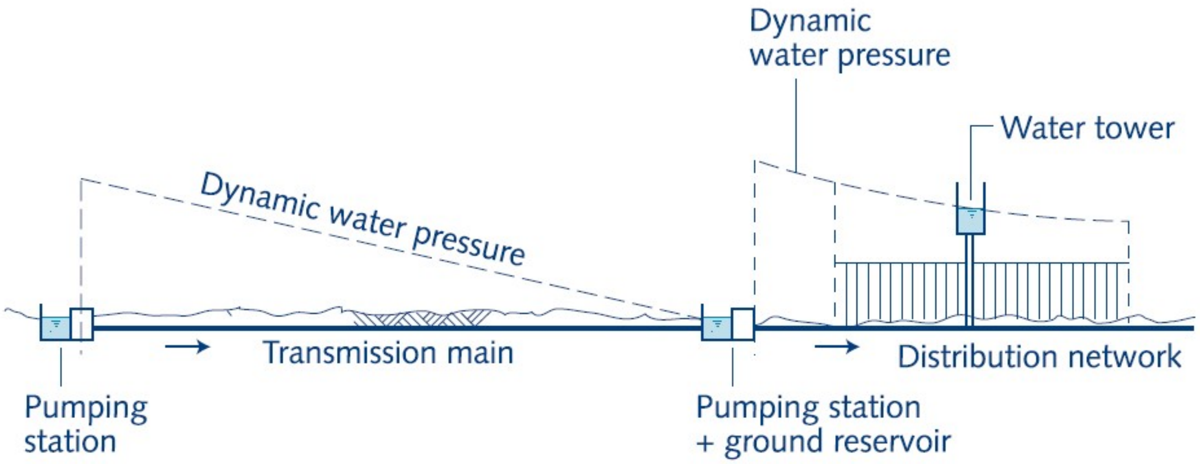
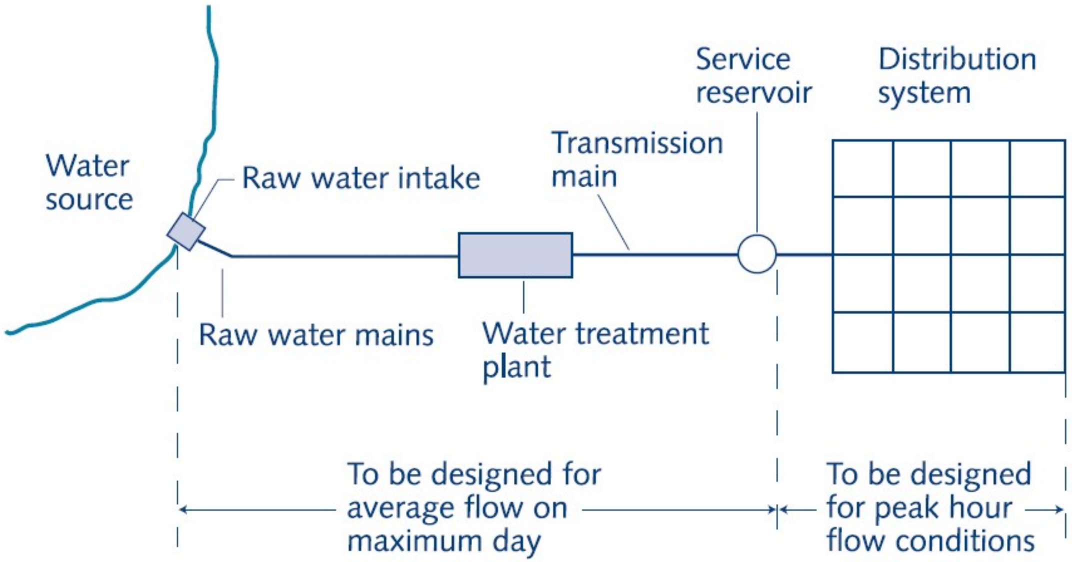


# MATERIALI PER CONDOTTE DI SISTEMI DI DISTRIBUZIONE



# Materiali per le condotte di acquedotto

| | pregi | difetti |
|---|---|---|
| Cls (muratura) | Grandi diametri (CLS armato)<br>Una volta diffuse…ora ok per acque grezze o grandi D | Funzionamento a pelo libero non sempre possibile<br>Scarsa resistenza mecc. → regolare le manovre in presenza di sollevamento |
| plastici | Igiene, tenuta, stabilità chimica (resistenza a corrosione int/ext.)<br>PEAD: facilità di giunzione (saldati termicamente) | PEAD T<40°<br>D<1200 (PEAD); 600(PVC)<br>PN<PN16 (Pesercizio=16 bar) |
| Metallici (acciaio e ghisa) | Tenuta, caratteristiche meccaniche<br>P es. < 2.6 MPa = 26bar(acciaio), 20-30 atm (ghisa)<br>(grandi dislivelli → grandi pressioni e transitori, + ATTRAVERSAMENTI) | Soggetete a corrosione → rivestimento int/ext e protezione catodica<br>Blocchi di ancoraggio se necessari |

# CORROSIONE

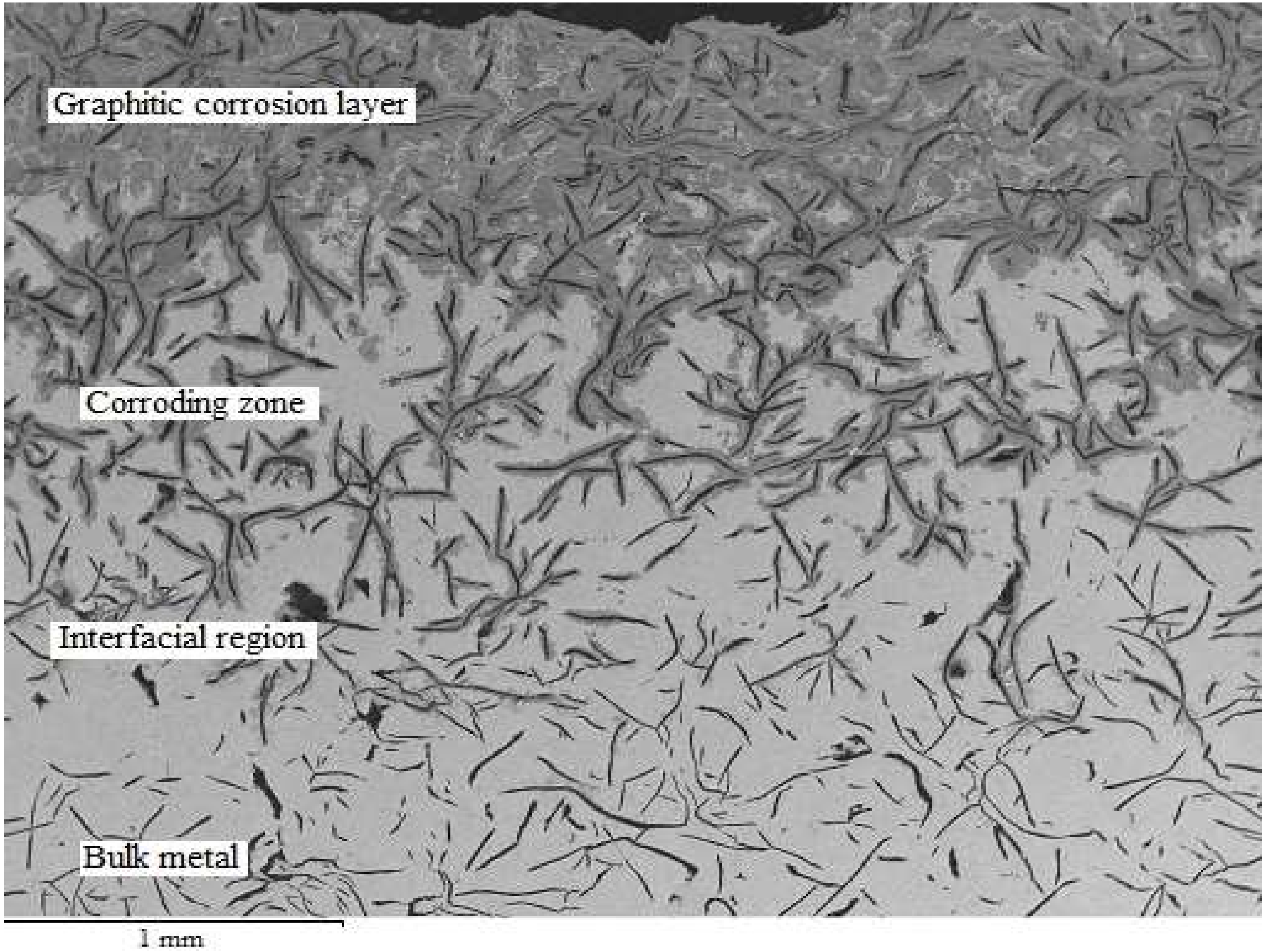
La corrosione dei tubi in materiale metallico genera:

Perdita di spessore della condotta a causa della solubilizzazione di metalli ossidati, con conseguente aumento delle perdite
Aumento della scabrezza del tubo e conseguente riduzione della capacità di portata
Influenza negativa sulle caratteristiche organolettiche delle acque trasportate

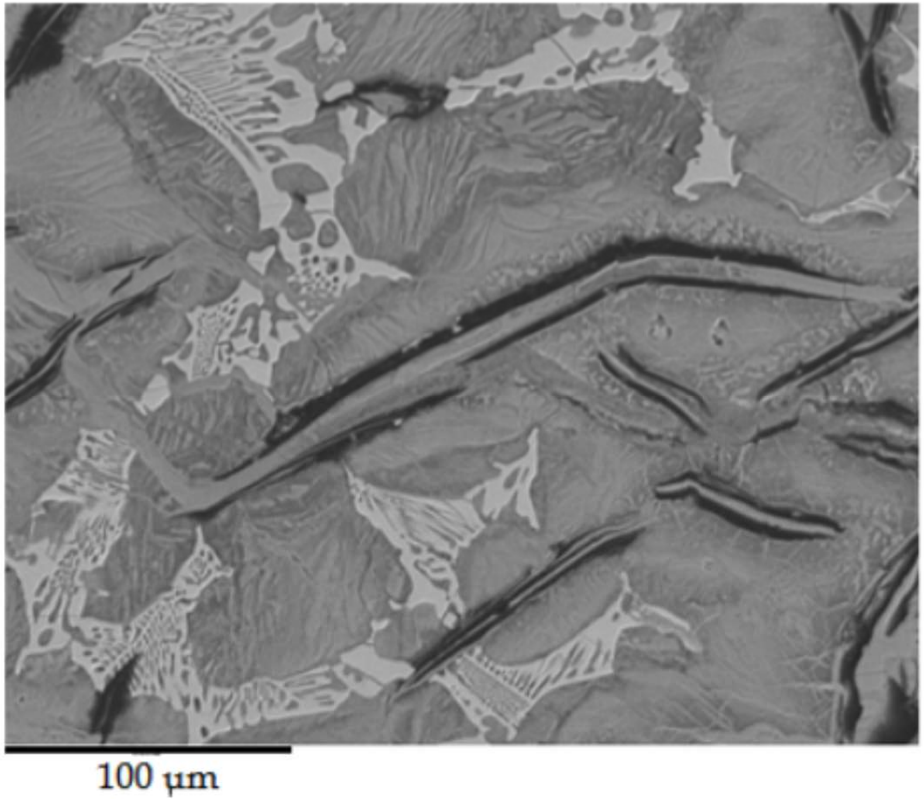
Per ridurre la corrosione:

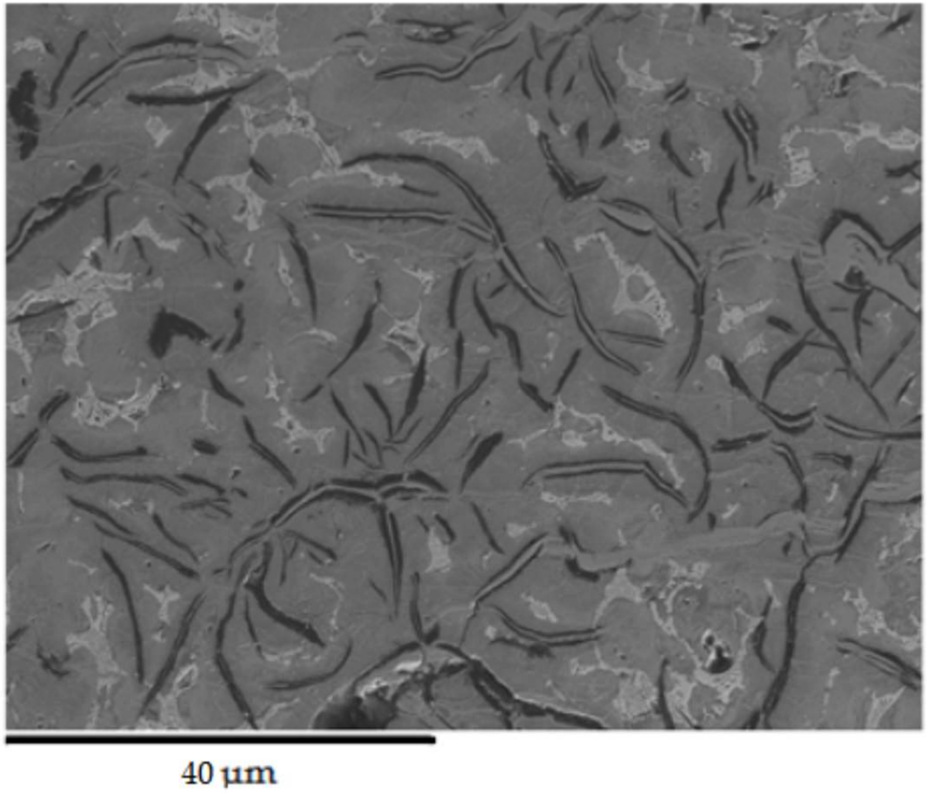
Rivestire internamente ed esternamente le condotte (resine epossidiche, bitumose, materiale plastico);
Predisporre un sistema di protezione attiva.

# Tubo in ghisa soggetto a corrosione

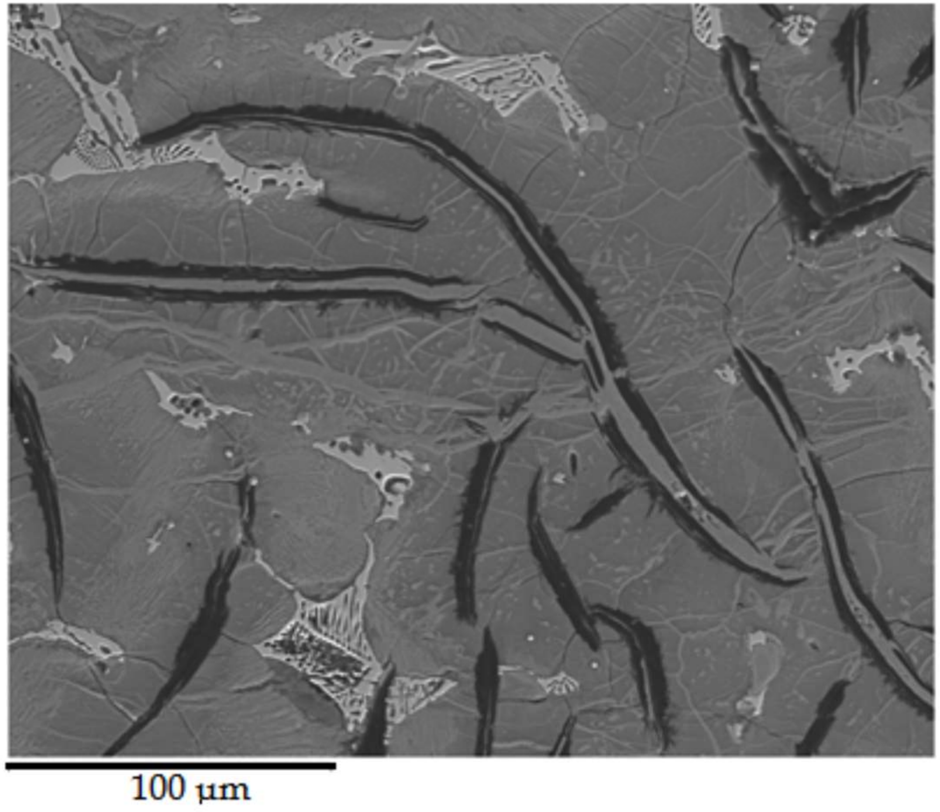


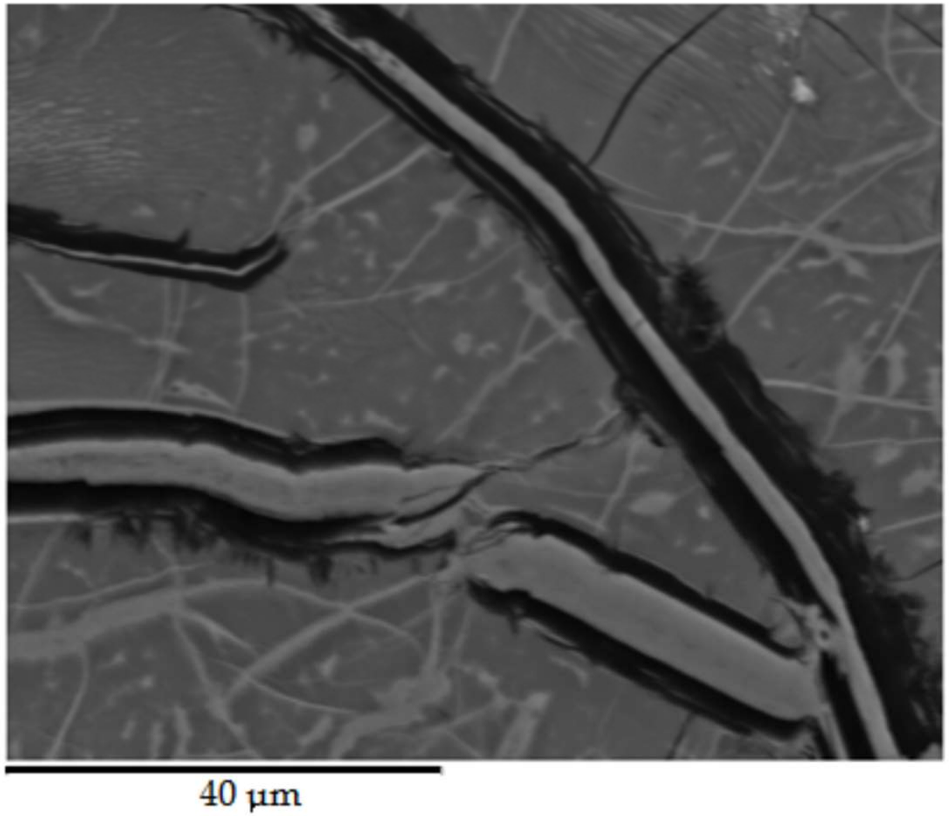
- Ferro quasi completamente ossidato
- Fiocchi di grafite deteriorati
- Ossido di ferro all'interno del fiocco di grafite





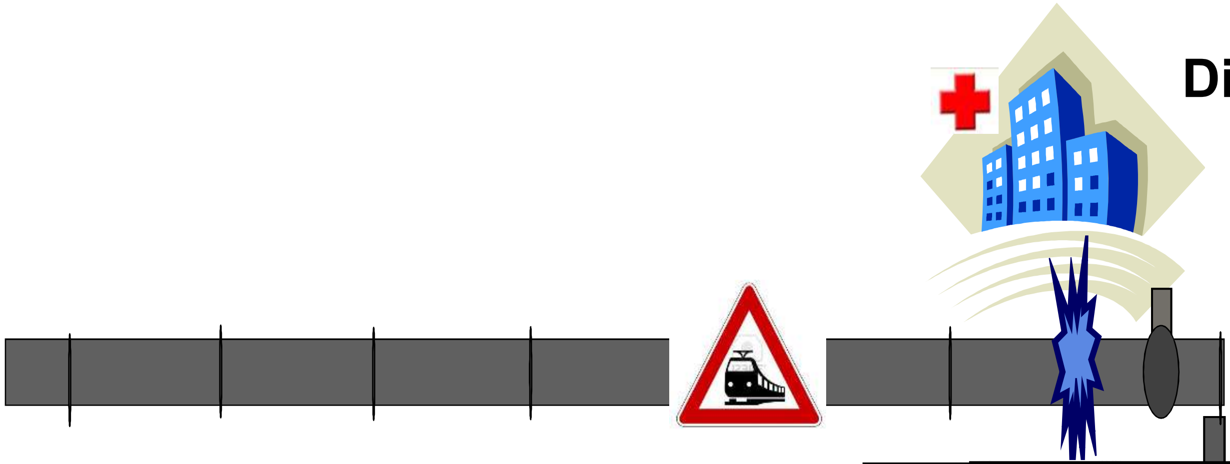
- A ingrandimenti più elevati, si possono vedere delle crepe all'interno della matrice.





# RICERCA PERDITE

# Trunk mains failure can have significant flooding consequences



Distribution Network

Distribution

Trunk Main Network

**Diametro=1 m**

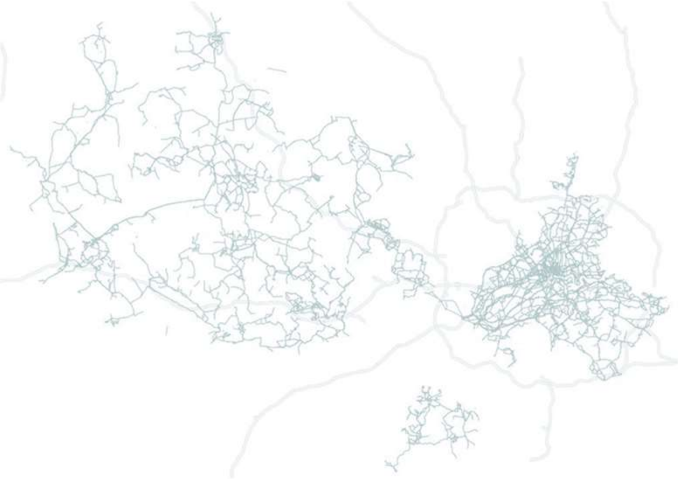
**Velocità= 0.75 m/s**

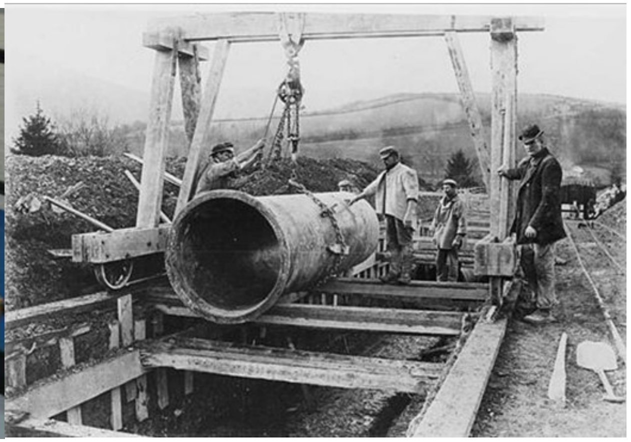
**Portata =0.6 m$^3$/s**

Failure of a 42 inch cast iron pipe in west London

Il costo del danno derivante dalla rottura di una condotta di grande diametro può arrivare a diversi milioni di sterline/euro

- La rete di distribuzione idrica di Londra costruita nel corso di molti decenni è composta da tubi diversi per materiale, metodo di fabbricazione, dimensioni ed età.
- Tutti i materiali si deteriorano a contatto con l'acqua.
- I tassi di deterioramento dipendono dal tipo di materiale e dall'ambiente in cui si trova ad operare la condotta.
- I tassi di deterioramento interno ed esterno sono (spesso) diverse.
- È necessario identificare i fattori di rischio che possono accelerare il deterioramento.





We don’t know **when** and
**where** a trunk main will burst

Una volta individuate le aree a rischio più elevato, è possibile intervenire in uno dei modi di seguito elencati:

→ sostituzione

→ riduzione delle pressioni

→ riconfigurazione della rete

→ messa in opera di misure di mitigazione della corrosione

## Fattori che determinano l’insorgenza di perdite

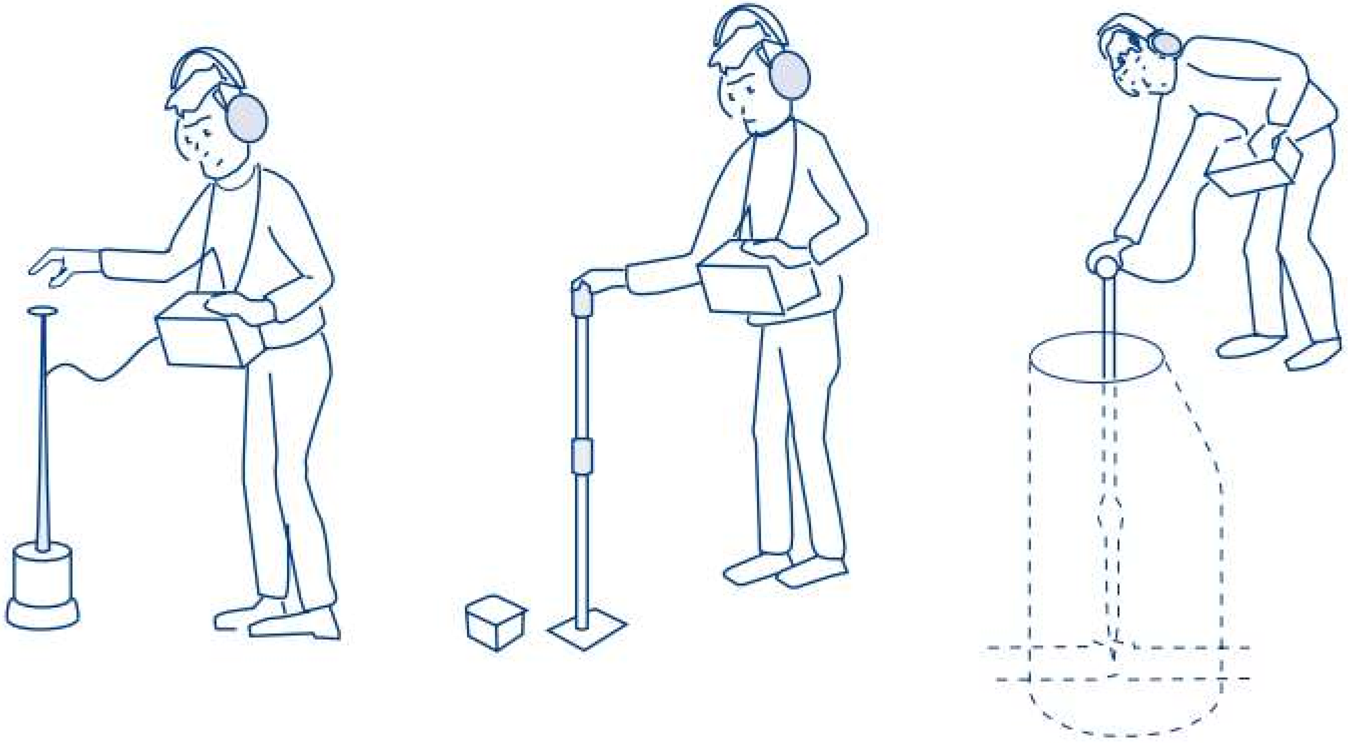
- caratteristiche dei terreni di posa, carichi sulla superficie del suolo, traffico, cedimenti
- difetti nelle condotte e mancanza di tenuta dei giunti
- danni accidentali prodotti da scavatori operanti nella zona
- età e corrosione delle condotte
- sbalzi di pressione
- sbalzi di temperatura

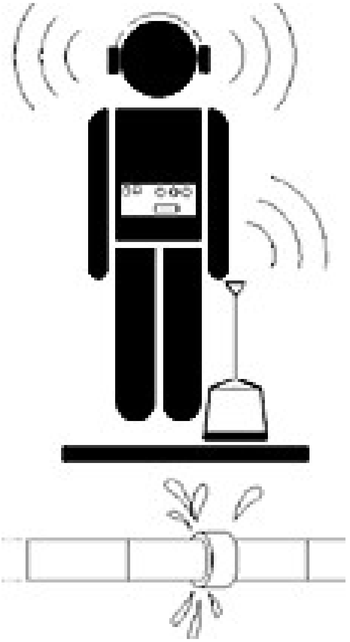
# LOCALIZZAZIONE DELLE PERDITE

**Acoustic detectors** rely on sounding directly on the pipe or fitting, or indirectly on the ground surface.

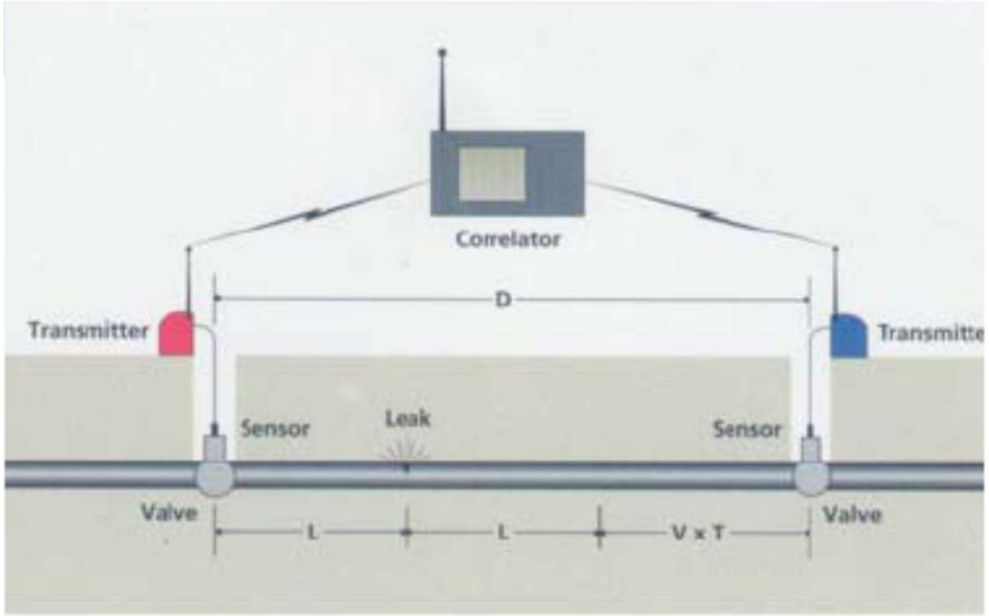
The noise generated from the leak is transmitted by the receiver attached to a stick, to the amplifier connected to a stethoscope.

This method is not always reliable; leaks at lower pressures and specifically those in plastic pipes may produce undetectable noise.





**Leak noise correlators** detect the exact burst location by registering the noise spreading through the water. By placing microphones at the ends of the controlled pipe section (up to a few hundred metres), the difference in time required for the leak noise to reach the microphones can be measured. The leak position can then be calculated from the known length of the section. This method is less accurate when being used in sections with plastic pipes or with more than one leak.

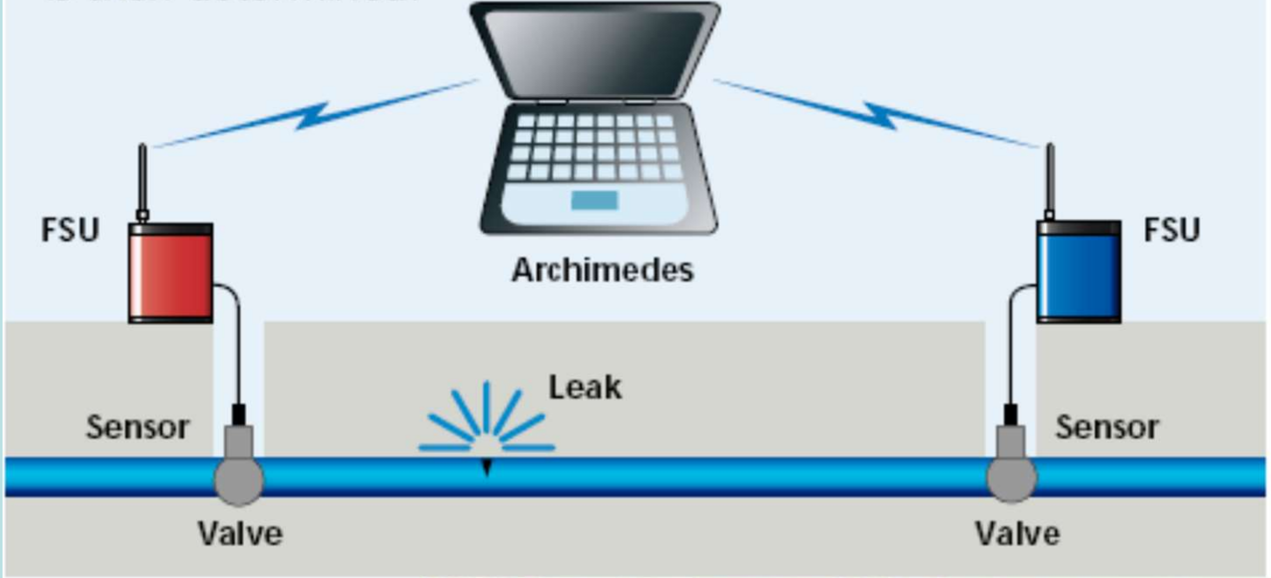


$$V = \frac{D}{t} = \frac{L-2x}{t} \Rightarrow$$

$$\Rightarrow x = \frac{L-Vt}{2}$$

## *Principle*

*Sensors are positioned either side of the suspected leak position and the time taken for the leak noise to reach respective sensors is measured. Entering the distance between sensors and the velocity of sound the leak position is then determined.*



*The ultimate in leak noise correlator performance for the most difficult applications*

# GESTIONE E MANUTENZIONE DEI SISTEMI DI DISTRIBUZIONE

Volumi d’acqua fatturati < Volumi d’acqua immessi in rete

↓

**Unaccounted-for water**

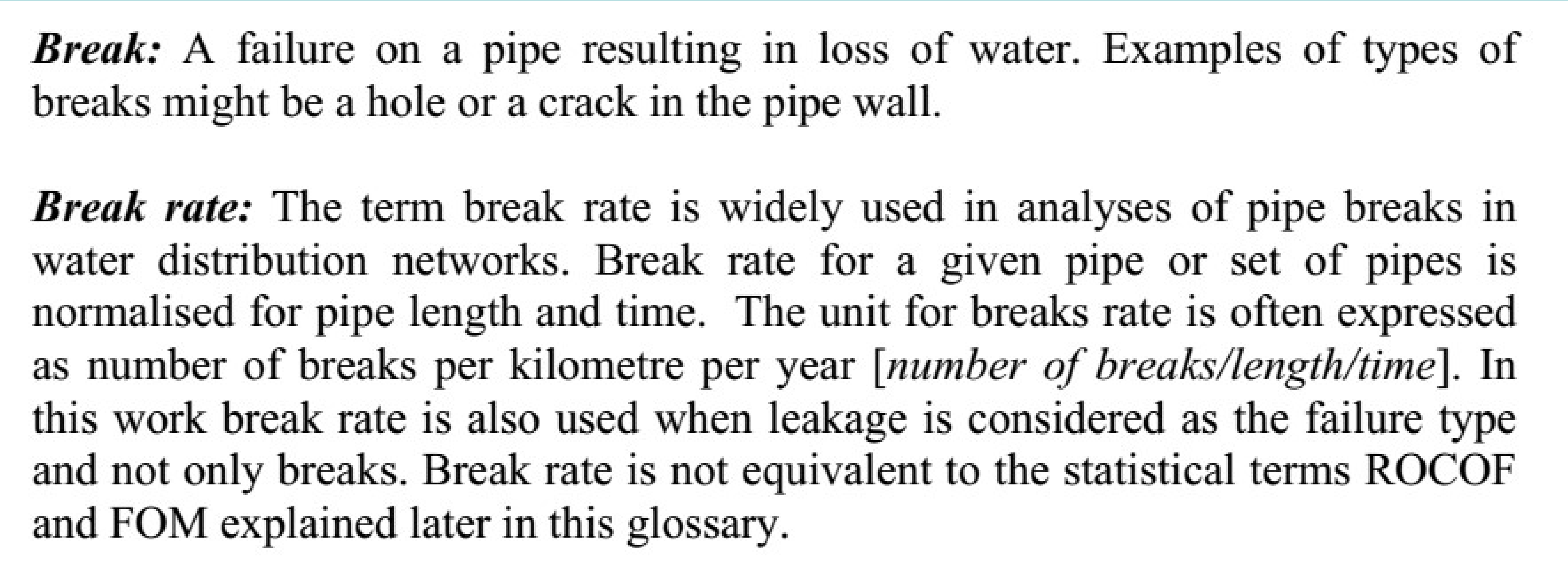
**(fino a 50% dei volumi immessi in rete!)**

Volumi d’acqua prelevati dalle utenze < Volumi d’acqua immessi in rete

↓

**Perdite**

# Glossary of terms

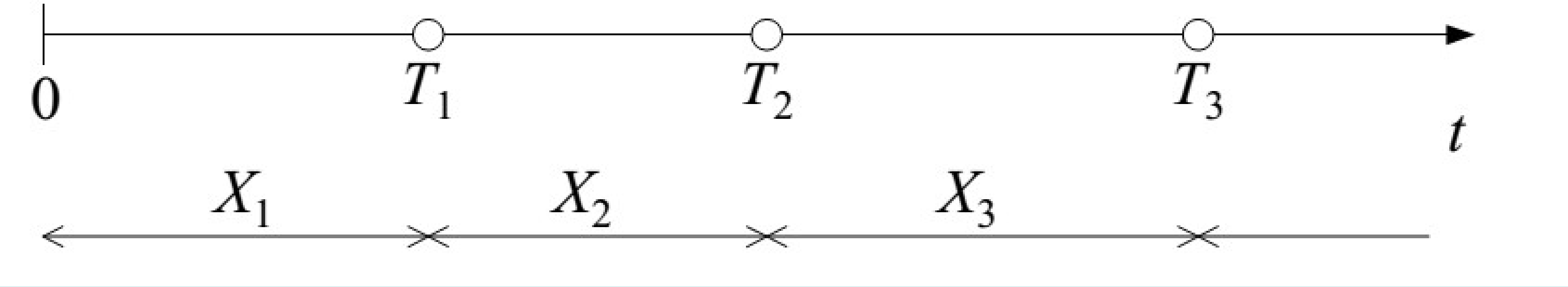


***Break:*** A failure on a pipe resulting in loss of water. Examples of types of breaks might be a hole or a crack in the pipe wall.

***Break rate:*** The term break rate is widely used in analyses of pipe breaks in water distribution networks. Break rate for a given pipe or set of pipes is normalised for pipe length and time. The unit for breaks rate is often expressed as number of breaks per kilometre per year [*number of breaks/length/time*]. In this work break rate is also used when leakage is considered as the failure type and not only breaks. Break rate is not equivalent to the statistical terms ROCOF and FOM explained later in this glossary.

ROCOF=rate of occurrence of failure of repairable systems

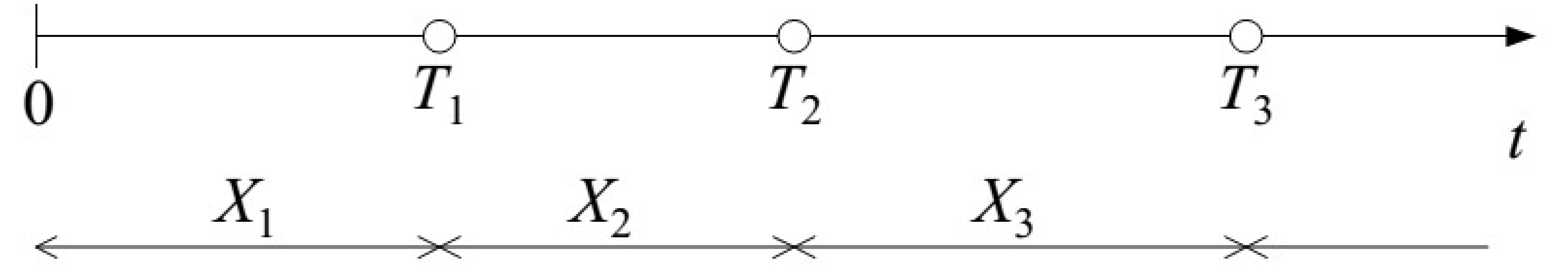
FOM=rate of occurrence of failure of NON repairable systems



***Hazard function:*** The hazard function *h(x)* or the force of mortality (FOM) is defined as the conditional probability that at time $x$ the component (pipe) will fail in a small time interval $(x,x+\Delta x)$, provided that it has not failed up to time $x$:

$$h(x) = \lim_{\Delta x \to 0} \frac{P\left[x \le X < x + \Delta x \mid X \ge x\right]}{\Delta x}$$

The term $h(x)\Delta x$ can best be interpreted as the probability that the *first* failure occurs in $(x, x+\Delta x)$.



***Failure:*** The term *failure* is in this work used for a break or leakage on a pipe.

***Failure rate:*** The term failure rate is in the statistical literature often used for both ROCOF (i.e. repairable systems) and FOM (i.e. non-repairable systems), which might cause some confusion. In order to avoid confusion the term will not be used in this work with a few exceptions in the literature review where it is explicit mentioned by an author.

***Failure time:*** $T_i$, i=1,2,3,..., measures the total time from 0, a convenient fixed origin, to the *i*th failure and is called the failure time for the *i*th failure (see also *interfailure times*).

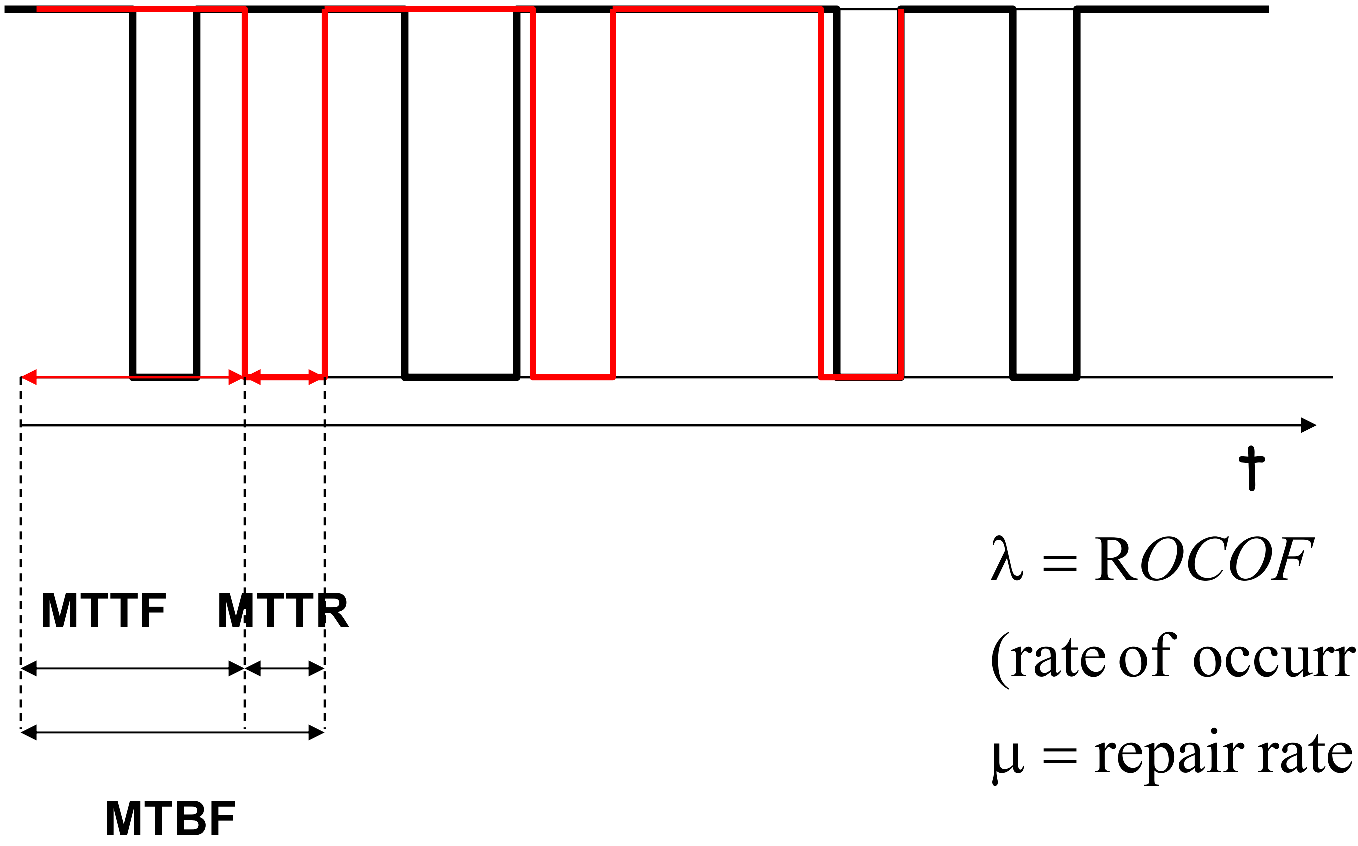
***Pipe:*** From one node in the water network to another (e.g. manhole, change in pipe diameter). Typically length is 50 – 150 m. Each pipe will normally consist of many pipe segments or lengths.

***Availability:*** The availability, $A(t)$ at time $t$ is the probability that an object (e.g. pipe) is functioning at time $t$. The average availability $A_{av}(t)$ denotes the mean proportion of time the object is functioning. If we have an object that is repaired to an "as good as new" condition every time it fails, the average availability is

$$A_{av} = \frac{MTTF}{MTTF + MTTR}$$

where MTTF (mean time to failure) denotes the mean functioning time and the MTTR (mean time to repair) denotes the repair time of the object. The average availability, $A_{av}(t)$ is used in network reliability analysis.

$$A = \frac{MTTF}{MTTF + MTTR} = \frac{\frac{1}{\lambda}}{\frac{1}{\mu} + \frac{1}{\lambda}} = \frac{\mu}{\mu + \lambda}$$



$\lambda = \mathrm{R}OCOF$

(rate of occurrence of failures)

$\mu$ = repair rate

***ROCOF (Rate of occurrence of failures):*** The ROCOF is the time derivative of the expected cumulative number of failures and is defined as:

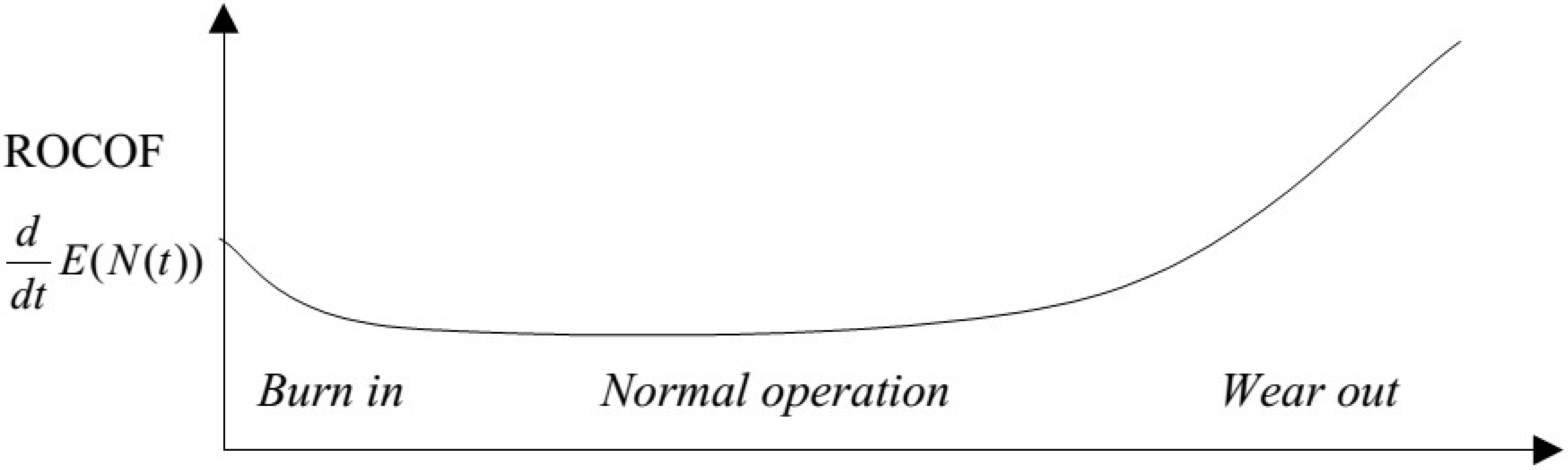
$$v(t)=\frac{dV(t)}{dt}=\frac{d}{dt}E(N(t))\overset{def}{\equiv} ROCOF$$

Where *V(t)= E(N(t))* denotes the mean number of failures in the interval (0,*t*]. follows that the ROCOF may be regarded as the mean number of failures p time unit at time *t*.

To best interpret the ROCOF, write:
v(t)*dt* = E[N(t+dt)] - E[N(t)]= expected number of failures in (t, t+dt]

or in terms of probabilities
v(t)*dt* = P(failure in (t, t+dt]

# ROCOF =rate of occurrence of failures



$$ROCOF \overset{def}{\equiv} \frac{d}{dt}E(N(t))$$

where $E(N(t))$ denotes the mean number of failures in the interval $(0,t]$

# Threshold Break Rate for Pipeline Replacement in Water Distribution Systems

G. V. Loganathan[1]; S. Park[2]; and H. D. Sherali[3]

JOURNAL OF WATER RESOURCES PLANNING AND MANAGEMENT / JULY/AUGUST 2002

**Abstract:** A comprehensive review of pipe replacement analyses is presented, from which an economically sustainable threshold break rate for replacement of pipelines in deteriorating water distribution systems is derived that yields some of the previously available replacement criteria under weaker restrictions. Relations of equivalence are established between the threshold break rate and both the rate of occurrence of failure (ROCOF) and the hazard rate functions. These statistical functions are used to predict break rates for a system. Optimal replacement times are obtained by equating the threshold break rate and the assessed (predicted) break rate from the ROCOF and the hazard rate functions. Design charts to determine the optimal threshold break rate as a function of pipe diameter and discount rate are also given, as well as numerical examples illustrating the developed theory.

**DOI:** 10.1061/(ASCE)0733-9496(2002)128:4(271)

**CE Database keywords:** Water distribution; Water pipelines; Replacement; Failure; Rehabilitation.

## Tasso di rottura economicamente sostenibile in reti acquedottistiche in fase di deterioramente. Limite in corrispondenza del quale la sostituzione è più economica della riparazione

Le reti di distribuzione soggette a **corrosione** non soddisfano la domanda di portata nè quella di prevalenza.

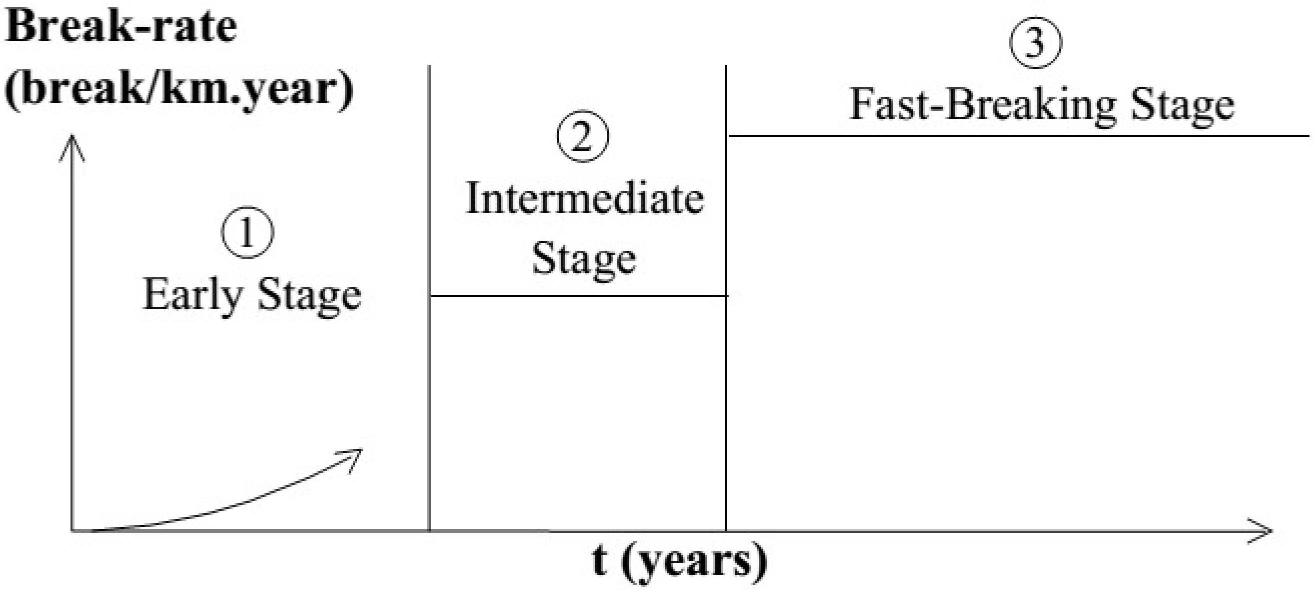
**Aumentano I costi di gestione (riparazione e sostituzione)**.

La manutenzione/sostituzione preventiva (prima della rottura) può risultare più conveniente di “non fare nulla finchè non avviene la rottura”.

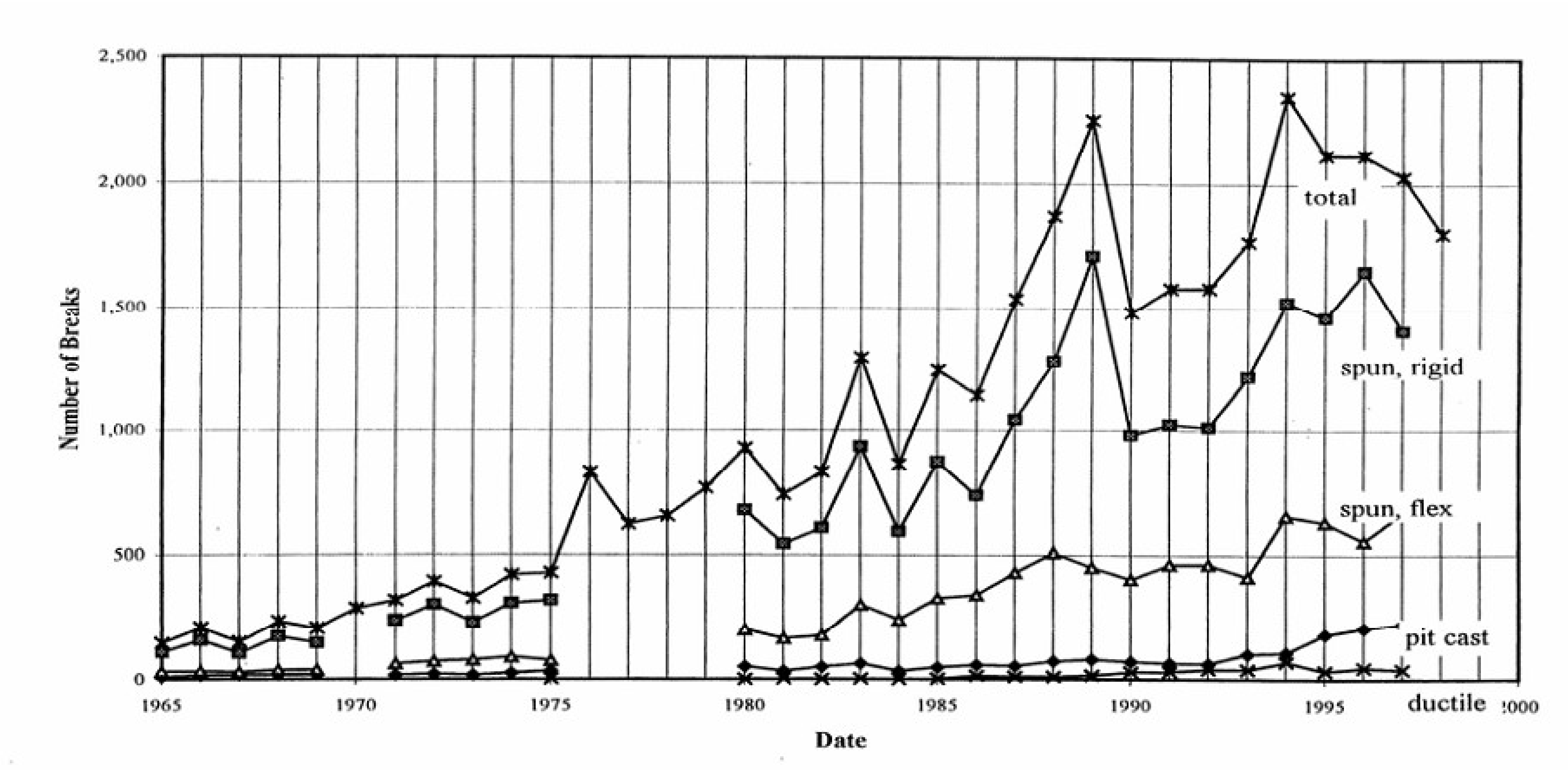
Se **posticipare la sostituzione** può essere una conveniente **strategia manageriale**, la manutenzione preventive può risultare anche più conveniente quando il tasso di rottura si avvicina ad un valore limite caratteristico.

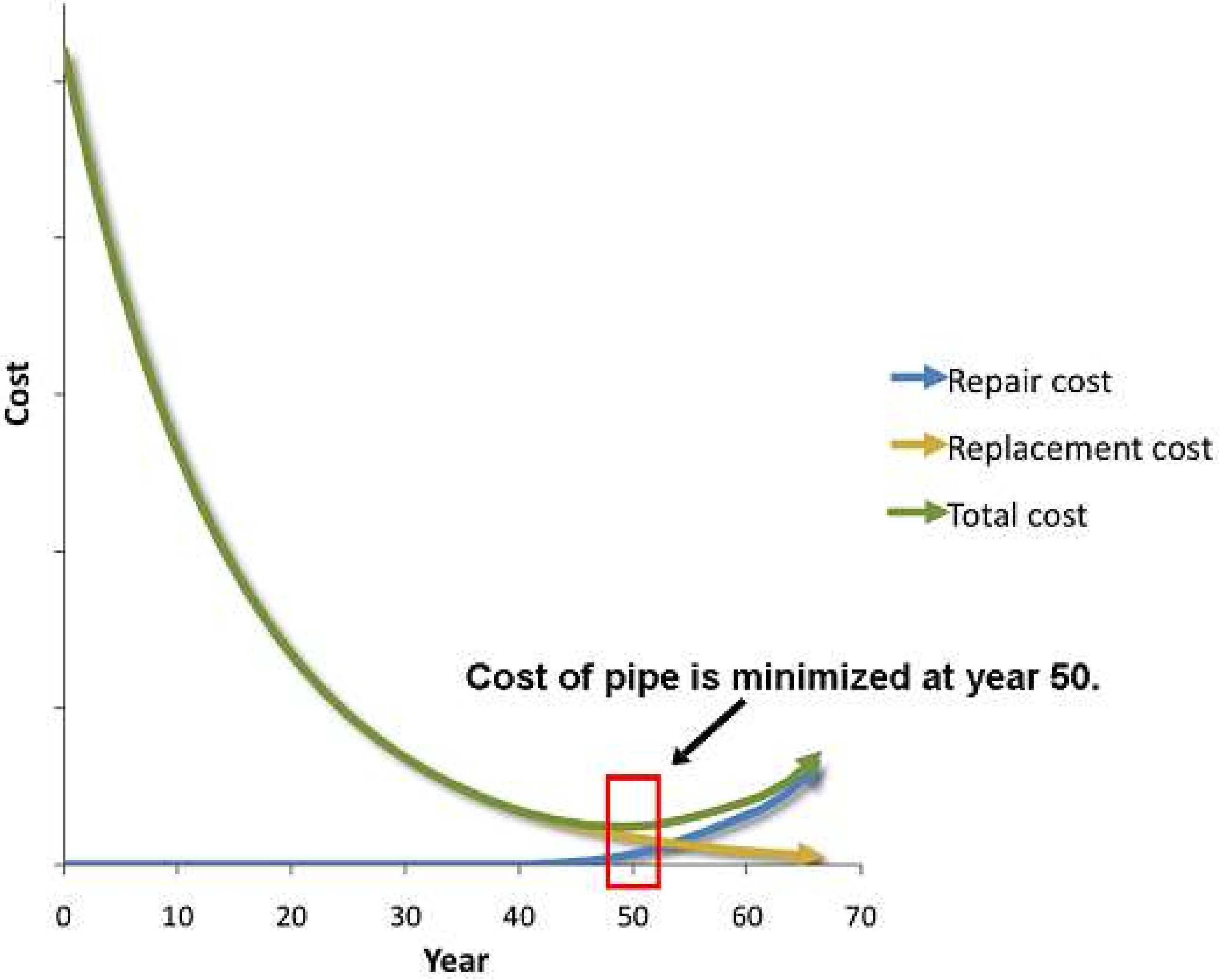
a. $Me \leftrightarrow Me^{z+} + z\,e^-$
b. $2H^+ + 2e^- \leftrightarrow H_2$
c. $O_2 + 2H_2O + 4e^- \leftrightarrow 4OH^-$

Durante la corrosione del ferro, il metallo si dissolve e gli elettroni liberi vengono partecipano a reazioni catodiche che coinvolgono acqua e ossigeno.


Break-rate
(break/km.year)
①
Early Stage
②
Intermediate
Stage
③
Fast-Breaking Stage
t (years)

Quando un tubo è nuovo, si verificano pochissime rotture.
Un tubo vecchio si rompe con frequenza più elevata nelle stesse condizioni di posa e carico di un tubo nuovo.
Pertanto, aumentando la frequenza di fallanza con il tempo ed essendo i costi di riparazione relativamente inferiori e un costo di sostituzione generalmente elevato la curva dei costi totali in funzione del tempo presenta un minimo.





Cost of pipe is minimized at year 50.

At the time of the **n**th break, a decision has to be made whether to replace the pipe at a cost of $\mathbf{F_n}$ or to repair it at a cost of $\mathbf{C_n}$

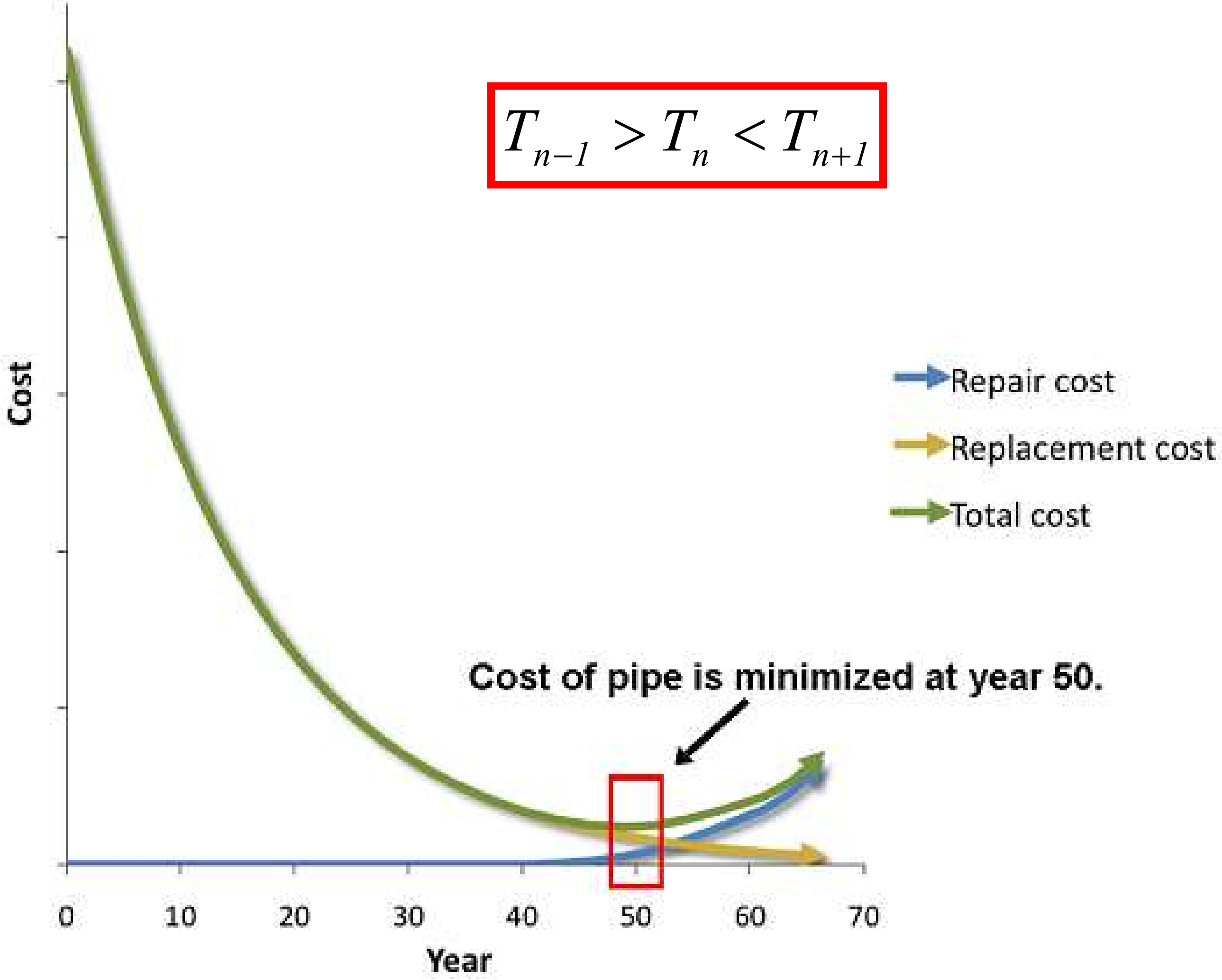
If we assume that the pipe will be replaced at the time of the nth break, $\mathbf{t_n}$, we can write the **total cost of the pipe**

$$\boxed{T_n = \sum_{i=1}^{n} \frac{C_i}{(1+R)^{t_i}} + \frac{F_n}{(1+R)^{t_n}}}$$

**R**=discount rate
$\mathbf{t_i}$=time of ith break measured from the installation year;
$\mathbf{C_i}$=repair cost of ith break
$\mathbf{F_n}$=replacement cost at time $t_n$
$\mathbf{T_n}$=total cost at time $t_n$

For the **total cost $T_n$ at time $t_n$ to be a minimum**, assuming a unimodal function, it must satisfy the condition

$$\boxed{T_{n-1} > T_n < T_{n+1}}$$



Cost of pipe is minimized at year 50.

The minimum to occur the only condition of interest is **$T_{n+1} > T_n$**

$$T_n = \sum_{i=1}^{n} \frac{C_i}{(1+R)^{t_i}} + \frac{F_n}{(1+R)^{t_n}}$$

$$T_{n+1} = \sum_{i=1}^{n+1} \frac{C_i}{(1+R)^{t_i}} + \frac{F_{n+1}}{(1+R)^{t_{n+1}}}$$

$$T_{n+1} - T_n = \frac{C_{n+1}}{(1+R)^{t_{n+1}}} + \frac{F_{n+1}}{(1+R)^{t_{n+1}}} - \frac{F_n}{(1+R)^{t_n}}$$

For **$T_{n+1} > T_n$**

$$\boxed{t_{n+1} - t_n < \frac{ln\left(\frac{C_{n+1}}{F_n} + \frac{F_{n+1}}{F_n}\right)}{ln(1+R)}}$$

The threshold break rate, **$Brk_{th}$** is the inverse of $t_{n+1}-t_n$

$$\boxed{Brk_{cur} > Brk_{th} = \frac{ln(1+R)}{ln\left(\frac{C_{n+1}}{F_n}+\frac{F_{n+1}}{F_n}\right)}}$$

**Whenever the current break rate, $Brk_{cur}$ equals or exceeds $Brk_{th}$ the pipe should be replaced.**

at an accelerated quick breaking stage, if we assume

$$F_{n+1} \approx F_n$$

by the property of logarithm for small values

$$\frac{1}{ln\left(\frac{C_{n+1}}{F_n}+1\right)} \approx \frac{F_n}{C_{n+1}} << 1$$

$$\boxed{Brk_{th} \approx \frac{F_n}{C_{n+1}} ln(1+R)}$$

## Break prediction model [Shamir and Howard, 1979]

$$\boxed{N(t) = N(t_o)e^{-A(t-t_o)}}$$

N(t) = number of breaks per 1000 ft length of pipe in year t
t = time in years
$t_0$= base year for the analysis (pipe installation year, or the first year for which data are available)
A = growth rate coefficient (1/year)

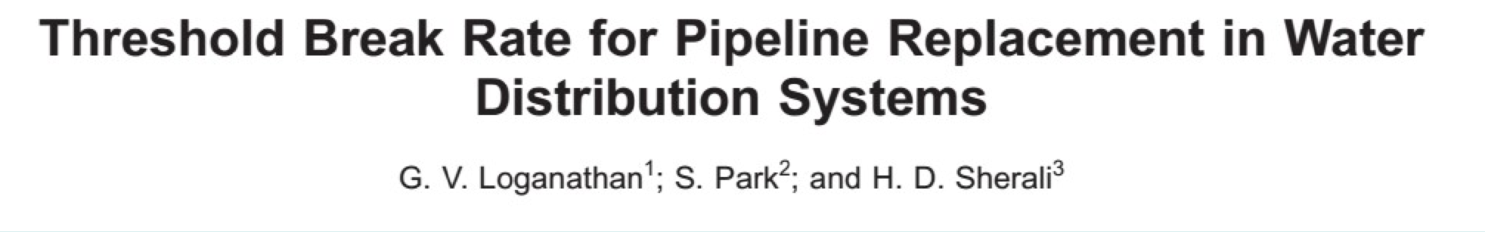
$$\boxed{Brk_{th} \approx \frac{F_n}{C_{n+1}} ln(1+R)}$$

For $F_{n+1} \approx F_n$

by setting **N(t) = N($t_0$) $Brk_{th}$**

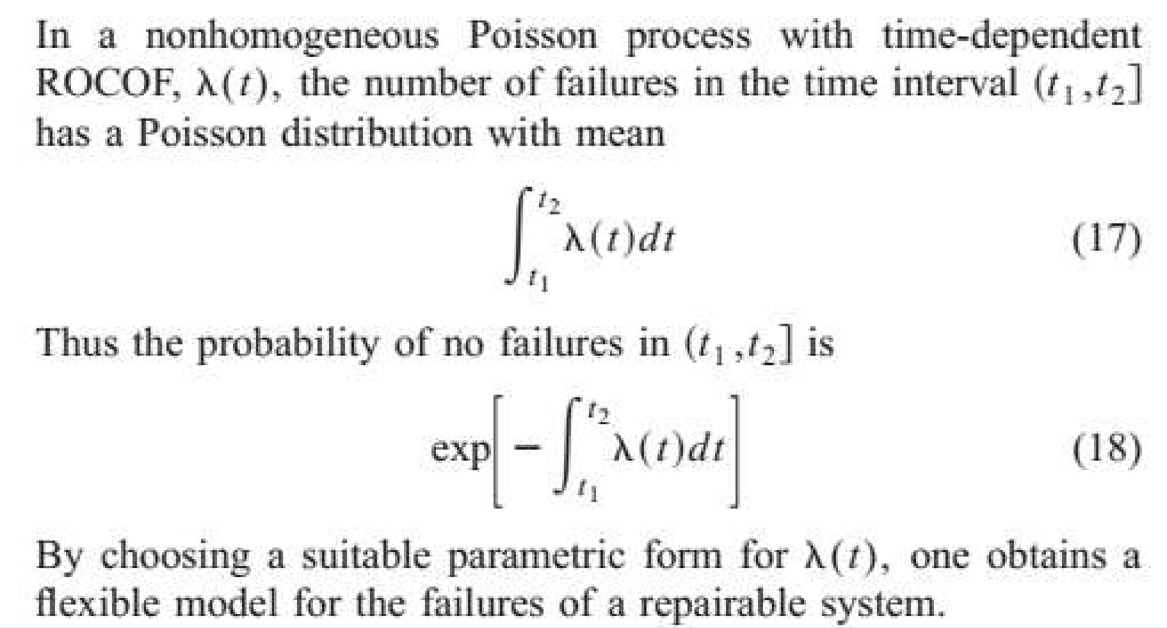
$$e^{A(t-t_0)} = \frac{F_n}{C_{n+1}} \ln(1+R)$$

$$\boxed{t = t_0 + \frac{1}{A} \ln\left[\frac{F_n}{C_{n+1}} \ln(1+R)\right]}$$



# Threshold Break Rate for Pipeline Replacement in Water Distribution Systems

G. V. Loganathan[1]; S. Park[2]; and H. D. Sherali[3]



In a nonhomogeneous Poisson process with time-dependent ROCOF, $\lambda(t)$, the number of failures in the time interval $(t_1, t_2]$ has a Poisson distribution with mean

$$\int_{t_1}^{t_2} \lambda(t)\,dt \tag{17}$$

Thus the probability of no failures in $(t_1, t_2]$ is

$$\exp\left[-\int_{t_1}^{t_2} \lambda(t)\,dt\right] \tag{18}$$

By choosing a suitable parametric form for $\lambda(t)$, one obtains a flexible model for the failures of a repairable system.

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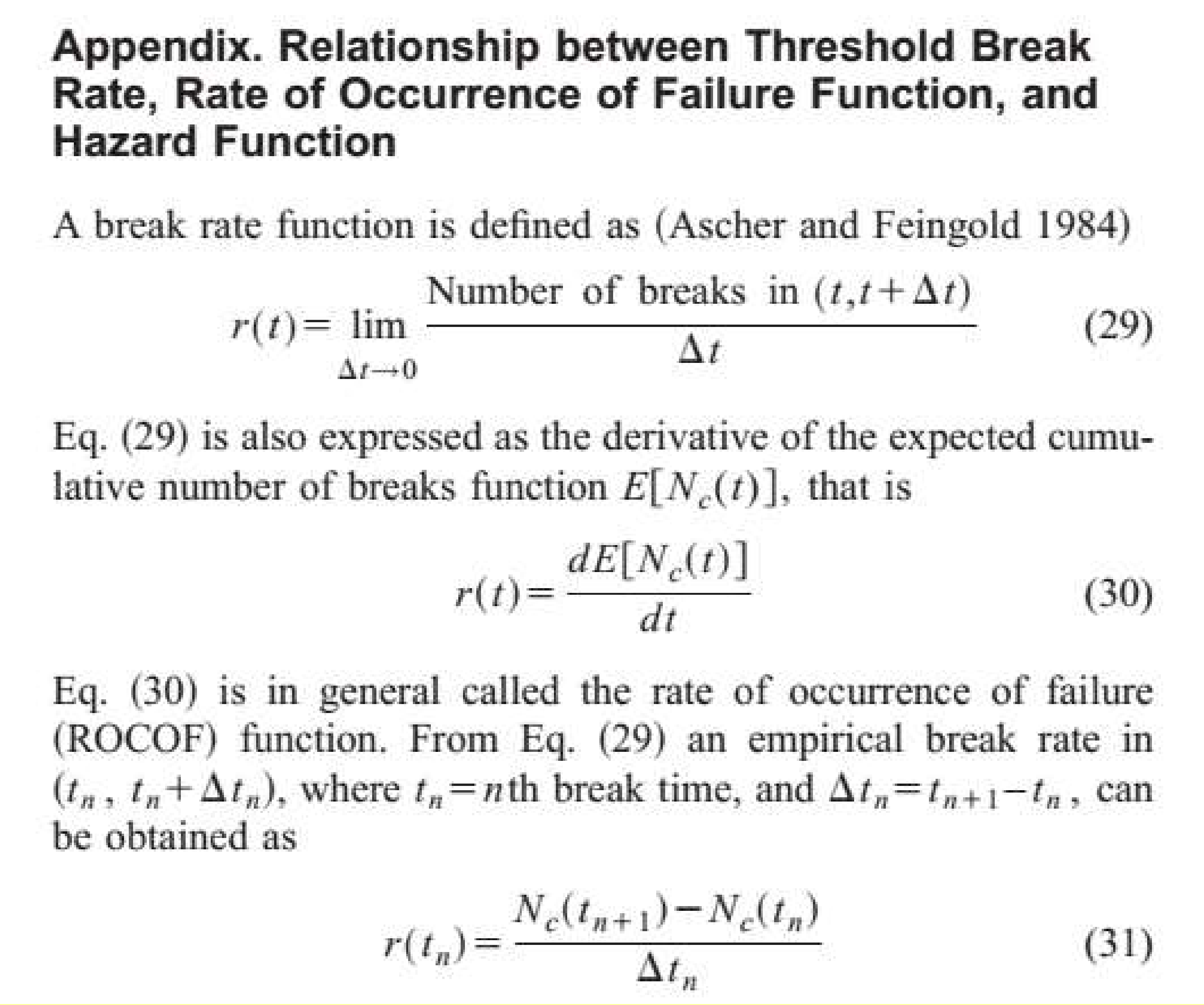


## Appendix. Relationship between Threshold Break Rate, Rate of Occurrence of Failure Function, and Hazard Function

A break rate function is defined as (Ascher and Feingold 1984)

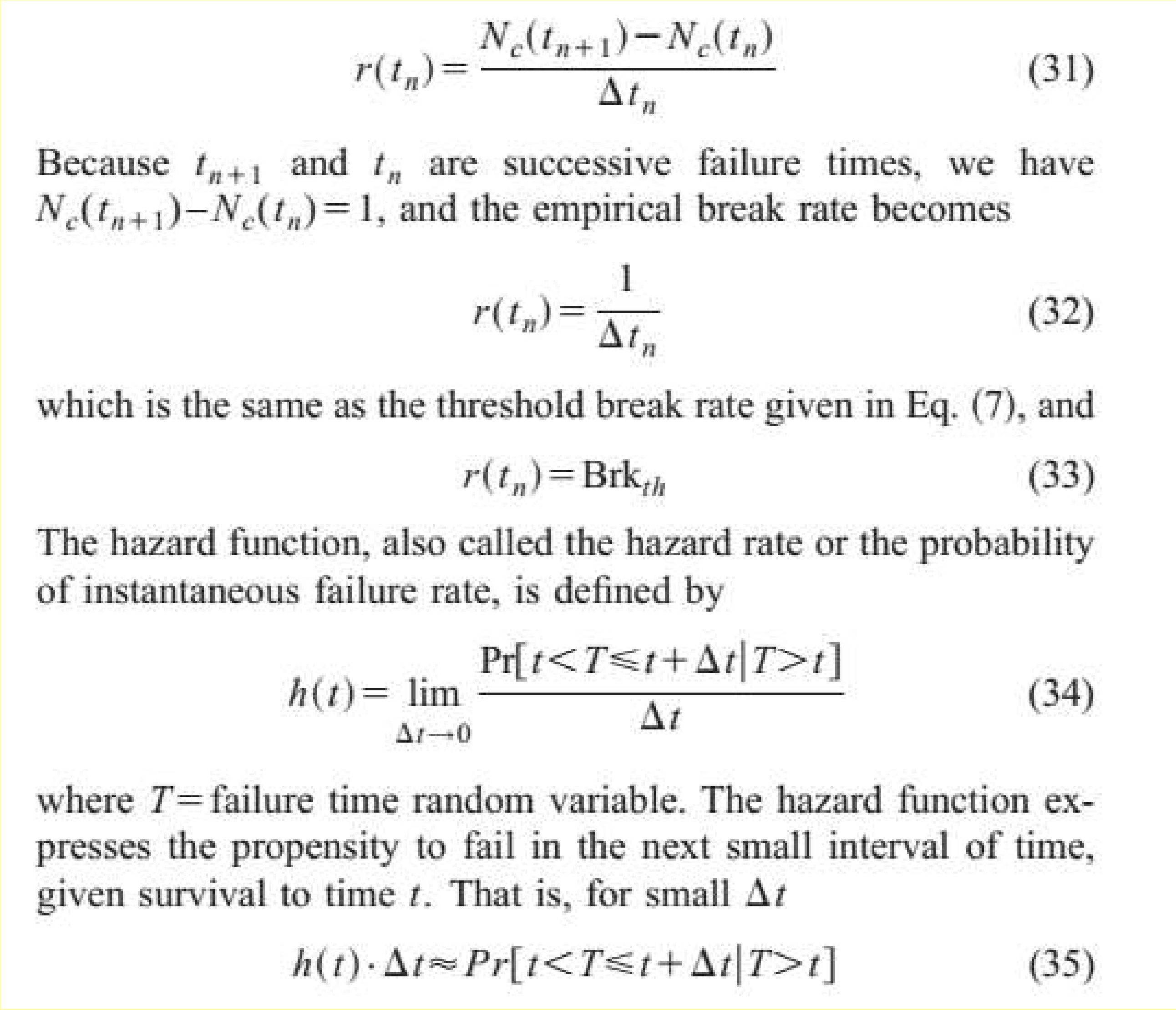
$$r(t) = \lim_{\Delta t \to 0} \frac{\text{Number of breaks in } (t, t+\Delta t)}{\Delta t} \tag{29}$$

Eq. (29) is also expressed as the derivative of the expected cumulative number of breaks function $E[N_c(t)]$, that is

$$r(t) = \frac{dE[N_c(t)]}{dt} \tag{30}$$

Eq. (30) is in general called the rate of occurrence of failure (ROCOF) function. From Eq. (29) an empirical break rate in $(t_n, t_n + \Delta t_n)$, where $t_n = n$th break time, and $\Delta t_n = t_{n+1} - t_n$, can be obtained as

$$r(t_n) = \frac{N_c(t_{n+1}) - N_c(t_n)}{\Delta t_n} \tag{31}$$



$$r(t_n) = \frac{N_c(t_{n+1}) - N_c(t_n)}{\Delta t_n} \tag{31}$$

Because $t_{n+1}$ and $t_n$ are successive failure times, we have $N_c(t_{n+1}) - N_c(t_n) = 1$, and the empirical break rate becomes

$$r(t_n) = \frac{1}{\Delta t_n} \tag{32}$$

which is the same as the threshold break rate given in Eq. (7), and

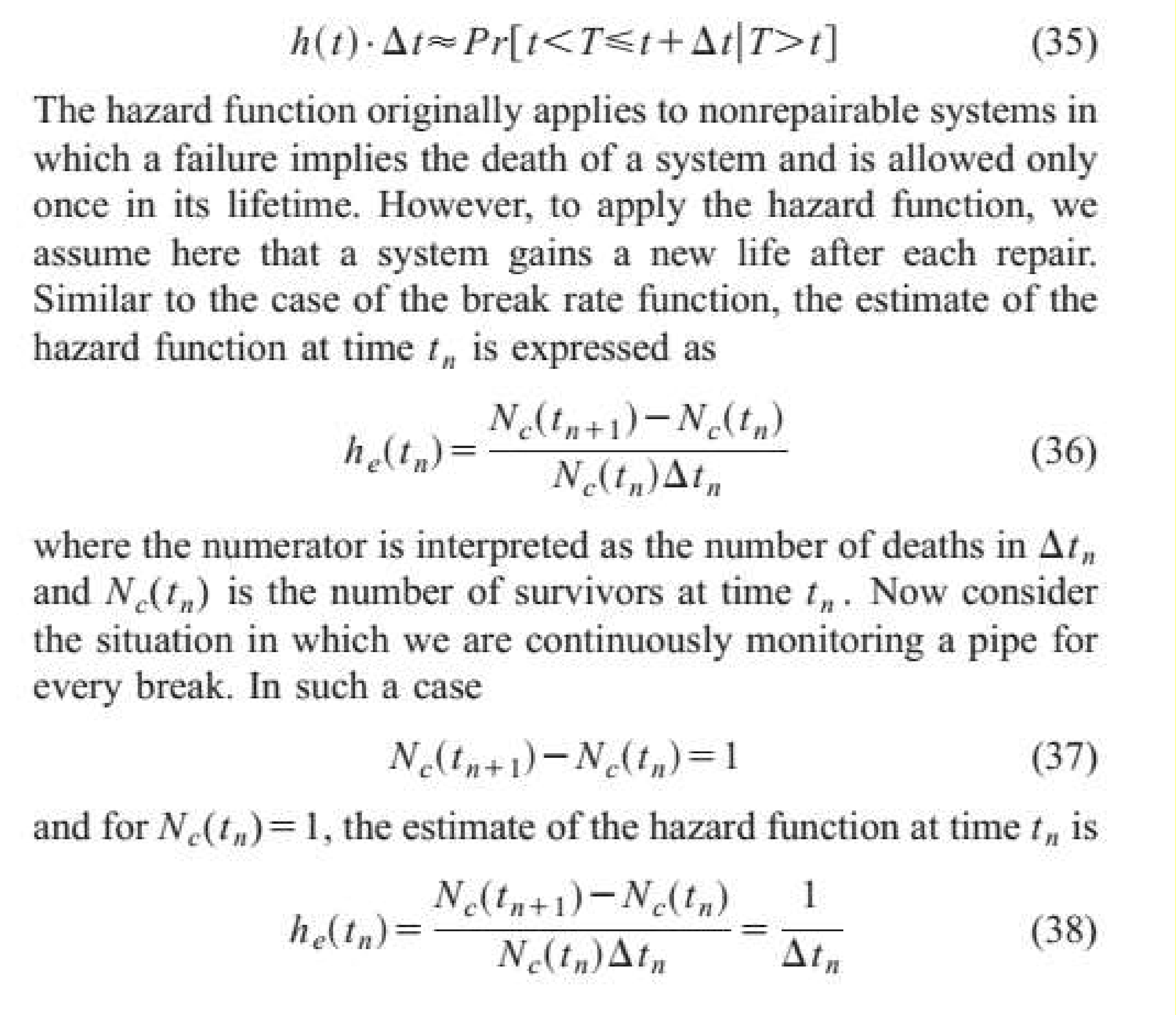
$$r(t_n) = \mathrm{Brk}_{th} \tag{33}$$

The hazard function, also called the hazard rate or the probability of instantaneous failure rate, is defined by

$$h(t) = \lim_{\Delta t \to 0} \frac{\Pr[t < T \leqslant t + \Delta t | T > t]}{\Delta t} \tag{34}$$

where $T$ = failure time random variable. The hazard function expresses the propensity to fail in the next small interval of time, given survival to time $t$. That is, for small $\Delta t$

$$h(t) \cdot \Delta t \approx Pr[t < T \leqslant t + \Delta t | T > t] \tag{35}$$



$$h(t)\cdot\Delta t \approx Pr[t<T\leqslant t+\Delta t \mid T>t] \tag{35}$$

The hazard function originally applies to nonrepairable systems in which a failure implies the death of a system and is allowed only once in its lifetime. However, to apply the hazard function, we assume here that a system gains a new life after each repair. Similar to the case of the break rate function, the estimate of the hazard function at time $t_n$ is expressed as

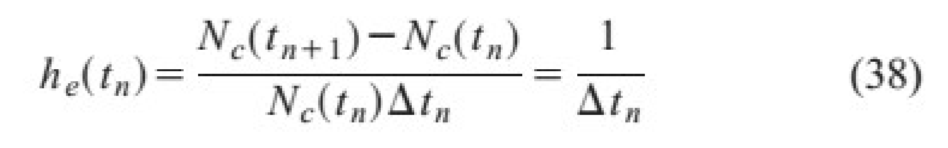
$$h_e(t_n)=\frac{N_c(t_{n+1})-N_c(t_n)}{N_c(t_n)\Delta t_n} \tag{36}$$

where the numerator is interpreted as the number of deaths in $\Delta t_n$ and $N_c(t_n)$ is the number of survivors at time $t_n$. Now consider the situation in which we are continuously monitoring a pipe for every break. In such a case

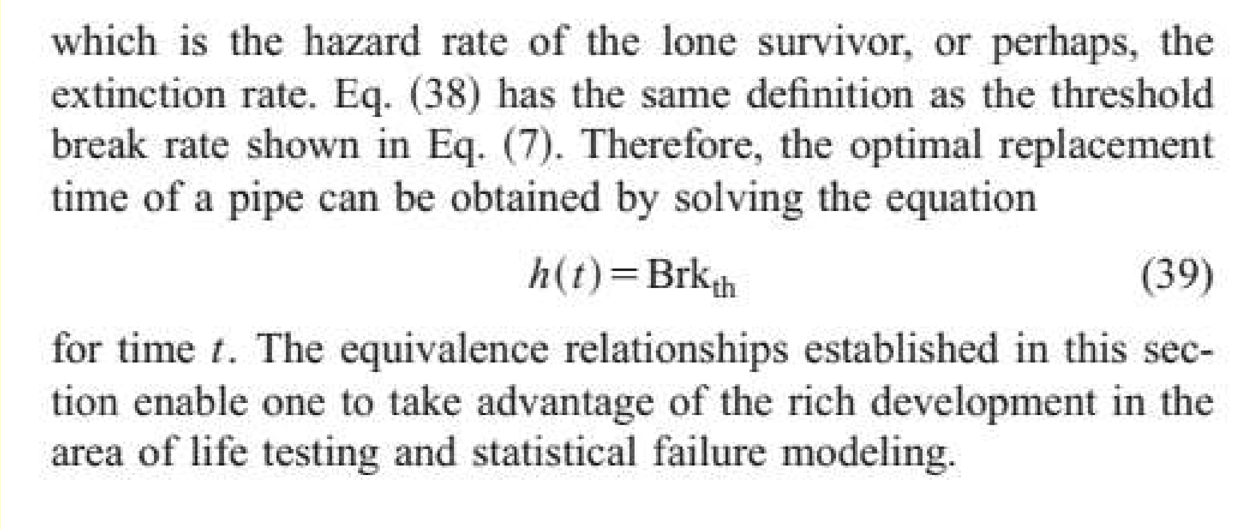
$$N_c(t_{n+1})-N_c(t_n)=1 \tag{37}$$

and for $N_c(t_n)=1$, the estimate of the hazard function at time $t_n$ is

$$h_e(t_n)=\frac{N_c(t_{n+1})-N_c(t_n)}{N_c(t_n)\Delta t_n}=\frac{1}{\Delta t_n} \tag{38}$$



$$h_e(t_n) = \frac{N_c(t_{n+1}) - N_c(t_n)}{N_c(t_n)\Delta t_n} = \frac{1}{\Delta t_n} \qquad (38)$$



which is the hazard rate of the lone survivor, or perhaps, the extinction rate. Eq. (38) has the same definition as the threshold break rate shown in Eq. (7). Therefore, the optimal replacement time of a pipe can be obtained by solving the equation

$$h(t) = \mathrm{Brk}_{\mathrm{th}} \qquad (39)$$

for time $t$. The equivalence relationships established in this section enable one to take advantage of the rich development in the area of life testing and statistical failure modeling.

# TECNOLOGIA NO-DIG PER LA RIABILITAZIONE DELLE CONDOTTE

Con l’esercizio le condotte:

- perdono impermeabilità
- acquisiscono resistenza idraulica

a causa di
- depositi
- lesioni
- accumulo di detriti/oggetti

Riabilitazione = ripristino delle condizioni originarie (senza sostituzione e quindi senza distruzione della condotta preesistente)

# Le tecnologie no-dig per la sostituzione delle condotte

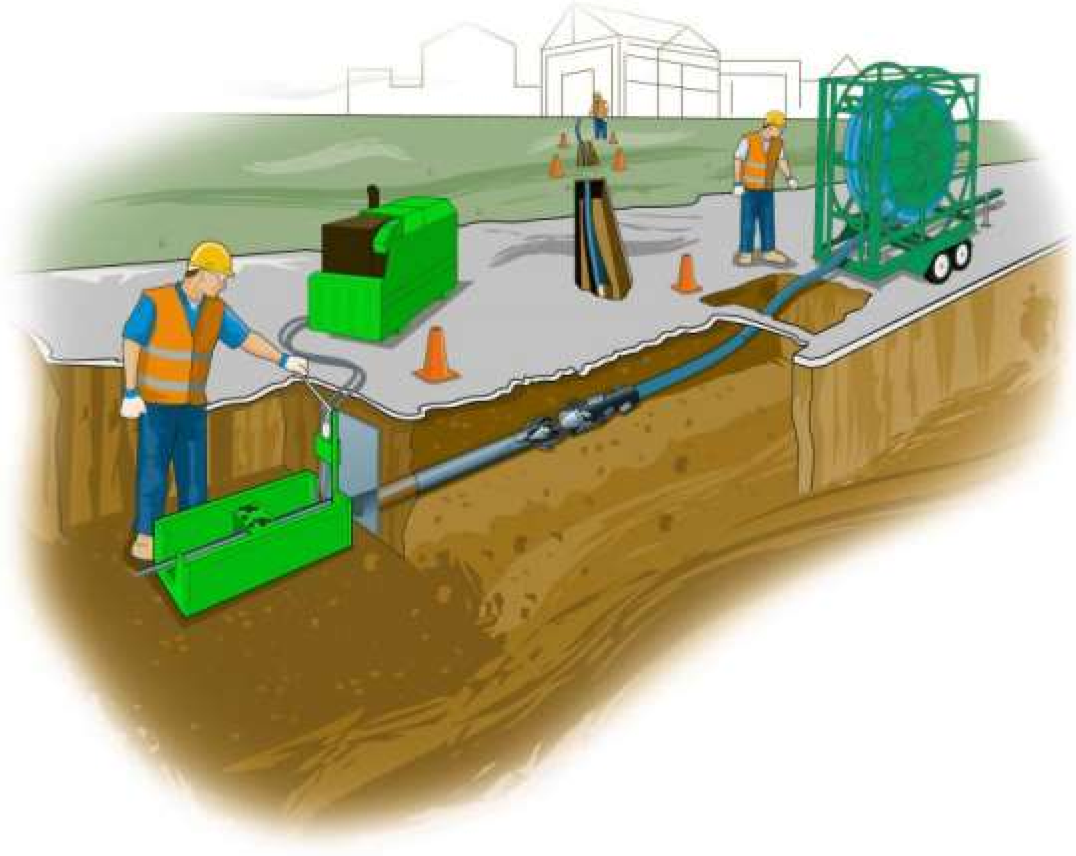
oltre che per la riabilitazione delle condotte vengono impiegate per l’incremento di diametro (fino a 50-100%)

C) Nel RELINING SOSTITUTIVO la sostituzione avviene dopo la demolizione della condotta esistente

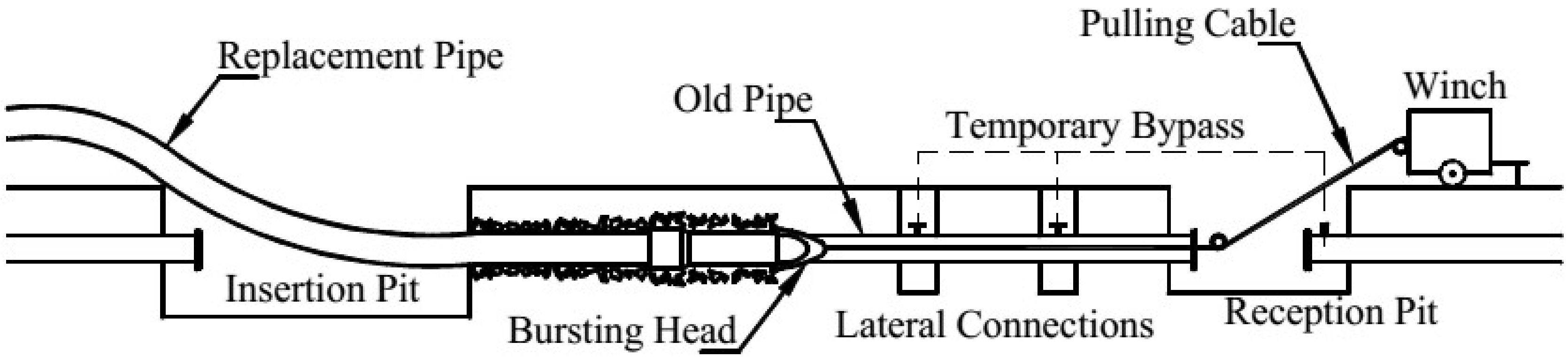
1C) Pipe bursting
2C) pipe splitting
3) Pipe eating

## Pipe bursting

can be either pneumatic, hydraulic expansion or static pull, fractures a pipe and displaces the fragments outwards while a new pipe is drawn in to replace the old pipe.



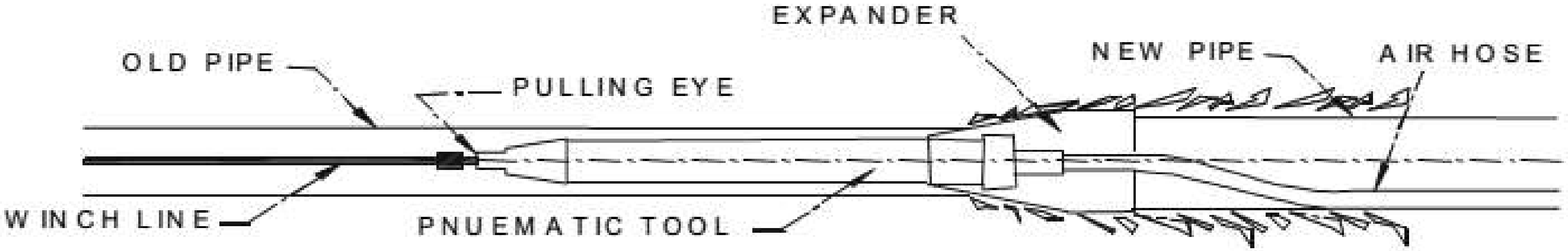
*Typical small diameter static pipe bursting operation.*



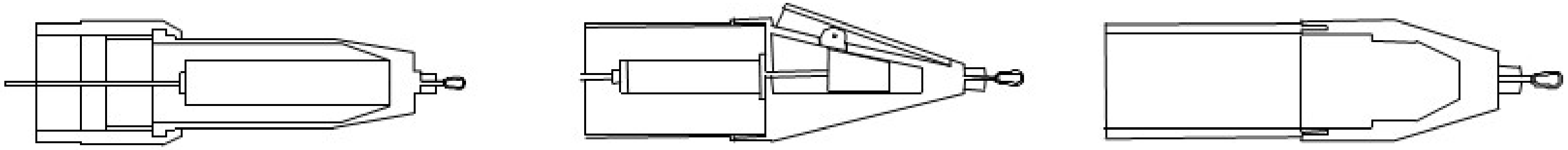
Typical pipe bursting operation layout

## techniques of trenchless pipe replacement

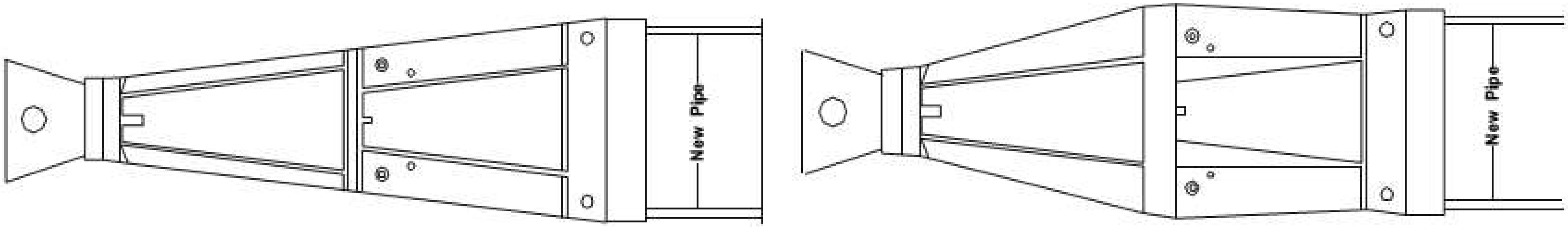
- **pipe bursting** using pneumatic bursting, hydraulic expansion, or static pull – techniques that fracture the existing pipe, displace the fragments outwards, and pull a new pipe in to replace the old pipe (this technique is by far the most widely used trenchless pipe replacement method);
- **pipe implosion** a technique that fractures the existing pipe inwards and displaces the pipe fragments outwards, and pulls a new pipe in to replace the old pipe;
- **pipe splitting** a technique that splits open existing ductile pipes, and pulls a new pipe in to replace the old pipe;
- **pipe eating** a technique that uses a specially-designed variation of a microtunneling machine, which excavates the old pipe in fragments and removes them rather than displaces them, and jacks the new pipe into the place as in a microtunneling operation;
- **pipe reaming** a technique that uses a specially-designedvariation of the reaming process from horizontal directional drilling, to excavate the existing pipe in fragments and remove them rather than displace them, and pulls a new pipe in to replace the old pipe;
- **pipe ejection and pipe extraction** techniques that remove the existing pipe as whole from the ground, by pushing or pulling it towards a reception pit where it is broken up and removed, and simultaneously install a new pipe



Bursting head of the pneumatic system



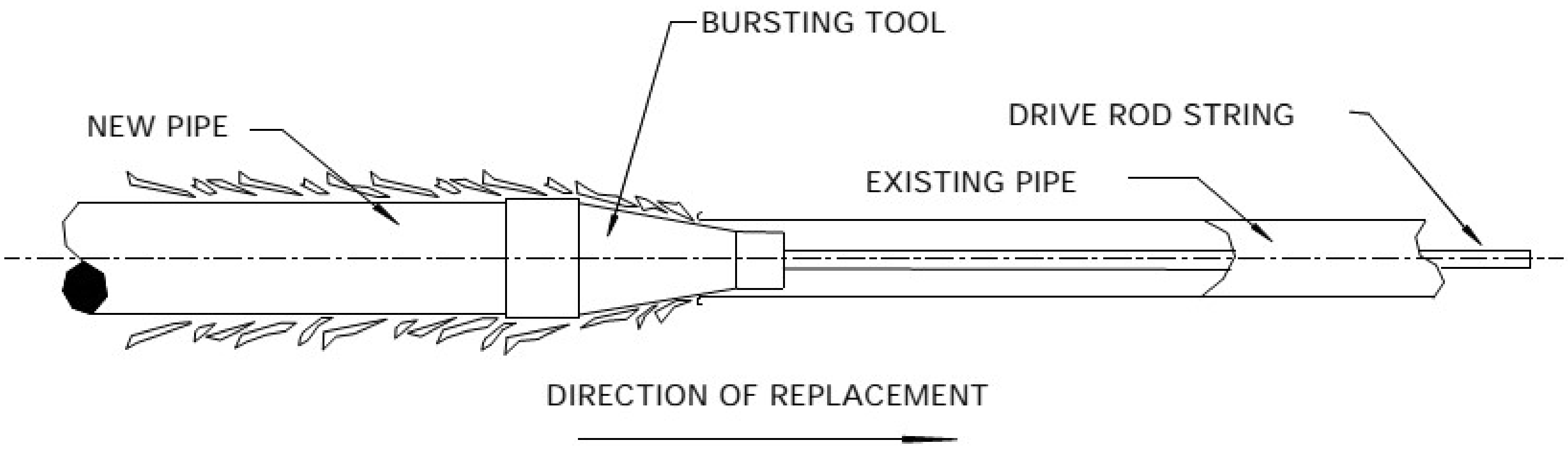
Pneumatic, hydraulic and static head



CONTRACTED BURSTING HEAD

EXPANDED BURSTING HEAD

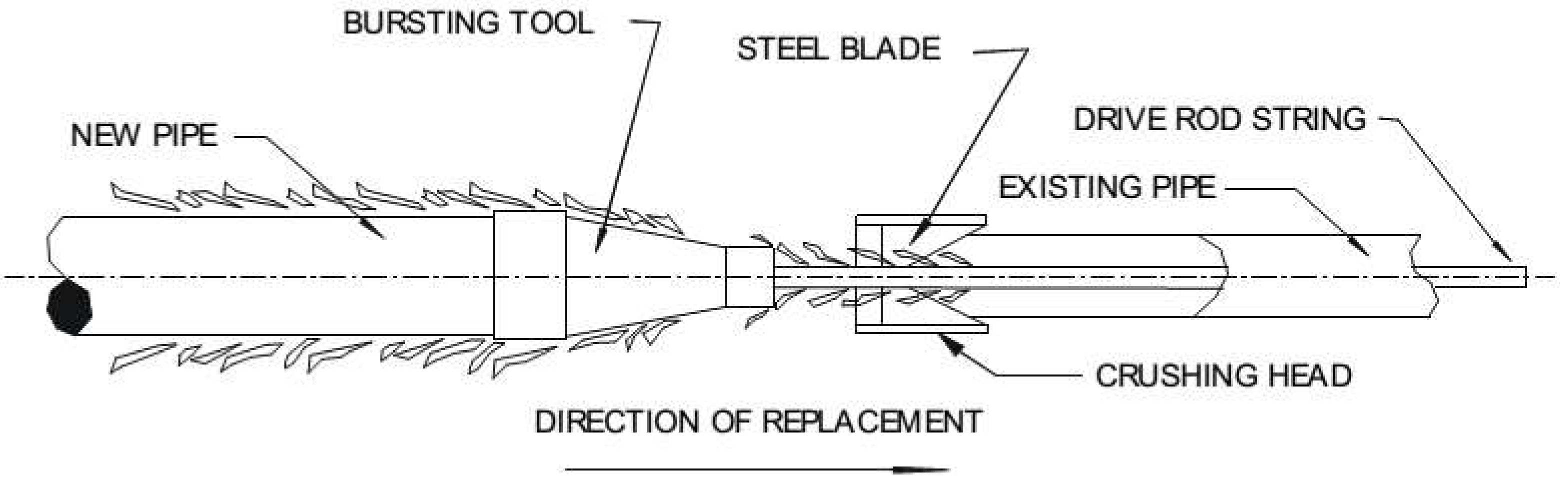
Hydraulic bursting head (Xpandit) in expanded and contracted positions



Bursting head of the static pull system

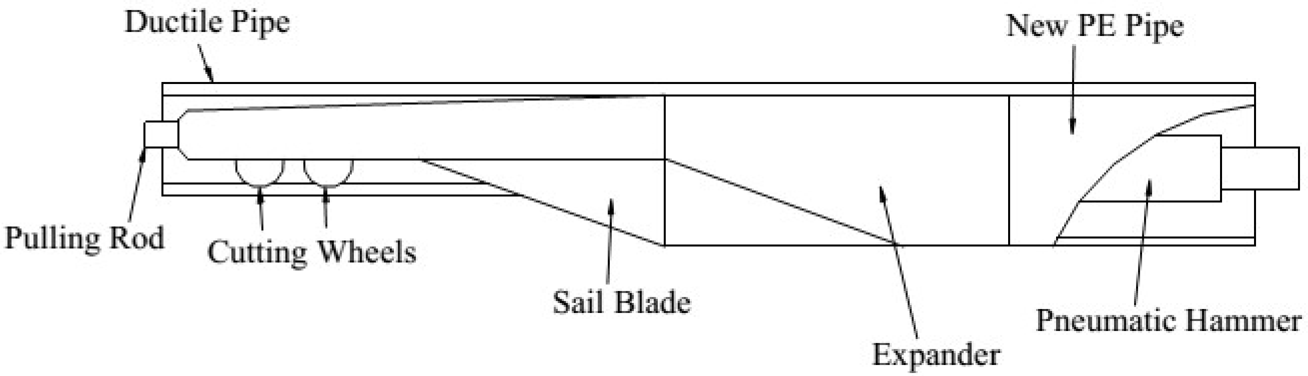
*initial phase in replacement of an asbestos cement pipe using the pipe bursting technique*

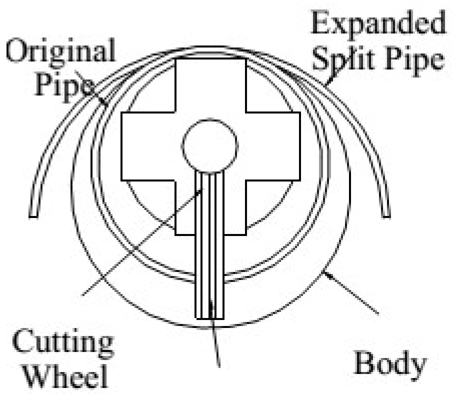
*sequence of stages in pipe bursting*



The crushing head in implosion (IMPIPE System)

- **pipe implosion**  a technique that fractures the existing pipe inwards and displaces the pipe fragments outwards, and pulls a new pipe in to replace the old pipe;



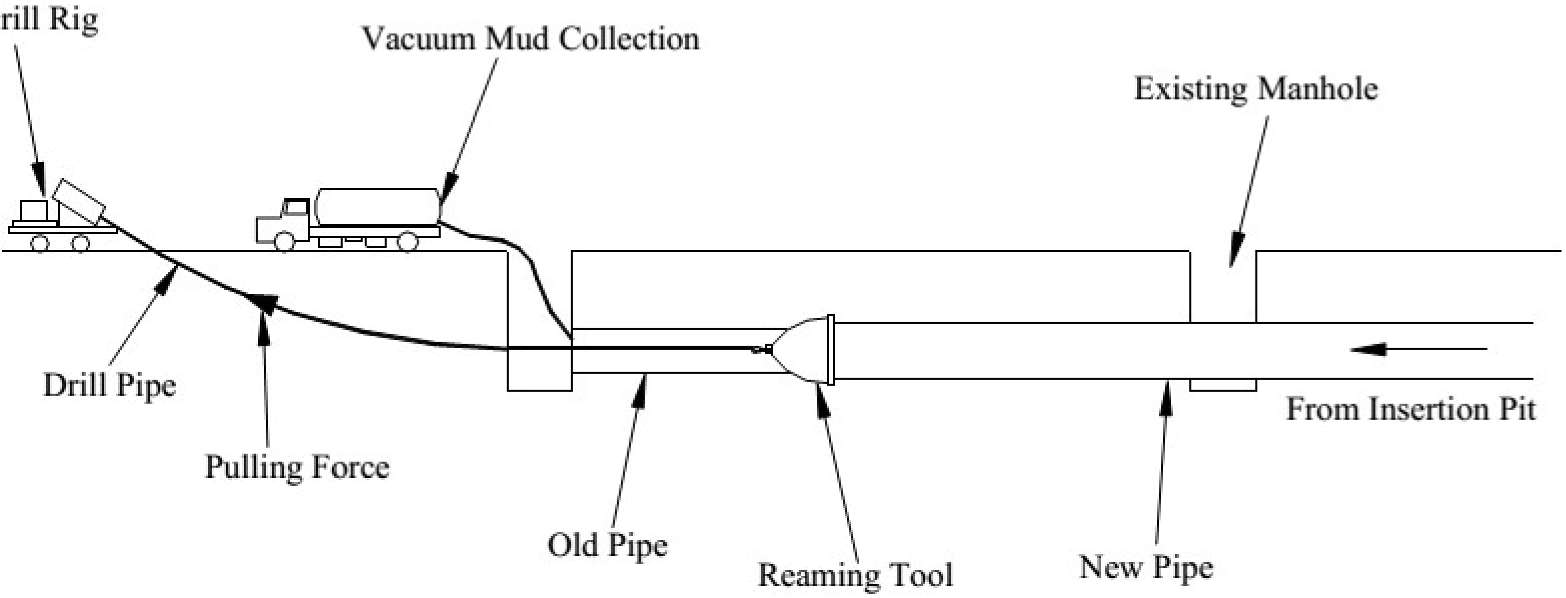


- **pipe splitting** a technique that splits open existing ductile pipes, and pulls a new pipe in to replace the old pipe;

Pipe splitting system and section view of the pipe splitting system (ConSplit)

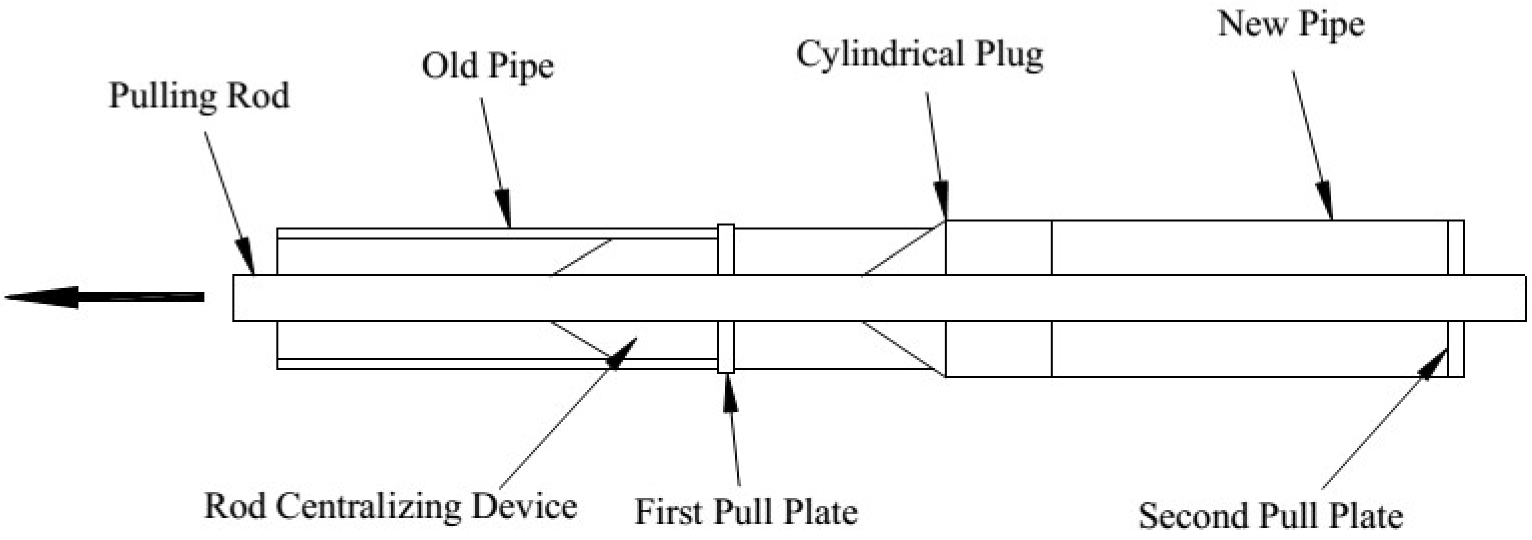
*close-up of pipe splitting*

*stages in application of pipe splitting for replacement of an old culvert under a road*



Pipe reaming

•**pipe reaming** a technique that uses a specially-designed variation of the reaming process from horizontal directional drilling, to excavate the existing pipe in fragments and remove them rather than displace them, and pulls a new pipe in to replace the old pipe;



**Pipe extraction**

- **pipe ejection and pipe extraction** techniques that remove the existing pipe as whole from the ground, by pushing or pulling it towards a reception pit where it is broken up and removed, and simultaneously install a new pipe

The terms **“close- fit liners”** or “modified slip- lining” refer to liners that are deliberately deformed prior to insertion, and then reverted to their original shape once in position so that they fit closely inside the host pipe. These techniques are a logical development of the basic slip-lining, and can be applied to both gravity and pressure pipes.

***Insertion, steaming and final connection of an old water pipe with application of C-Compact PEHD pipe***

***Roll-Down machine for longitudinal deformation of HDPE pipe to Pn16***

*opposed rollers for reducing diameter and insertion of drawn pipe*

# Le tecnologie no-dig per la riabilitazione delle condotte

si basano sull’impiego di una “calza” (LINER). Si distinguono in:

A) Riabilitazioni con inserimento di una tubazione nuova entro quella già esistente
A1) Close fit lining
A2) Slip lining

B) Riabilitazioni con formazione di un nuovo rivestimento all’interno della condotta esistente
B1) Curled in place lining

Prima di effettuare la riabilitazione viene sempre effettuata l’ispezione e la pulitura della condotta da risanare

## Cured -in-place liners

This method is based on the original cured- in - place well known and widely used sewer renovation method. It utilizes a glass fiber reinforced felt tube which is impregnated with epoxy resin. The tube is installed by means of water pressure as described above for woven liner. These liners are available  in different thickness and diameter.

The methods referred to by the name **Cured in Place Pipe** involve preparation of a tube made of plastic, fabric or a plastic-fabric compound of the same size and length as the inside of the pipe to be replaced.

From the inside of the tube, in contact with the fabric or felt, a given quantity of **resin** is poured and spread evenly around to fully impregnate the surface which will, when the lining is inserted, be in contact with the inside of the pipe to be relined.

After **impregnation**, the liner composed of tube + resin measuring up to 300 mm in diameter is normally wound up inside an inversion chamber.

The end of the tube placed inside the inversion chamber is **sealed**, while the other end is turned inside out and sealed around the rim of the inversion chamber’s exit connection.

**Air pressure** flowing from inside the inversion chamber turns the tube inside out and unrolls it inside the pipe to be lined.

Pressure in the inversion chamber and the tube ensures that the surface of the resin-impregnated fabric tube **adheres** all over the inner surface of the pipe to be renewed.

***insertion of the tube impregnated with resin and cooled, after anchoring the inversion flange***

*stages in application of C.I.P.P. thermosetting tubes*

*inside view of an oval-shaped sewer pipe before and after relining*

# GENOA

*panoramic view of the part of the city centre which is home to many of the 190 rehabilitation sites using trenchless technologies since 1990*

***two archive photos illustrating the first No-Dig work in Genoa. Swage Lining DE500 mm in 1994 in the Circonvallazione a Mare area and the first experiment with Pipe Bursting in the old city centre, near S.Agostino theatre***

# PADUA

*images of SIL's work in the centre of Padua*

*equipment used for pipe bursting work via Plebscito and in the Sheraton area in Padua*

# VENICE

***Venice: work sites where pipes are being renewed by traditional methods. It is clear that the inconvenience to pedestrians and shops is considerable***

***the C-Compact pipe is inserted in the pipeline, which runs perpendicular to the boat. A pipe with a wide curve is then prepared to aid its insertion***