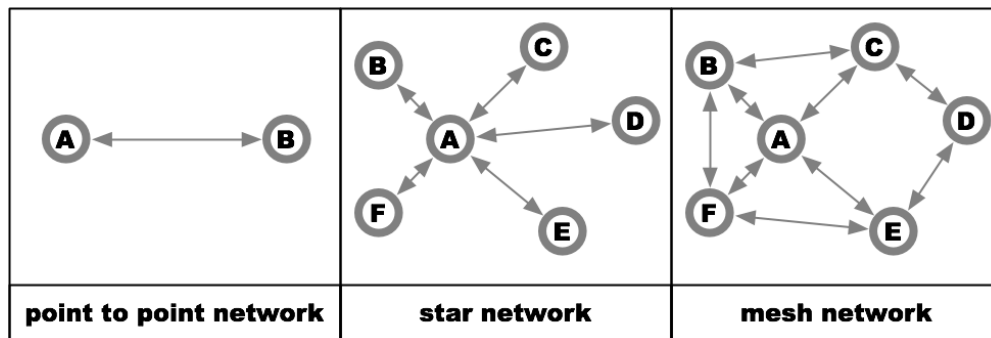
SPIDER II 8TX/2FX EEC  
(by HIRSCHMANN-INET)

IGT-1205AT  
(by PLANET)



## Network structure

Three network structures are possible, as shown in the figure below.



On Pipeline Projects, a linear architecture (a sequence of “point-to-point” connections) is deemed to be best suited.

All material required for interconnecting monitoring units FG-NET-LL with satellite units FG-BBOX-LL will be supplied by Pipeline Construction Contractor or designated Subcontractor.

### • **Satellite Enclosures**

IP65 satellite enclosure will have to be provided for each of the FG-BBOX-LL units installed in the field (non-sheltered environment).

Satellite enclosure will host the following devices :

- FG-BBOX-LL
- zener barrier
- optic switch (plus associated transformer if required)

If the monitored area is classified as explosive, the satellite enclosure will have to be suitable for IECEx / ATEX Zone 0 or Zone 1.

### Typical ATEX Zone 0 Satellite Enclosure



## 5.2 Installation Recommended Practices

The installation of the sense cable on the field will have to be performed (by Contractor) according to the following TTK recommended practices.

NB : in all cases, FG-OD sense cables shall be accessible after the installation - to examine or remove FG-OD sense cables once they have been installed along the fuel system.

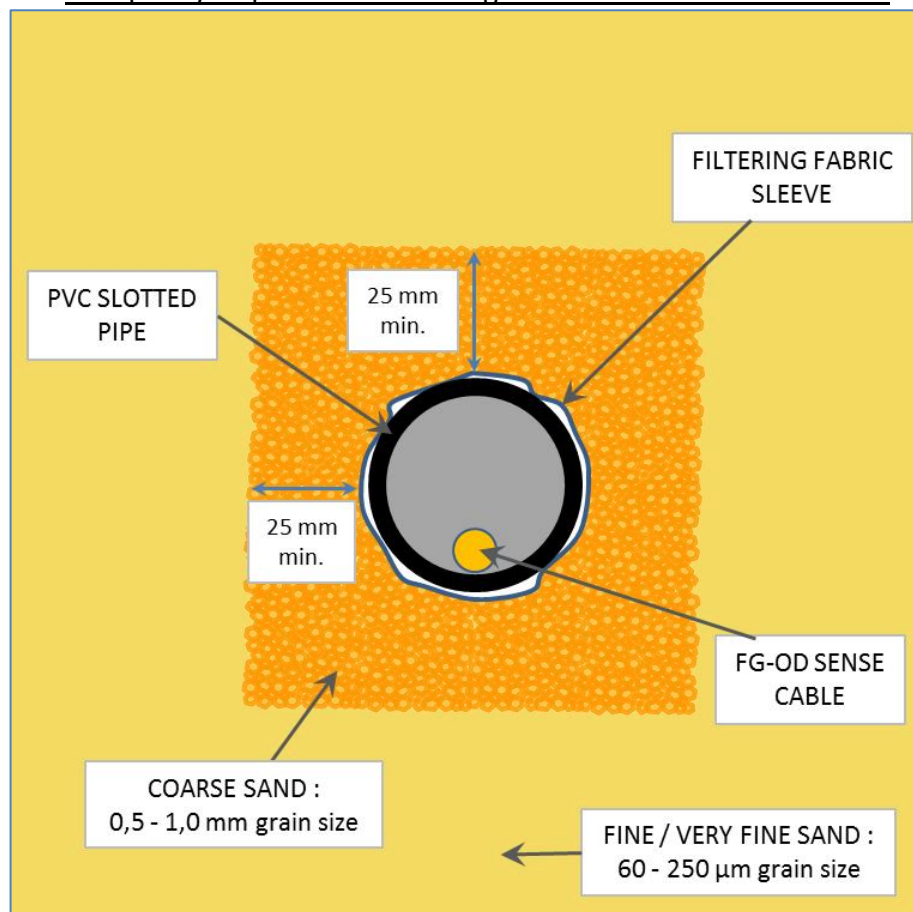
FG-OD sense cables shall be installed in a clean environment, to avoid mechanical damage of the cables during installation / maintenance that could be caused e.g. by coarse sand or debris.

- Slotted conduits protected by filtering fabric sleeves, in which pulling tape / cable has been inserted, will be installed close to the fuel line bottom crown, in the trench opened during the pipeline construction.
- Fine sand, coarse sand or small size gravels will have to be provided around the slotted conduits, to ensure proper drainage and avoid plugging of the filtering fabric sleeve by fine particles, following the picture below.

NB : In replacement to, or in addition to, the filtering fabric, a geotextile layer wrapping the slotted pipe can be used.

### Draw-pits along the Pipeline

#### Soil quality requirements relating to slotted conduit installation



- After a section of a certain length (e.g. 50m) of slotted pipe is put in place close to the pipeline, pulling tape / cable to be inserted inside slotted pipe using an appropriate rod – see example below.



The entire length of slotted pipe between two consecutive draw-pits shall be fitted with inserted pulling tape / cable.


- Large radius ( $R=700\text{mm}$  min.) bends and risers shall be provided inside the draw pits - risers shall be secured to the draw pit walls thanks to riser anchors, or embedded into gravel / concrete bed.
- Draw-pits to be installed following best construction practices – in particular, proper draw-pit stability with time / anchoring in the ground to be ensured.
- The pulling connector (provided with a pulling ring) will have to be connected at one end of the string for allowing sense cable installation.
- Each end of the pulling tape, pre-installed inside the slotted pipe, will have to be left out of the riser.
- Once the installation of a slotted pipe section between two consecutive draw pits is completed, the sense cable can be pulled in between two consecutive draw-pits, from a draw pit at one side.
- Pulling tape end – left at riser top – will be secured to the ring of the pulling end plug.
- 7m pre-connected jumper cable (FG-NOD7) will be connected, on one end, to the pulling end plug, and, on the other end, to the end connector of the sense cable string to be installed.
- Pulling tape will be pulled from the top of the riser of the consecutive draw pit and sense cable string will be inserted into the slotted pipe, until the sensing string end (connection to FG-NOD7 jumper cable) will reach the bottom of the draw-pit (long radius elbow).
- The free end of the jumper cable (FG-NOD7) will be connected to the following sense cable string.
- The same pulling operation described above will be performed for all the draw pits
- Any excess length of jumper cable will be left loose from the top of the risers, in the draw pit.



- Riser outlet to be “closed” by using filtering fabric or geotextile, in order to prevent sand / debris ingress into the riser.
- The different strings connected with FG-NOD7 jumper cable will form a circuit of up to 40 sense cables connected to a FG-BBOX-LL unit.
- Each circuit of a FG-BBOX-LL unit would generally extend through several draw pits.

**Disclaimer :**

TTK's FG-OD cables are certified ATEX / IECEx as per the above mentioned marking, according to EN / IEC 60079-0, EN / IEC 60079-18 and EN / IEC 80079-34.  
Special installation precautions are required where explosive areas are concerned. E.g. the use of zener barriers, specific location of alarm and/or satellite panels, .... The customer is responsible for the verification that the design and installation of the detection system, in an ATEX / IECEx classified zone, is consistent with the classification of the area. The customer retains sole responsibility for their use of TTK's products.

TTK - Type : FG-OD  
CE 0081  II 1 G  
Ex ia IIB T4 Ga  
LCIE 13 ATEX 3082X  
IECEx LCIE 13.0072X

-30°C < T < +100°C

