Meeting of CEN/TC 165/WG 10

"Installation of buried pipes for gravity drain and sewer systems"

Tightness tests for gravity drain and sewer systems

Results of an experimental research based on an equivalence criteria in order to make comparable air and water tests

Antonio MIGLIO, PhD, P.Eng.

Mr. Giovanni GABELLI

AFNOR Normalisation
Paris – France
31st May 2011

OVERVIEW

Motivation and aim of the research

Methods "L" and "W": Concept of Equivalence

Results of an experimental research based on an equivalence criteria.

The motivation comes from the statement at paragraph 13.1, EN1610:1997:

"*In the event of a **single or continued air test failure**, recourse to water test is allowed and the result of the **water test alone shall be decisive***"

WHAT IS THE REASON FOR THIS STATEMENT?

HOW CAN IT BE EXPLAINED?

If the methods are equivalent ⇒ it is not necessary to have recourse to the method "W"

BUT

If the methods are not equivalent ⇒ it is not possible to compare them ⇒

The aim of the research is twofold:

- to demonstrate that the **air pressure test (method "L") and water pressure test (method "W")** performed according to current requirements **are not equivalent to each other**;

- to propose an **equivalence criteria in order to make comparable the air and water tests**.

OVERVIEW

Motivation and aim of the research

Methods "L" and "W": Concept of Equivalence

Results of an experimental research based on an equivalence criteria.

EQUIVALENT TEST METHODS – DEFINITION

Two or more TEST METHODS are defined

EQUIVALENT

if they give the SAME RESULT (or JUDGEMENT)

Two or more test methods are equivalent to each other although they are derived in different ways.

The **test methods "W" and "L"** are defined **equivalent if both** – at the end of test and for the respective requirements of the current standard – **give an unambiguous result** (or **unambiguous judgement**) **for the tested pipeline**.

EQUIVALENT TEST METHODS	
WATER	**AIR**
Test result	**Test result**
$w<w_{amm} \Rightarrow$ "Tightness"	$\Delta p<\Delta p_{amm} \Rightarrow$ "Tightness"
$w=w_{amm} \Rightarrow$ "Tightness limit"	$\Delta p=\Delta p_{amm} \Rightarrow$ "Tightness limit"
$w>w_{amm} \Rightarrow$ "No tightness"	$\Delta p>\Delta p_{amm} \Rightarrow$ "No tightness"

NON-EQUIVALENT TEST METHODS	
WATER	**AIR**
Test result	**Test result**
$w<w_{amm}$ ⇒ "Tightness"	$\Delta p=\Delta p_{amm}$ ⇒ "Tightness limit" or $\Delta p>\Delta p_{amm}$ ⇒ "No tightness"
$w=w_{amm}$ ⇒ "Tightness limit"	$\Delta p<\Delta p_{amm}$ ⇒ "Tightness" or $\Delta p>\Delta p_{amm}$ ⇒ "No tightness"
$w>w_{amm}$ ⇒ "No tightness"	$\Delta p<\Delta p_{amm}$ ⇒ "Tightness" or $\Delta p=\Delta p_{amm}$ ⇒ "Tightness limit"

NON-EQUIVALENT TEST METHODS	
AIR	**WATER**
Test result	**Test result**
$\Delta p < \Delta p_{amm} \Rightarrow$ "Tightness"	$w = w_{amm} \Rightarrow$ "Tightness limit" or $w > w_{amm} \Rightarrow$ "No tightness"
$\Delta p = \Delta p_{amm} \Rightarrow$ "Tightness limit"	$w < w_{amm} \Rightarrow$ "Tightness" or $w > w_{amm} \Rightarrow$ "No tightness"
$\Delta p > \Delta p_{amm} \Rightarrow$ "No tightness"	$w < w_{amm} \Rightarrow$ "Tightness" or $w = w_{amm} \Rightarrow$ "Tightness limit"

The **test methods "W" and "L"** are defined **equivalent if both** – at the end of test and for the respective requirements of the current standard – **give an unambiguous result** (or **unambiguous judgement**) **for the tested pipeline**.

EQUIVALENT TEST METHODS (Dimensionless form)	
WATER	**AIR**
Test result	**Test result**
$w/w_{amm} < 1$ "Tightness"	$\Delta p/\Delta p_{amm} < 1 \Rightarrow$ "Tightness"
$w/w_{amm} = 1 \Rightarrow$ "Tightness limit"	$\Delta p/\Delta p_{amm} = 1 \Rightarrow$ "Tightness limit"
$w/w_{amm} > 1 \Rightarrow$ "No tightness"	$\Delta p/\Delta p_{amm} > 1 \Rightarrow$ "No tightness"

NON-EQUIVALENT TEST METHODS (Dimensionless form)	
WATER	**AIR**
Test result	**Test result**
$w/w_{amm} < 1 \Rightarrow$ "Tightness"	$\Delta p/\Delta p_{amm} = 1 \Rightarrow$ "Tightness limit" or $\Delta p/\Delta p_{amm} > 1 \Rightarrow$ "No tightness"
$w/w_{amm} = 1 \Rightarrow$ "Tightness limit"	$\Delta p/\Delta p_{amm} < 1 \Rightarrow$ "Tightness" or $\Delta p/\Delta p_{amm} > 1 \Rightarrow$ "No tightness"
$w/w_{amm} > 1 \Rightarrow$ "No tightness"	$\Delta p/\Delta p_{amm} < 1 \Rightarrow$ "Tightness" or $\Delta p/\Delta p_{amm} = 1 \Rightarrow$ "Tightness limit"

NON-EQUIVALENT TEST METHODS (Dimensionless form)	
AIR	**WATER**
Test result	**Test result**
$\Delta p/\Delta p_{amm} < 1 \Rightarrow$ "Tightness"	$w/w_{amm} = 1 \Rightarrow$ "Tightness limit" or $w/w_{amm} > 1 \Rightarrow$ "No tightness"
$\Delta p/\Delta p_{amm} = 1 \Rightarrow$ "Tightness limit"	$w/w_{amm} < 1 \Rightarrow$ "Tightness" or $w/w_{amm} > 1 \Rightarrow$ "No tightness"
$\Delta p/\Delta p_{amm} > 1 \Rightarrow$ "No tightness"	$w/w_{amm} < 1 \Rightarrow$ "Tightness" or $w/w_{amm} = 1 \Rightarrow$ "Tightness limit"

TIGHTNESS LIMIT – DEFINITION

Test with water (method "W")

It is at the tightness limit when

$w \cong w_{amm}$

or

$w/w_{amm} \cong 1$ **(dimensionless form)**

w is the measured leakage per square meter of internal wetted area (l/m^2)

w_{amm} is the allowable leakage per square meter of internal wetted area (l/m^2).

Test with air (method "L")

It is at the tightness limit when

$\Delta p \cong \Delta p_{amm}$

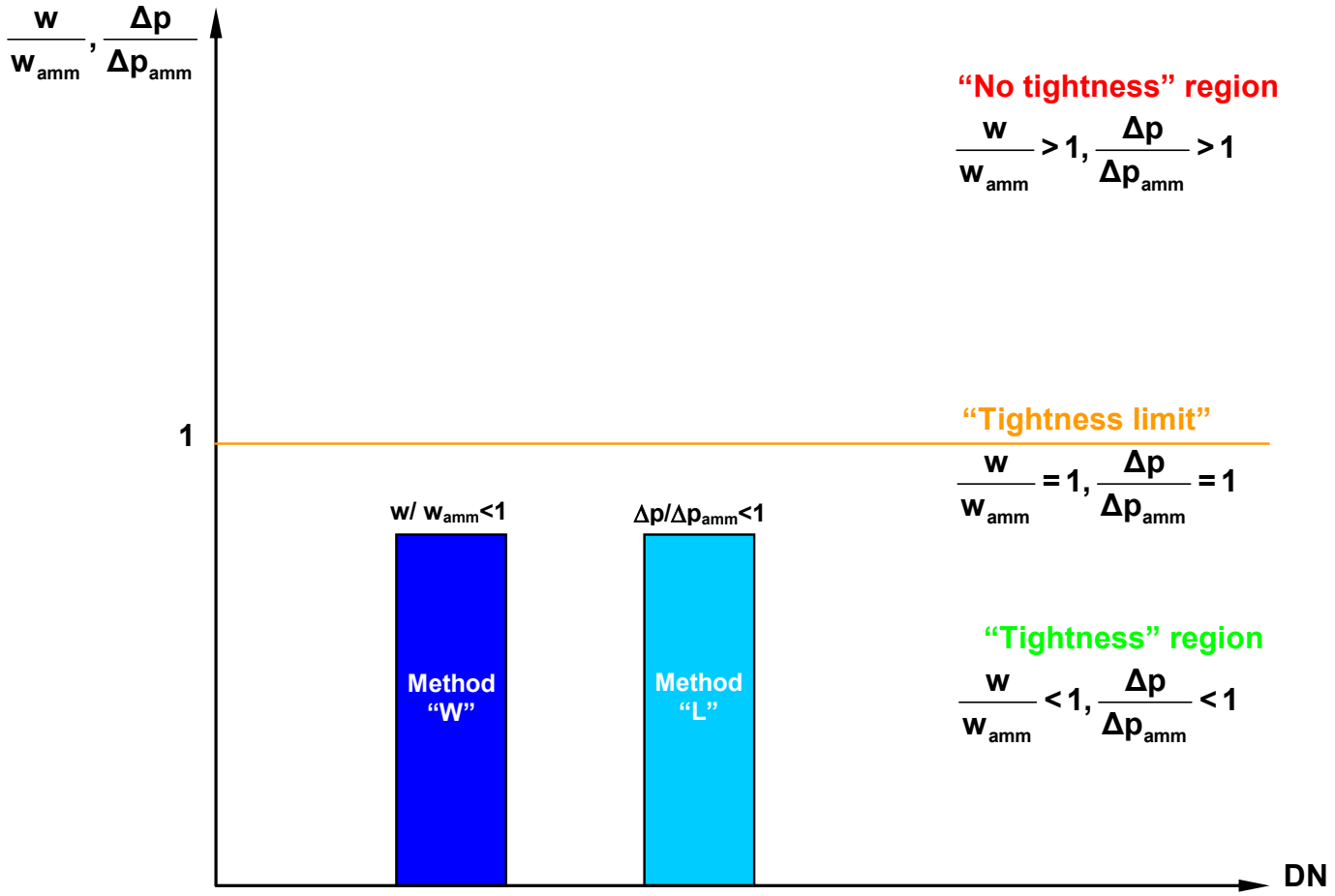
or

$\Delta p/\Delta p_{amm} \cong 1$ **(dimensionless form)**

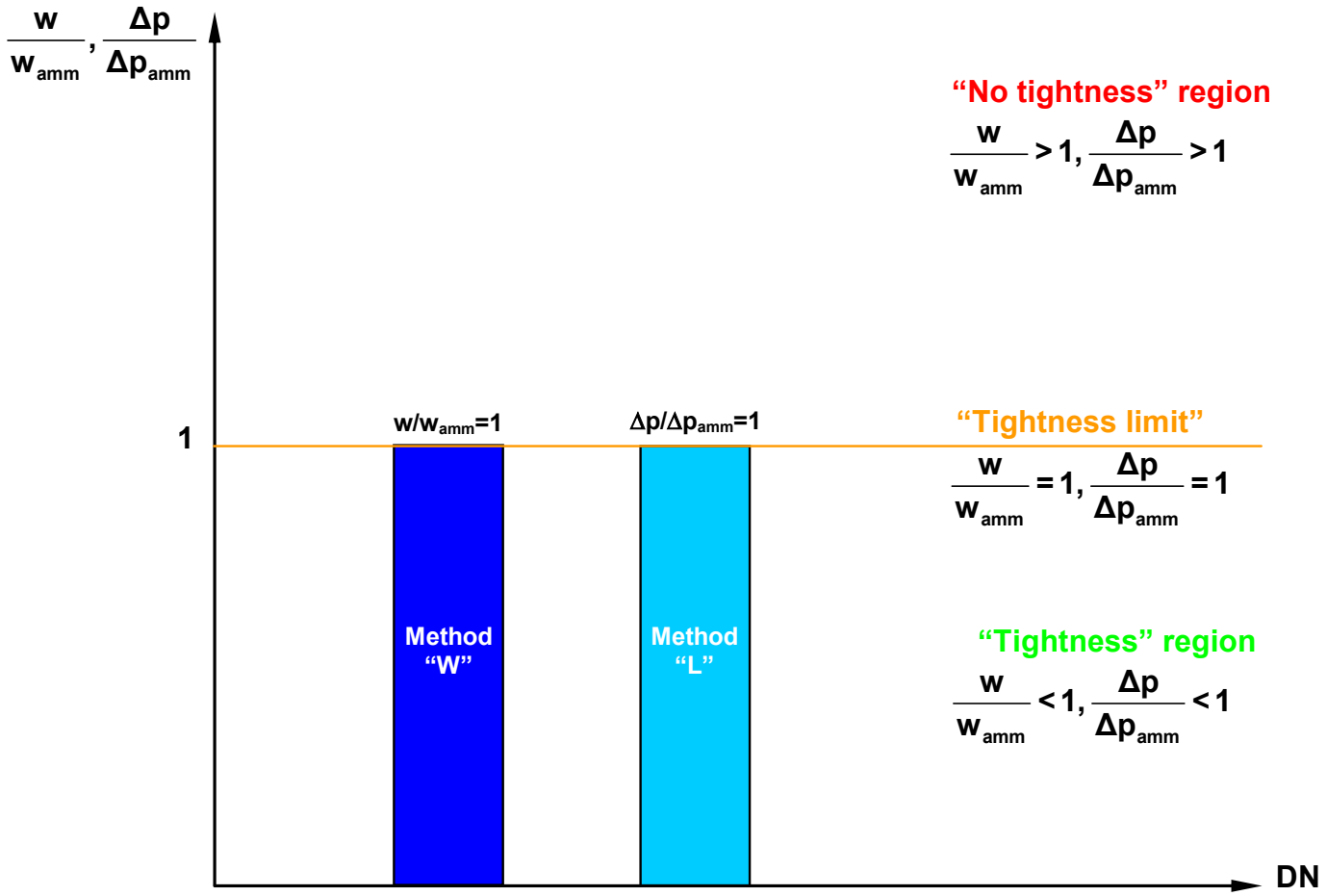
Δp is the measured pressure drop (mbar)

Δp_{amm} is the allowable pressure drop (mbar).

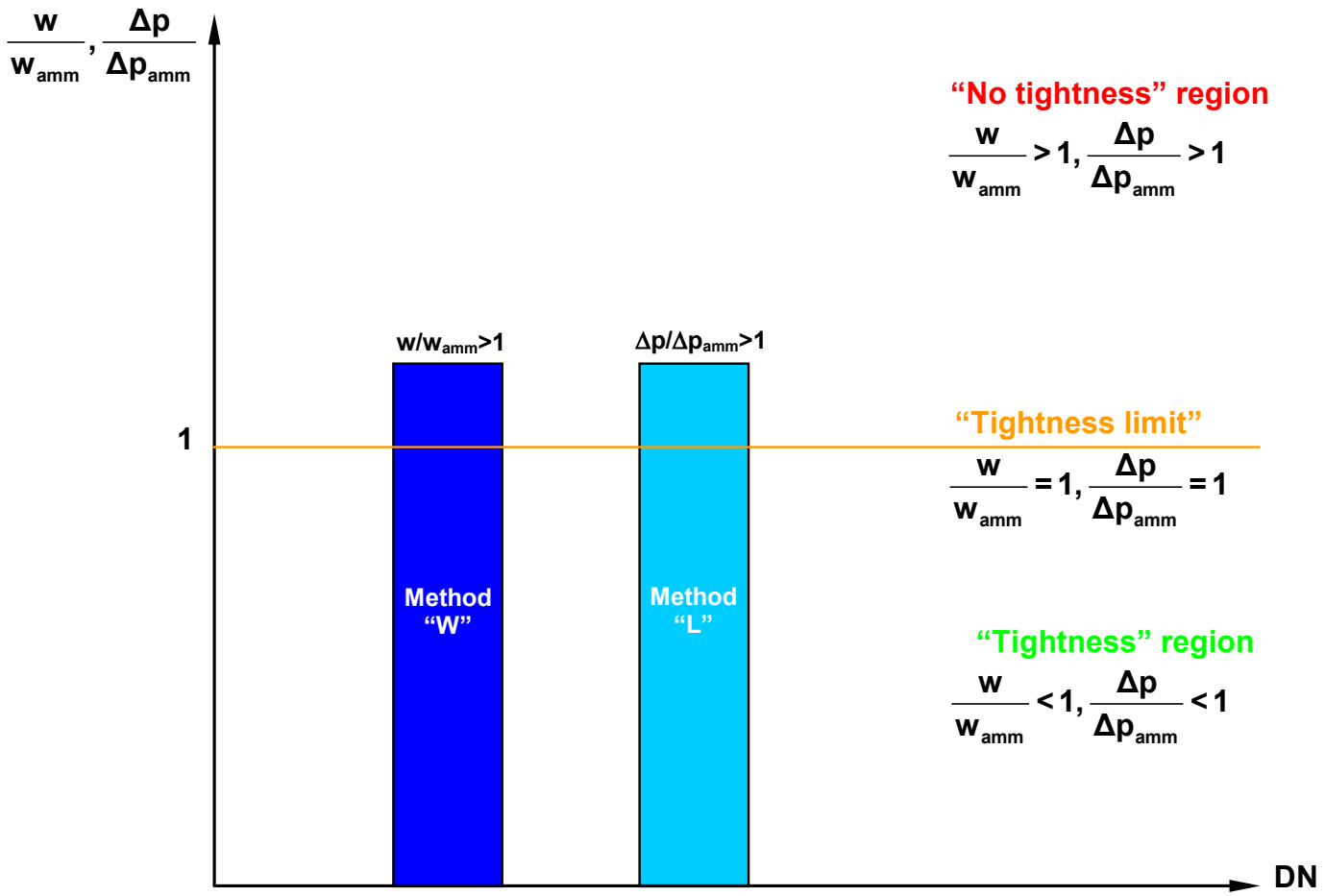
Equivalent test methods – Case: "Tightness"



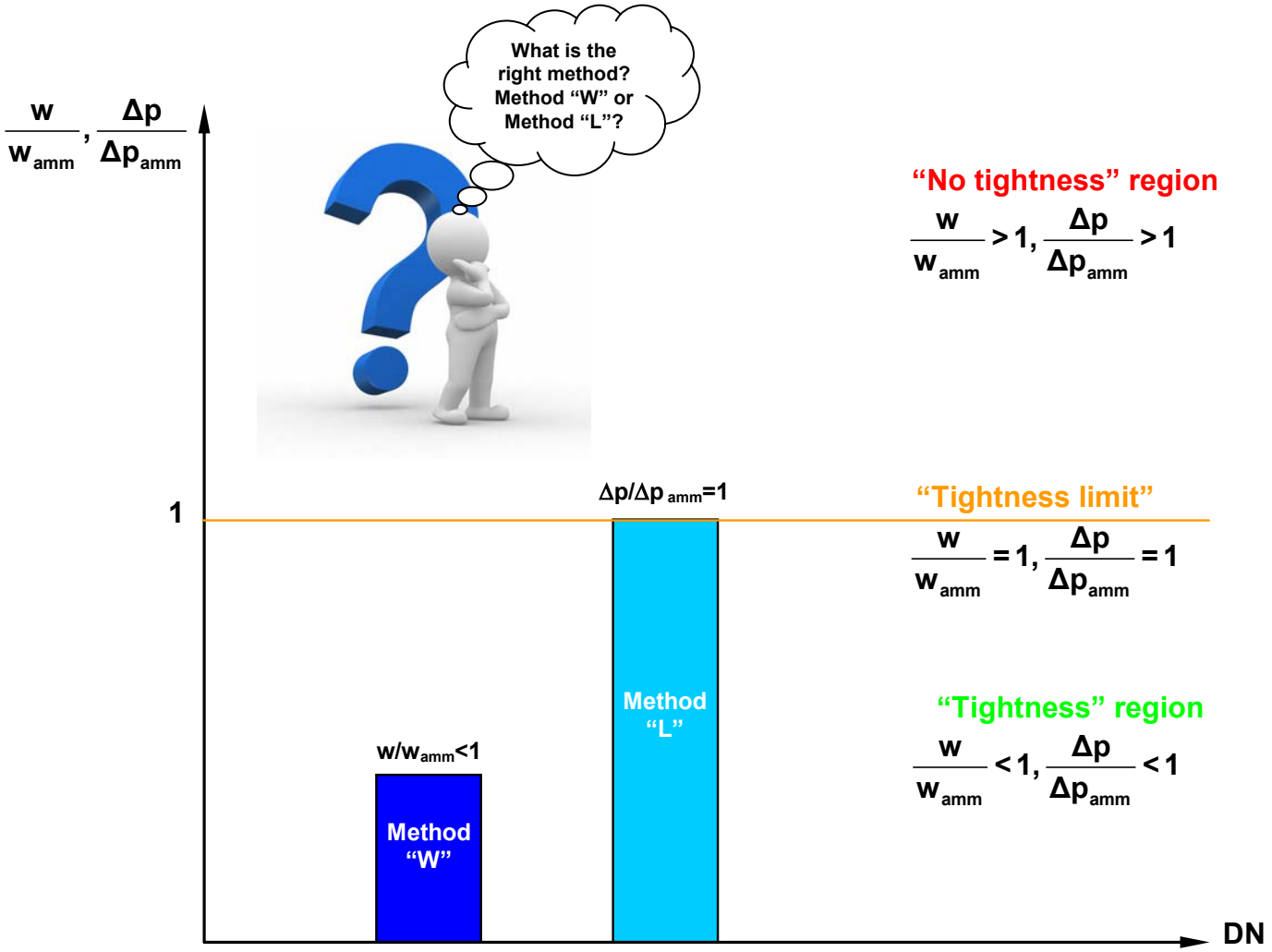
Equivalent test methods – Case: "Tightness limit"



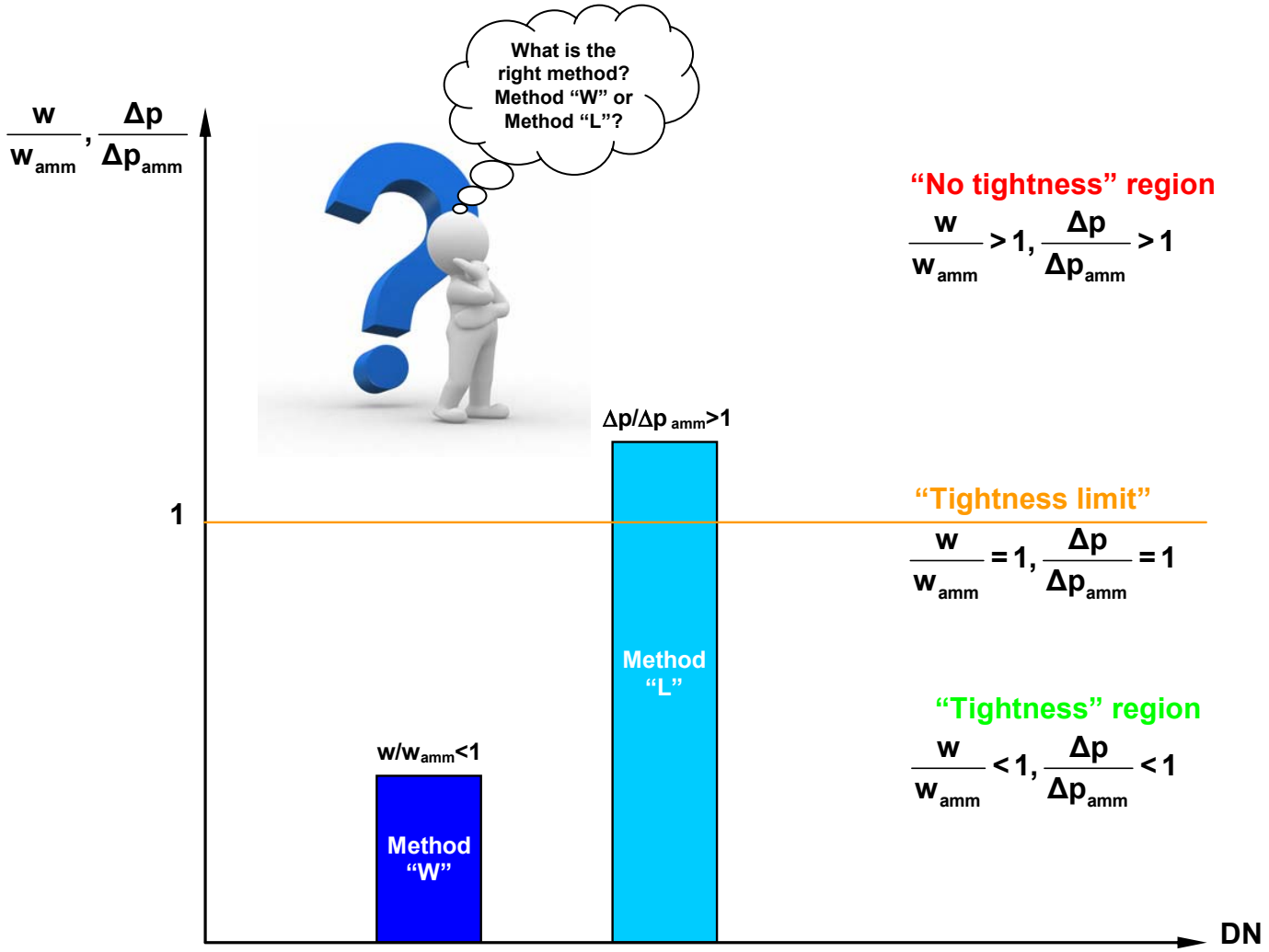
Equivalent test methods – Case: "No tightness"



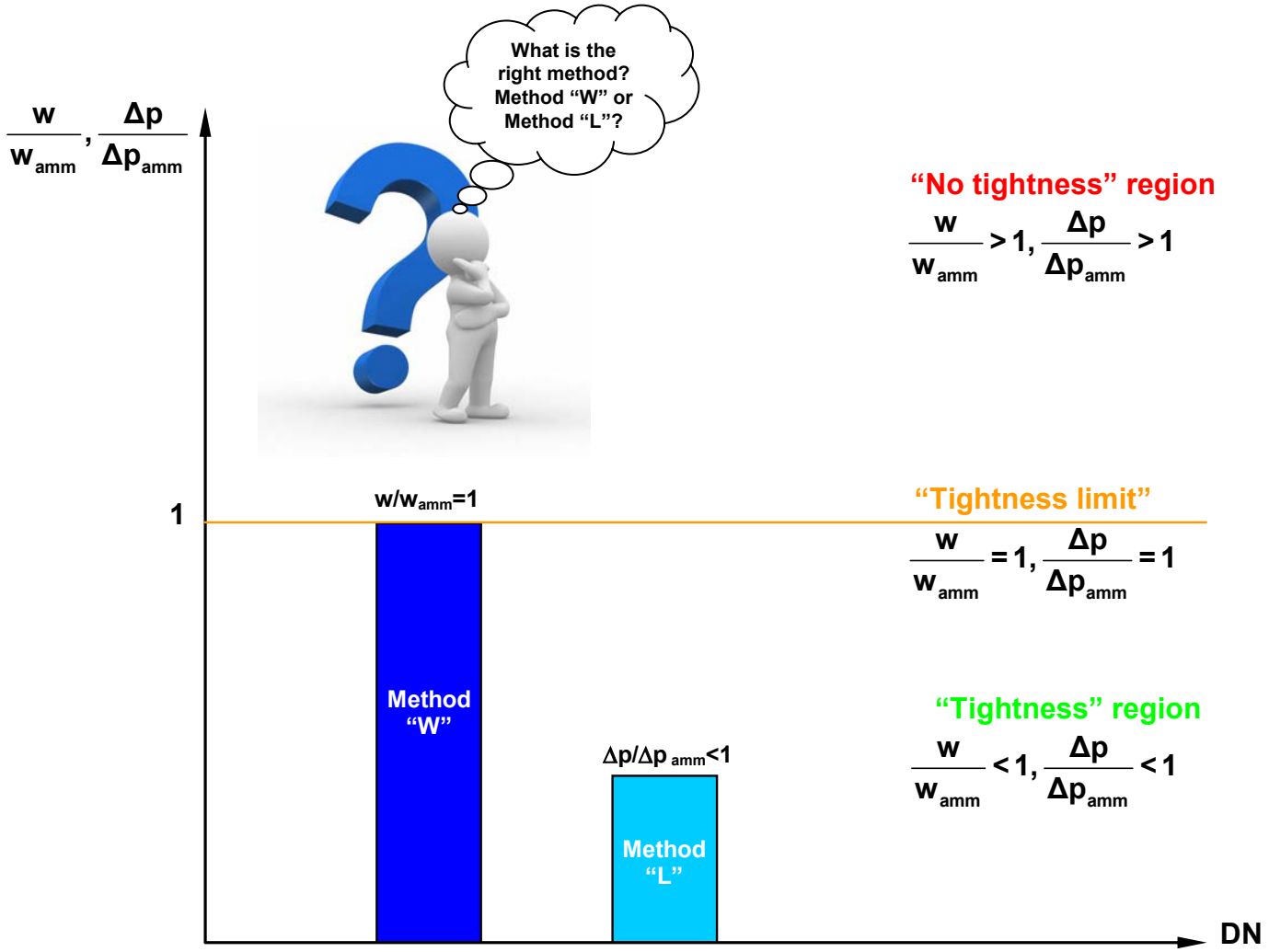
Non-equivalent test methods



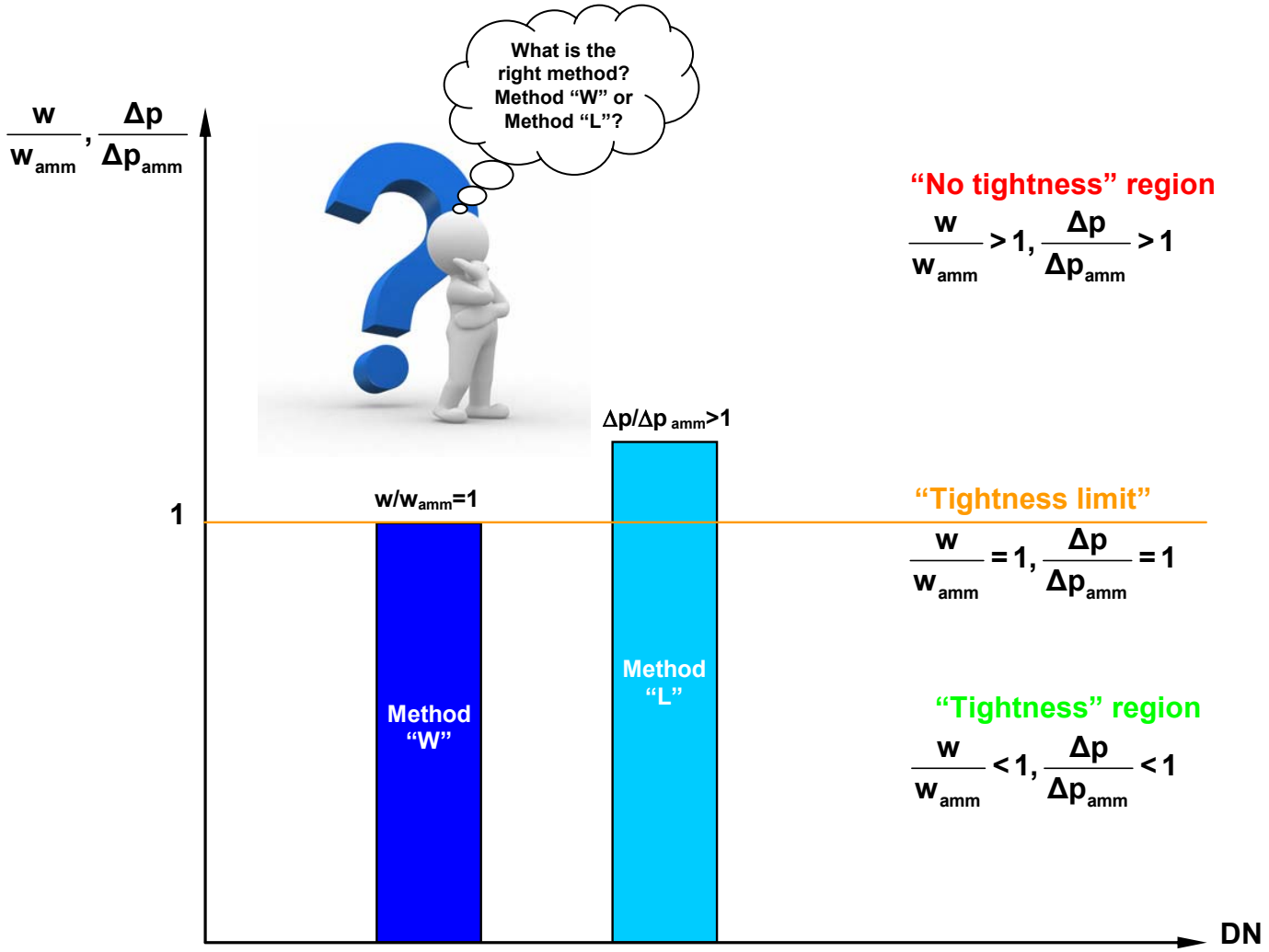
Non-equivalent test methods



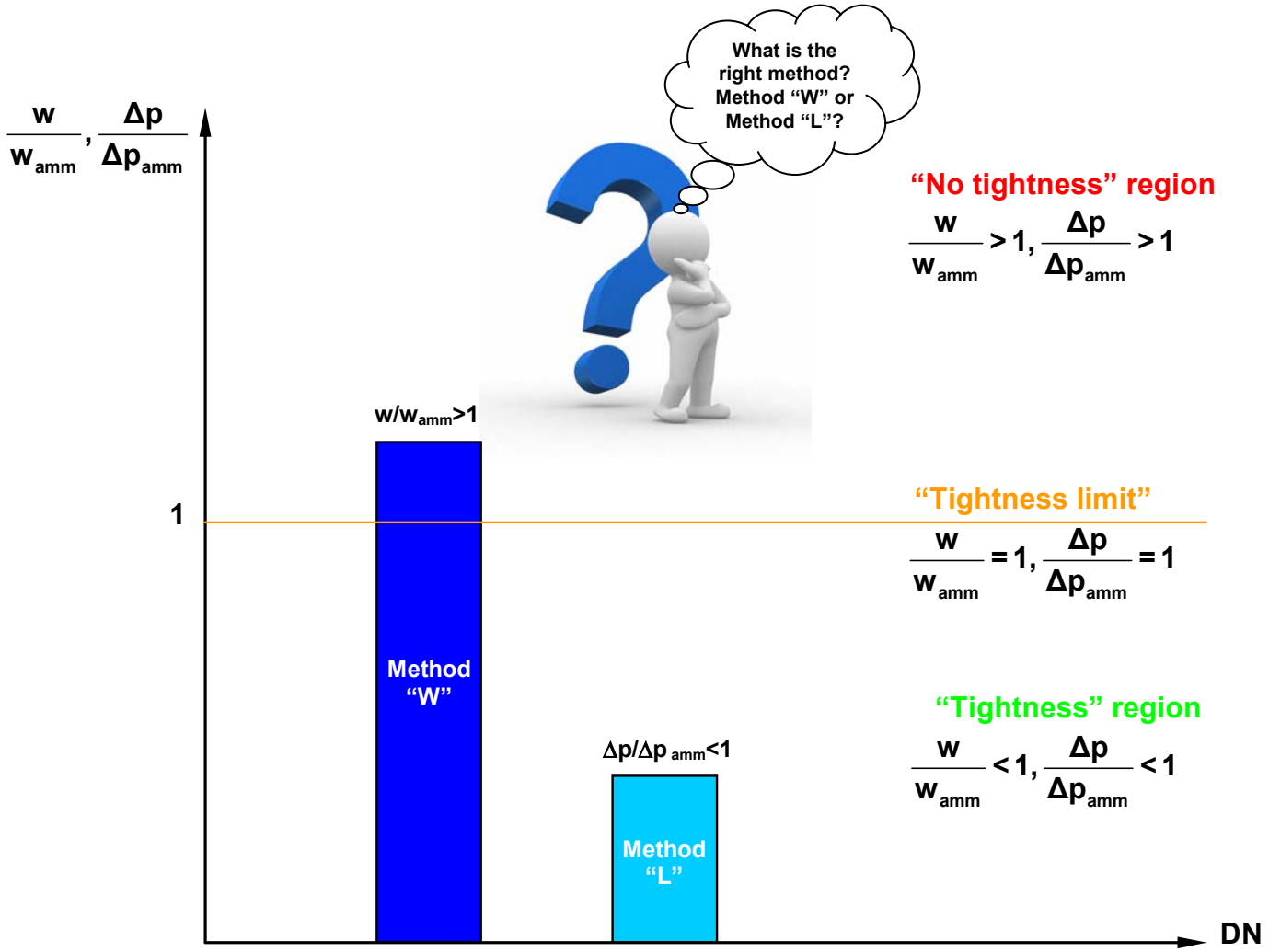
Non-equivalent test methods



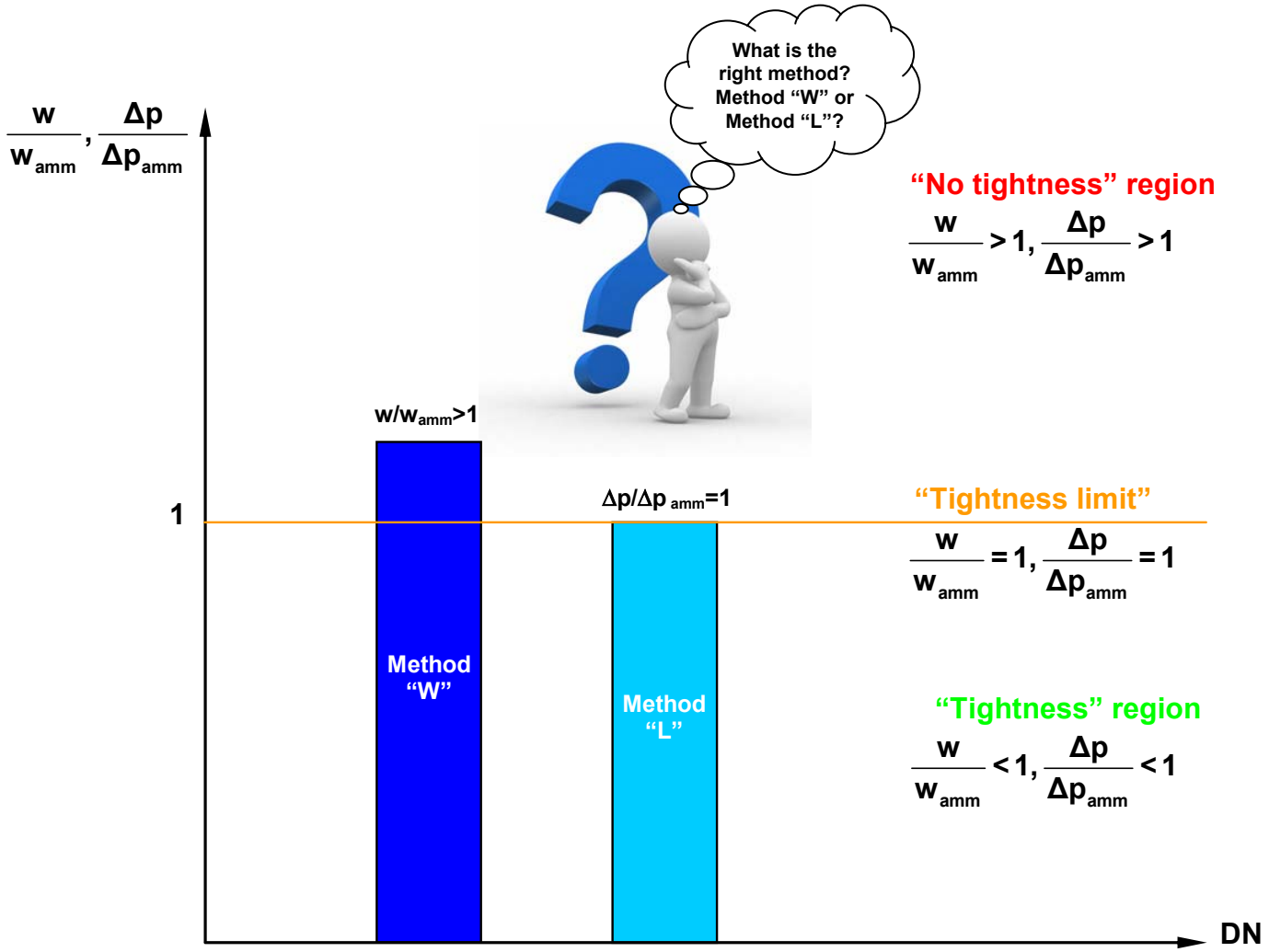
Non-equivalent test methods



Non-equivalent test methods



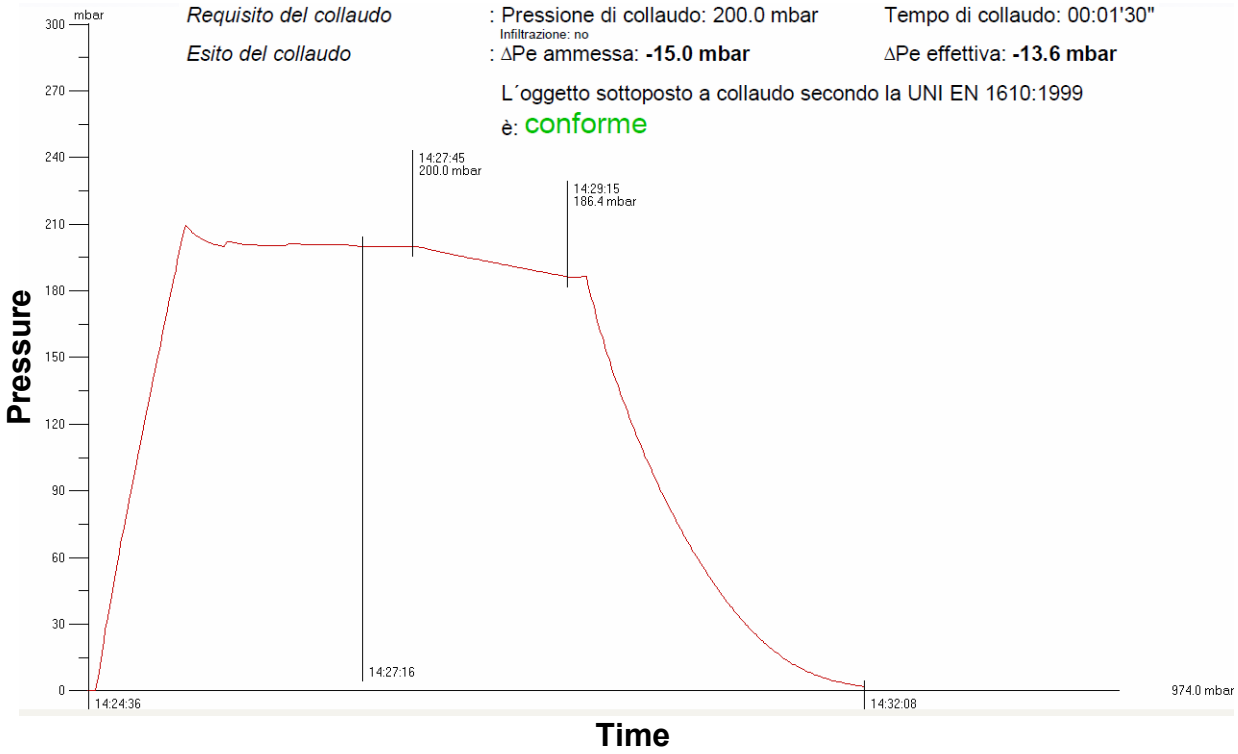
Non-equivalent test methods



Real case #1 – Air pressure test

Pipe length tested: 15,00 m
Inner diameter: 200 mm

The leakage was simulated using an artificial circular hole (0,80 mm diameter)



Standard: UNI EN 1610:1999

Test method: "LD"

Requirements:

- p_0=200 mbar
- Δp=15 mbar
- t=1'30''

Real case #1 – Water pressure test

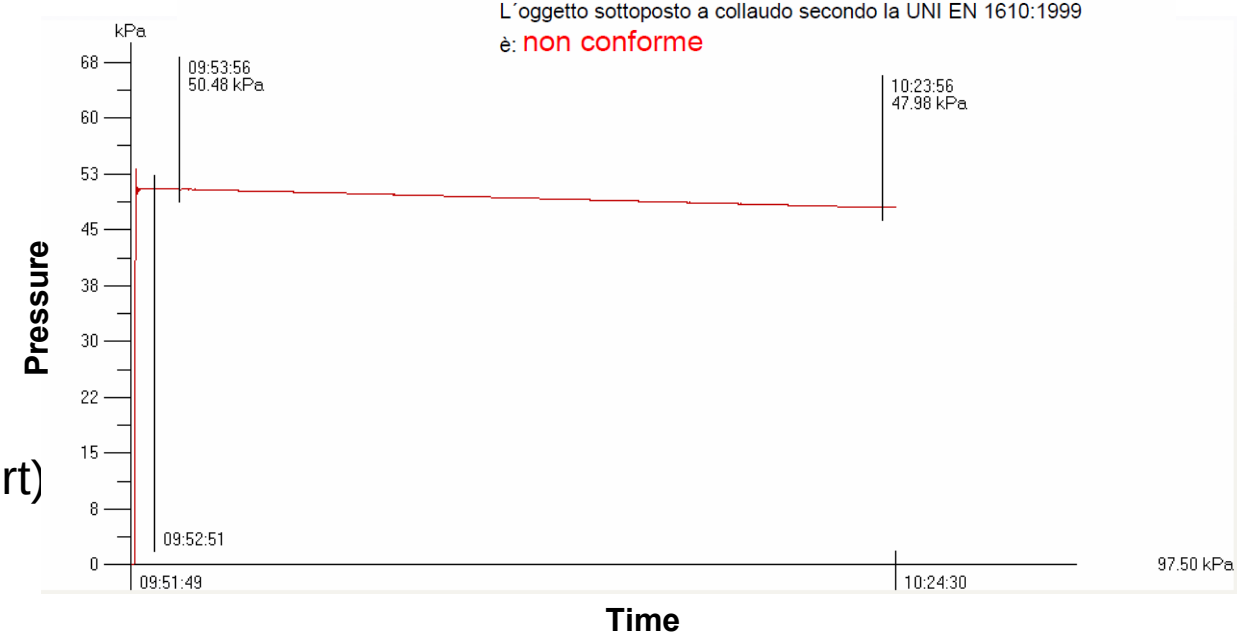
Pipe:Vitrified clay pipe
Pipe length tested: 15,00 m
Inner diameter: 200 mm

The leakage was simulated using an artificial circular hole (0,80 mm diameter)

Requisito del collaudo : Pressione: 50,00 Tempo di collaudo: 00:30'00"
Perdita d'acqua consentita 0.15 l/m² = **1.41 l** per superficie 9.42 m²
Rabbocco manuale: l Evaporazione/Assorbimento: l
Infiltrazione: no

Esito del collaudo : Perdita d'acqua effettiva secondo il test: **7.07 l**

L´oggetto sottoposto a collaudo secondo la UNI EN 1610:1999 è: non conforme



Standard: UNI EN 1610:1999

Test method: "W"

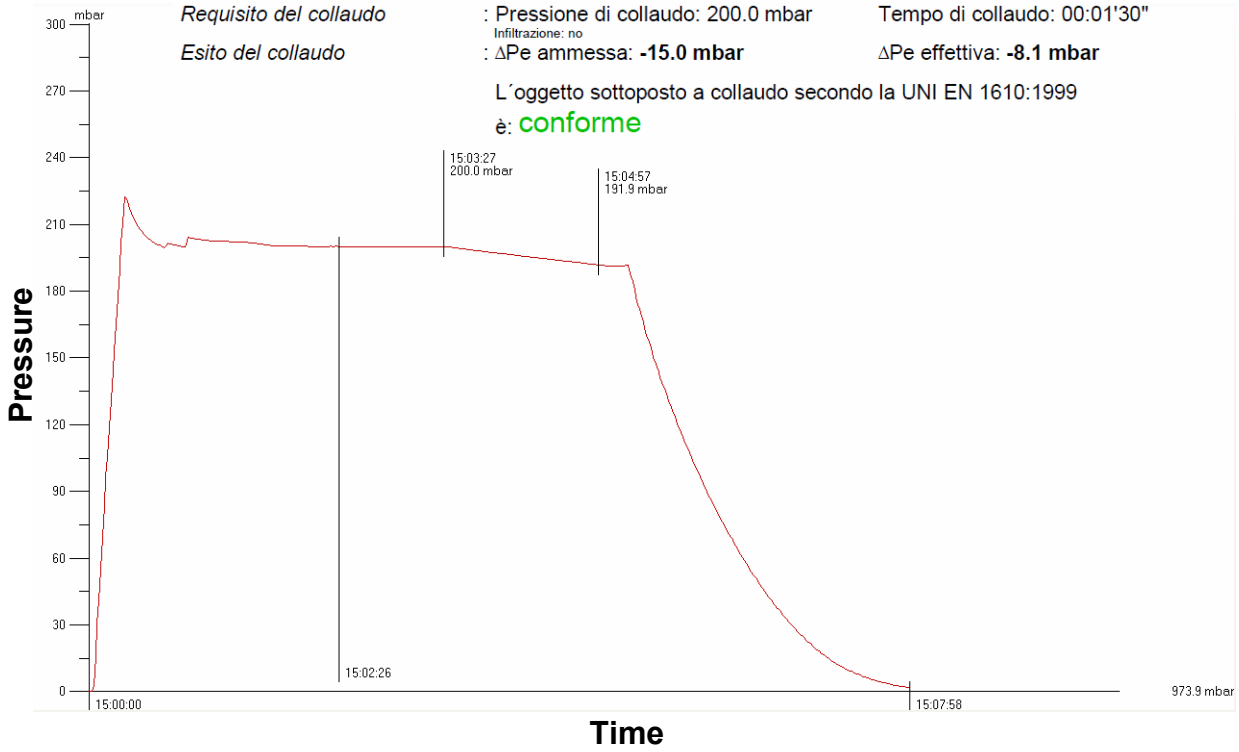
Requirements:

- p_0=50 kPa (measured at invert)
- w_{amm}=0,15 l/m²
- t=30'

Real case #2 – Air pressure test

Pipe:Vitrified clay pipe
Pipe length tested: 15,00 m
Inner diameter: 200 mm

The leakage was simulated using an artificial circular hole (0,60 mm diameter)



Standard: UNI EN 1610:1999

Test method: "LD"

Requirements:

- p_0=200 mbar
- Δp=15 mbar
- t=1'30''

Real case #2 – Water pressure test

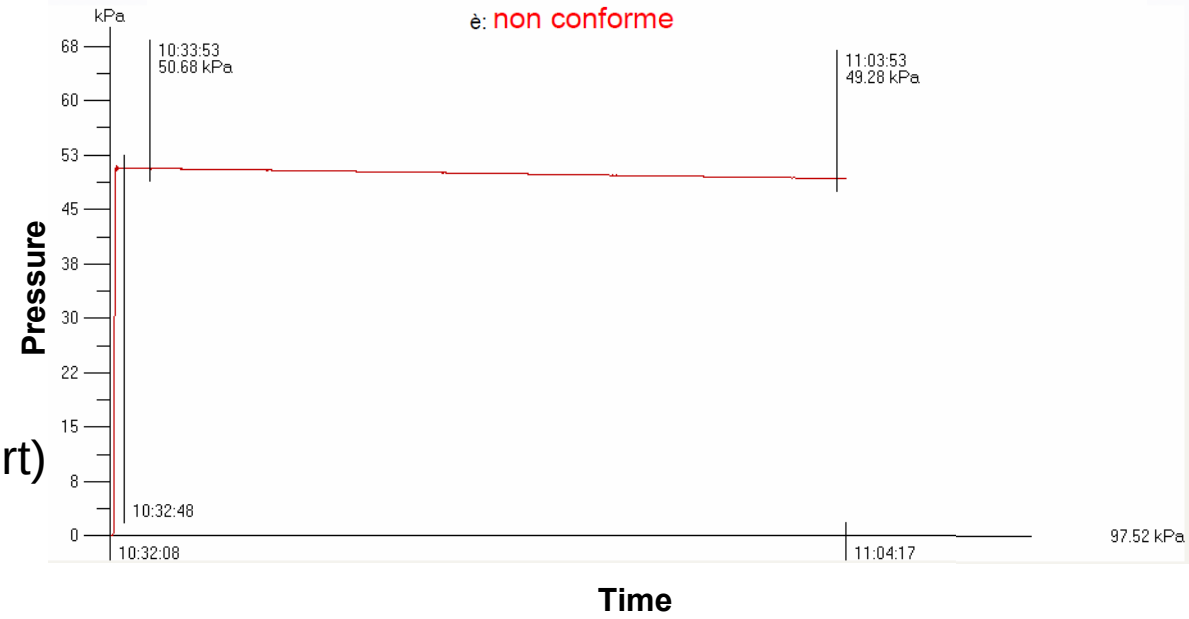
Pipe:Vitrified clay pipe
Pipe length tested: 15,00 m
Inner diameter: 200 mm

The leakage was simulated using an artificial circular hole (0,60 mm diameter)

Requisito del collaudo : Pressione: 50,00 Tempo di collaudo: 00:30'00"
Perdita d'acqua consentita 0.15 l/m² = **1.41 l** per superficie 9.42 m²
Rabbocco manuale: l Evaporazione/Assorbimento: l
Infiltrazione: no

Esito del collaudo : Perdita d'acqua effettiva secondo il test: **3.96 l**

L´oggetto sottoposto a collaudo secondo la UNI EN 1610:1999 è: non conforme



Standard: UNI EN 1610:1999

Test method: "W"

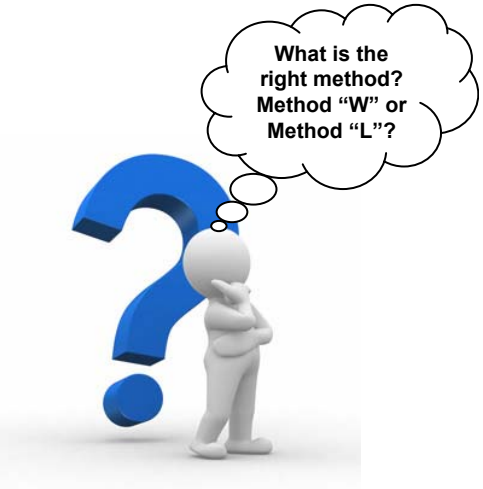
Requirements:

- p_0=50 kPa (measured at invert)
- w_{amm}=0,15 l/m²
- t=30'

Test Number	TEST METHOD	
	AIR ("LD")	WATER ("W")
	Test result	Test result
#1	$\Delta p/\Delta p_{amm}=0,91<1$	$w/w_{amm}=5,01>1$
#2	$\Delta p/\Delta p_{amm}=0,54<1$	$w/w_{amm}=2,81>1$

⇓

In both cases (#1 and #2)
the method "LD" and method "W"
are NOT EQUIVALENT!



OVERVIEW

Motivation and aim of the research

Methods "L" and "W": Concept of Equivalence

Results of an experimental research based on an equivalence criteria.

Equivalence criteria to make comparable "W" and "LD" methods

In order to make comparable (or equivalent) air test (in the present work only method "LD" was analyzed) and water test, an equivalent criteria was defined.

The experimental tests were carried-out (period 2009-2010) by **Dr. Miglio** and nuova Contec team group at Cellina Valley-nuova ConTec using pipes of different diameter.

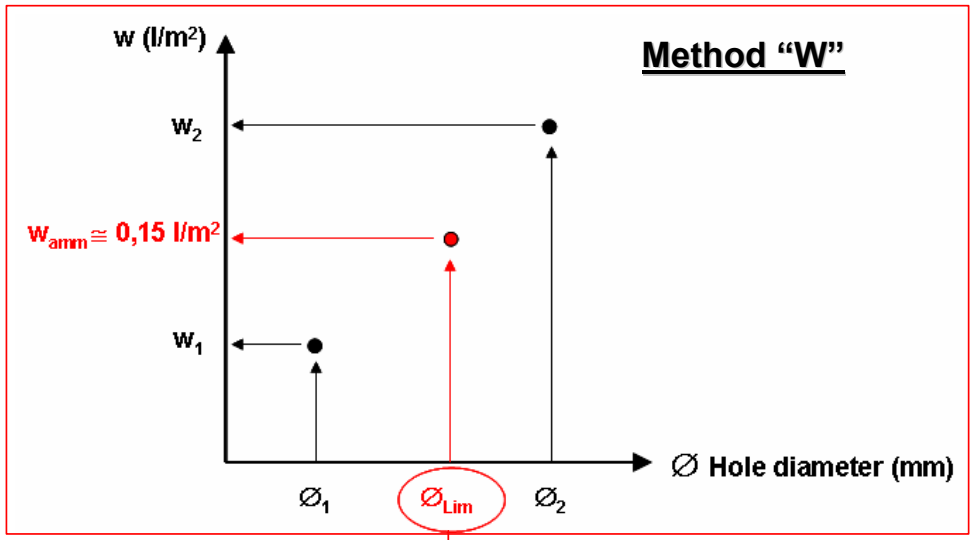
nuovaConTec

Cellinavalley

Equivalence criteria

The **criteria** adopted to make **equivalent** the **air test and water test** for a pipeline **was to evaluate the "maximum allowable leakage area"** (represented by a circular hole) **capable of generating a water leakage equal to allowable leakage for pipeline** (i.e., 0,15 l/m^2 during 30 min, in according to standard UNI EN 1610:1999). In this way, the **"maximum allowable leakage area" identifies** the "**tightness limit**" **condition for the water test (method "W")**.

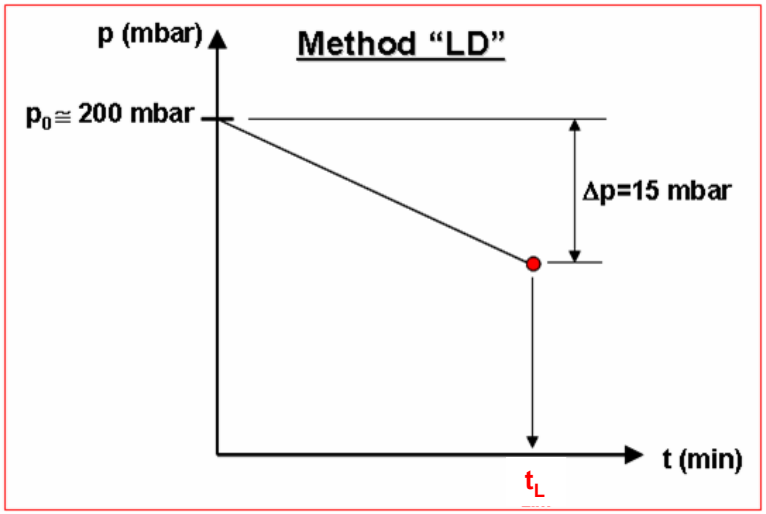
For the air test (method "LD"), **the "test time", t_L, was calculated using the same "maximum allowable leakage area"**. The "test time" is that time at which the pressure drop is equal to 15 mbar (requirement established by UNI EN 1610:1999 for method "LD"). The **"test time" identifies** the "**tightness limit**" **condition for the air test (method "LD")**.



EQUIVALENCE CRITERIA ADOPTED:

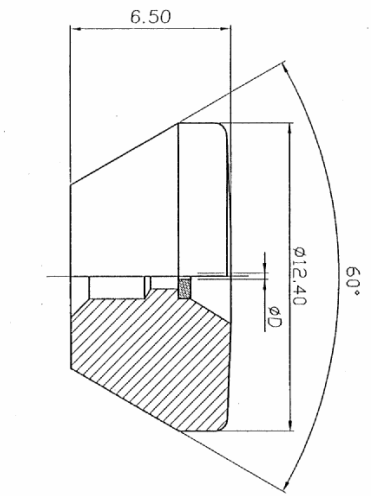
The METHOD "W" and the METHOD "LD" have the SAME "MAXIMUM ALLOWABLE LEAKAGE AREA"

"Maximum allowable leakage area" (represented by a circular hole)



Circular hole used in the tests

The different “maximum allowable leakage areas” used in the tests were represented by a circular hole placed in a nozzle. The hole thickness was 1,0 mm, the hole diameter ranged from 0,28 a 0,40 mm.



Pipes used in the tests

The tests were carried-out using pipes made of different material, diameter and test length (distance between internal faces of the test sealing bags).

Pipe material	**DN (mm)**	**ID (mm)**	**L_{Eff} (m)**	**$\varnothing_{Lim}$ (mm)**
Ductile iron	125	120	16,00	0,28
Vitrified clay	200	200	18,40	0,38
PVC	315	300	13,50	0,40
PVC	500	475	5,80	0,33
PVC	710	675	3,30	0,30
Steel (used only for air pressure test)	1000	990	4,10	0,40

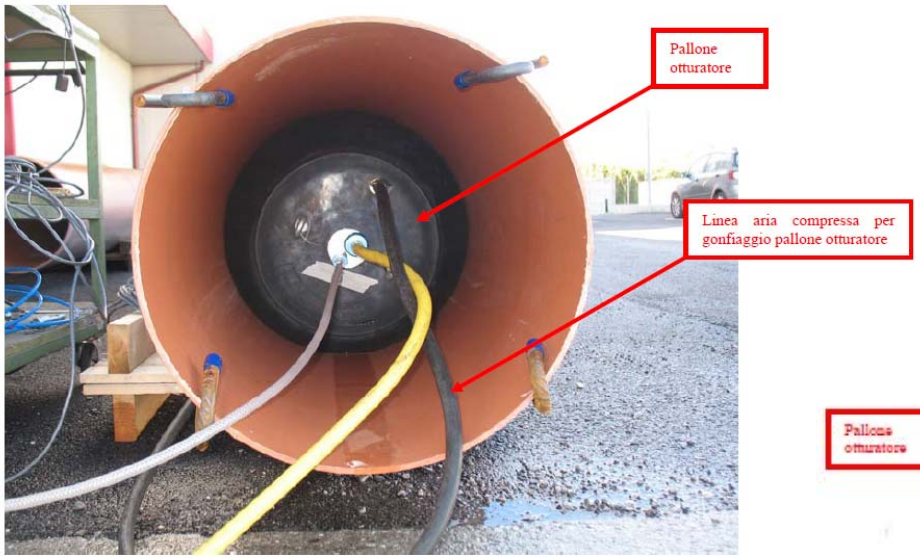
TEST METHOD "W" – EXPERIMENTAL EQUIPMENT

General view

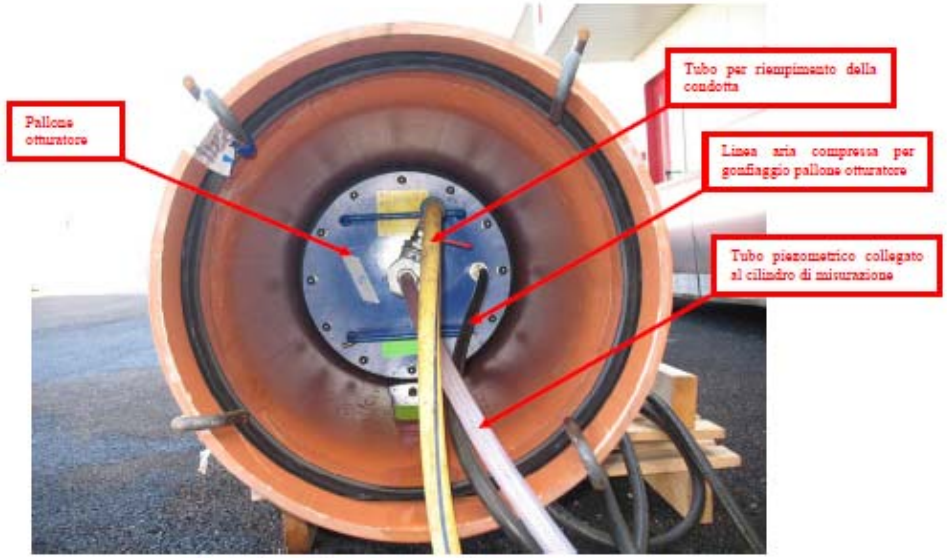
TEST METHOD "W" – EXPERIMENTAL EQUIPMENT

Piezometric column

TEST METHOD "W" – EXPERIMENTAL EQUIPMENT

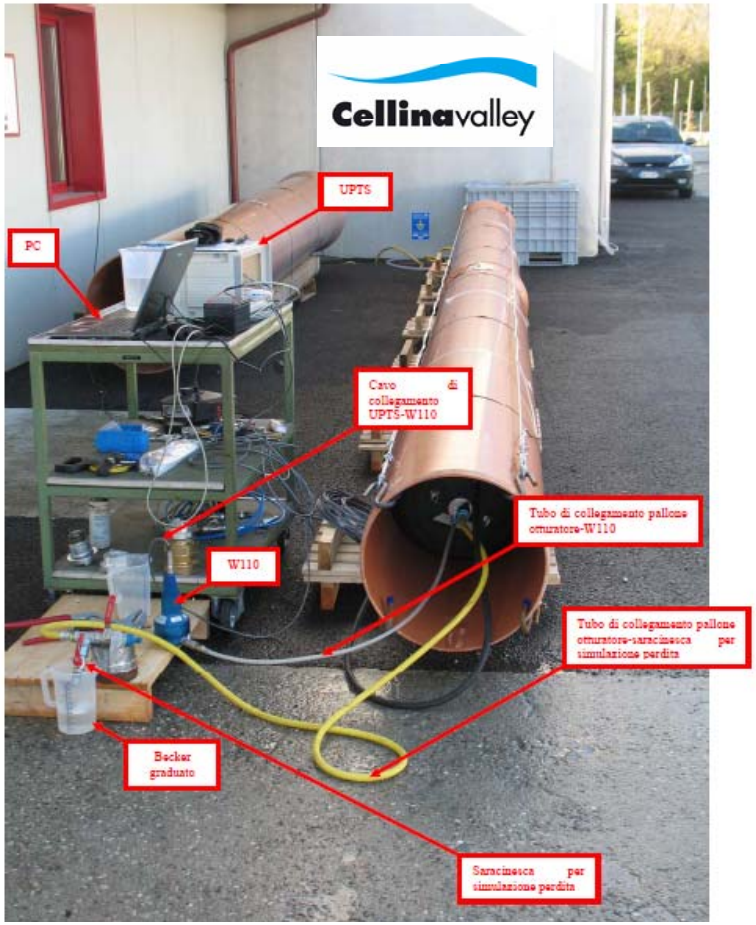


Sealing bag – Downstream view



Sealing bag – Upstream view

TEST METHOD "W" – EXPERIMENTAL EQUIPMENT



Downstream view – Pipeline and instrumentation

Measuring cup

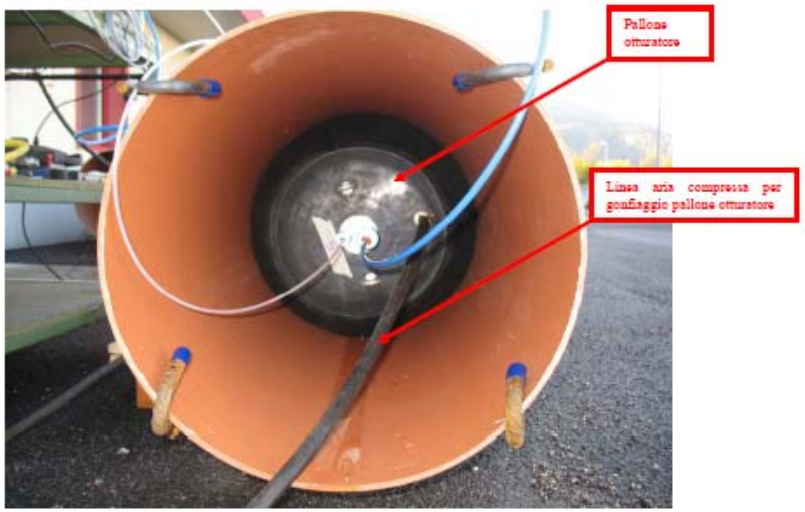
Leakage simulation equipment and pressure sensor

TEST METHOD "W" – EXPERIMENTAL EQUIPMENT

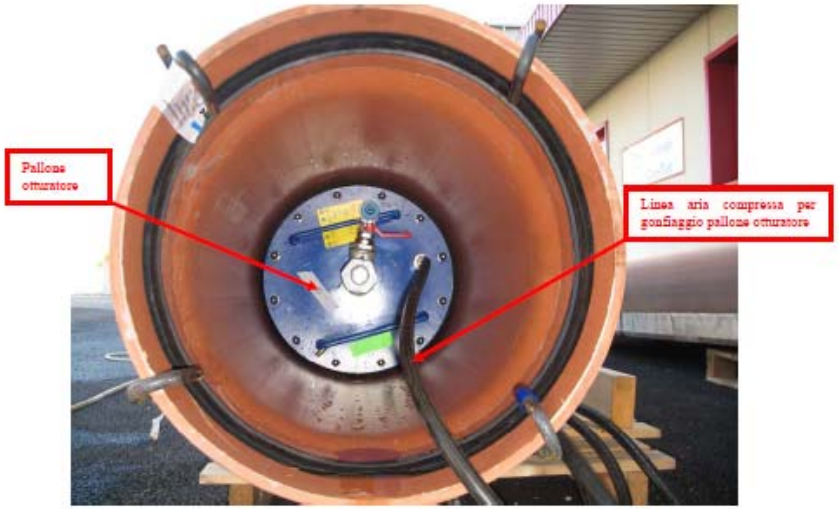
UPTS System

UPTS System and PC for data acquisition

TEST METHOD "LD" – EXPERIMENTAL EQUIPMENT

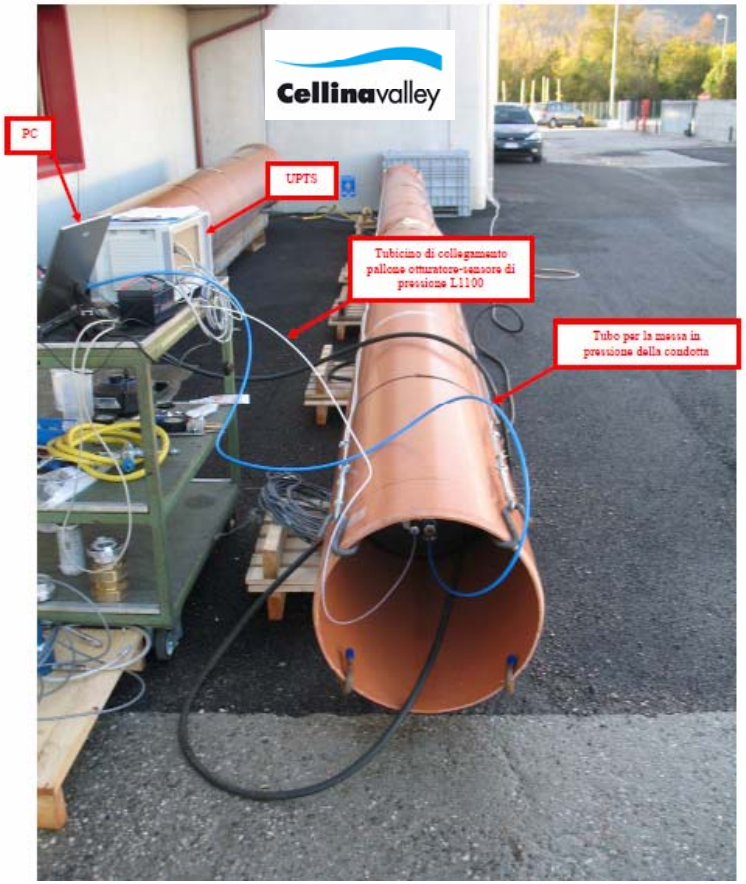


Sealing bag – Downstream view



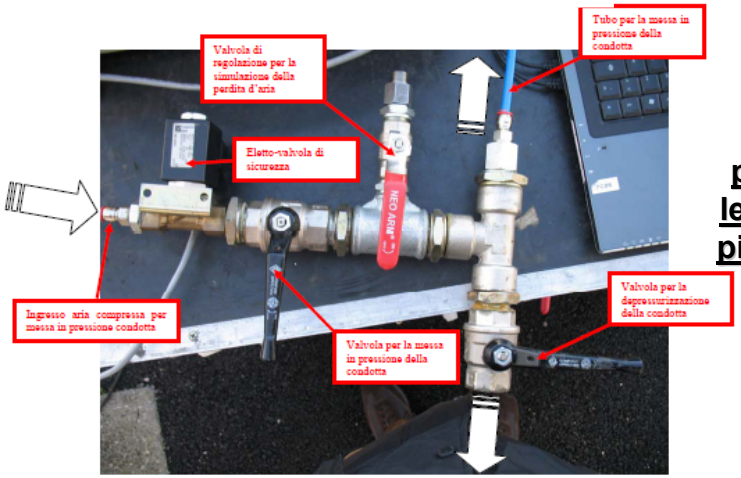
Sealing bag – Upstream view

TEST METHOD "LD" – EXPERIMENTAL EQUIPMENT



Downstream view – Pipeline and instrumentatio

Compressed air line for pressurizing the pipeline



Control device for pipeline pressurizing, leakage simulation and pipeline depressurizing

EXPERIMENTAL RESULTS – VALIDITY

The experimental results are valid for “Soaked concrete pipes and all other material” and method “LD”, and under the following conditions:

a) Test pressure equal to 50 kPa (measured at the pipe invert) for method “W”, test pressure p_0=200 mbar and pressure drop Δp=15 mbar for method “LD”;

b) The “maximun allowable leakage areas” were represented by a single geometry, i.e. circular hole;

c) The hole diameters were very small (from 0,28 a 0,40 mm);

d) The ratio between the hole thickness, L, and the hole diameter, ∅, was less than 30, i.e. L/∅<30;

e) The tests were carried-out using high accuracy and calibrated instrumentation, which is demonstrated by certificate issued by an accredited institution.

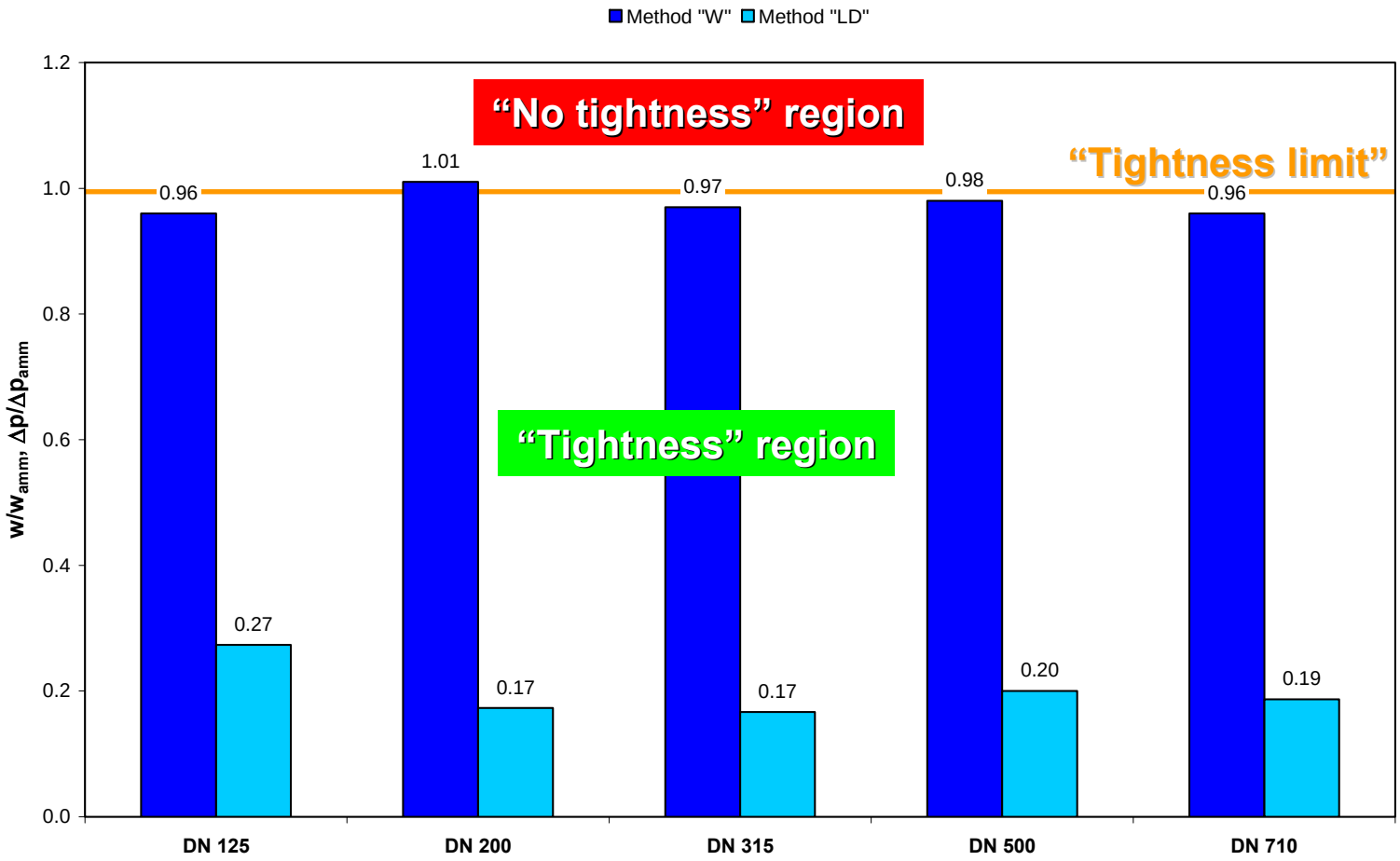
EXPERIMENTAL RESULTS

The tests were carried-out in according to UNI EN 1610:1999

			Test Method							
			Water ("W")				Air ("LD")			
Test number	Inner pipe diameter (mm)	Hole diameter (mm)	p_0 (kPa)	t (min)	w (l/m^2)	w/w_{amm}	p_0 (mbar)	t_L (min)	Δp (mbar)	$\Delta p/\Delta p_{amm}$
#1 – DN125	120,0	0,28	50	30	0,144	0,96	200	1,5	4,1	0,27
#2 – DN200	200,0	0,38	50	30	0,152	1,01	200	1,5	2,6	0,17
#3 – DN315	299,6	0,40	50	30	0,146	0,97	200	2,0	2,5	0,17
#4 – DN500	475,4	0,33	50	30	0,147	0,98	200	3,0	3,0	0,20
#5 – DN710	675,2	0,30	50	30	0,144	0,96	200	4,5	2,8	0,19

EXPERIMENTAL RESULTS

The tests were carried-out in according to UNI EN 1610:1999



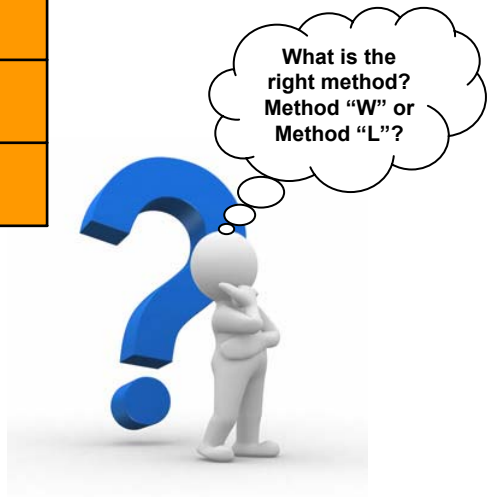
EXPERIMENTAL RESULTS

The tests were carried-out in according to UNI EN 1610:1999

Test Number	TEST METHOD	
	AIR ("LD")	WATER ("W")
	Test result	Test result
#1 – DN125	$\Delta p/\Delta p_{amm}=0,27<1$	$w/w_{amm}=0,96\cong1$
#2 – DN200	$\Delta p/\Delta p_{amm}=0,17<1$	$w/w_{amm}=1,01\cong1$
#3 – DN315	$\Delta p/\Delta p_{amm}=0,17<1$	$w/w_{amm}=0,97\cong1$
#4 – DN500	$\Delta p/\Delta p_{amm}=0,20<1$	$w/w_{amm}=0,98\cong1$
#5 – DN710	$\Delta p/\Delta p_{amm}=0,19<1$	$w/w_{amm}=0,96\cong1$

⇓

In all cases
the method "LD" and method "W"
are NOT EQUIVALENT!



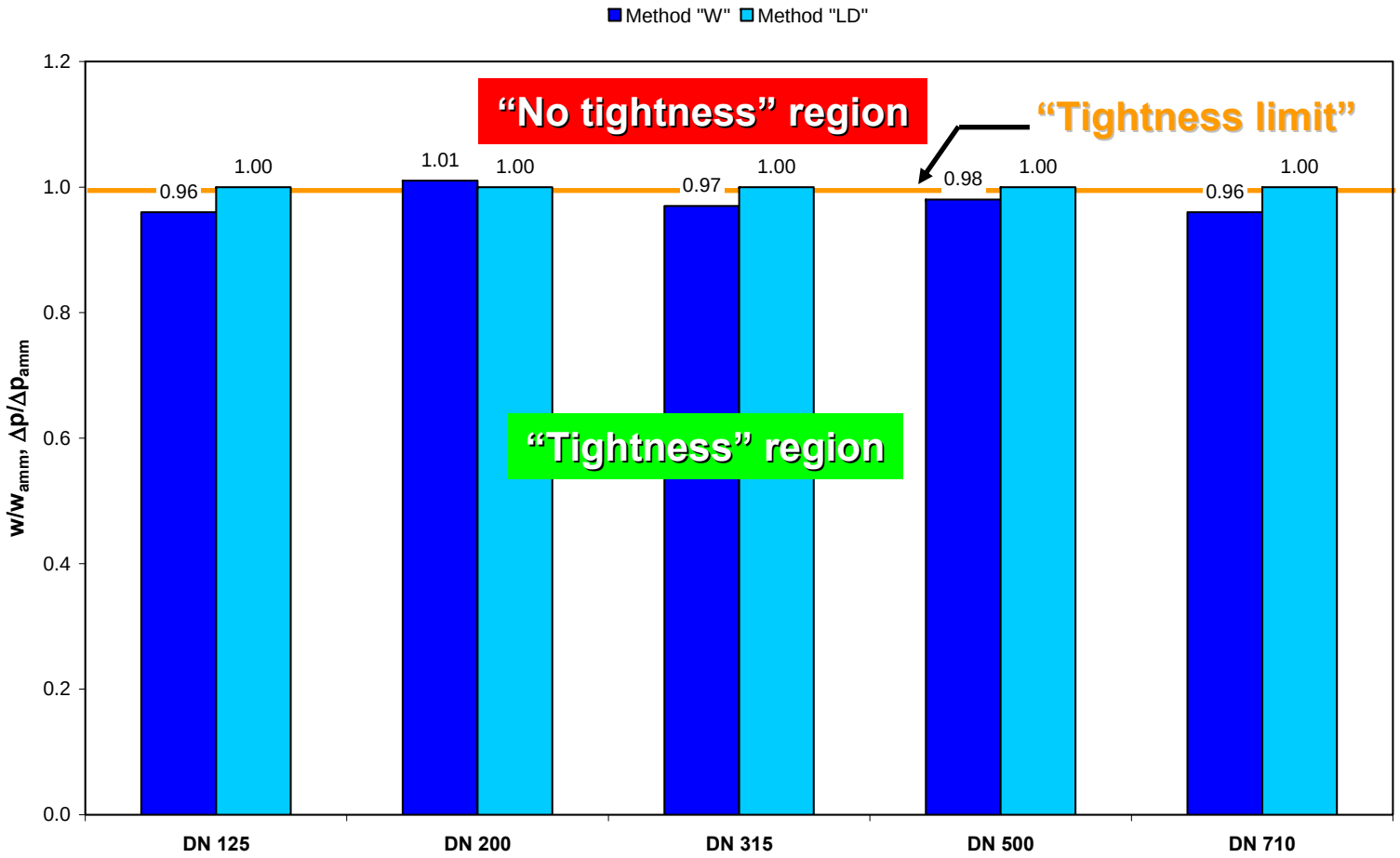
EXPERIMENTAL RESULTS

The tests were carried-out in according to EQUIVALENT CRITERIA

			Test Method							
			Water ("W")				Air ("LD")			
Test number	Inner pipe diameter (mm)	Hole diameter (mm)	p_0 (kPa)	t (min)	w (l/m^2)	w/w_{amm}	p_0 (mbar)	Δp (mbar)	t_L (min)	$\Delta p/\Delta p_{amm}$
#1 – DN125	120,0	0,28	50	30	0,144	0,96	200	15,0	5,2	1,00
#2 – DN200	200,0	0,38	50	30	0,152	1,01	200	15,0	8,2	1,00
#3 – DN315	299,6	0,40	50	30	0,146	0,97	200	15,0	12,0	1,00
#4 – DN500	475,4	0,33	50	30	0,147	0,98	200	15,0	19,4	1,00
#5 – DN710	675,2	0,30	50	30	0,144	0,96	200	15,0	26,9	1,00

EXPERIMENTAL RESULTS

The tests were carried-out in according to EQUIVALENT CRITERIA



EXPERIMENTAL RESULTS

The tests were carried-out in according to EQUIVALENT CRITERIA

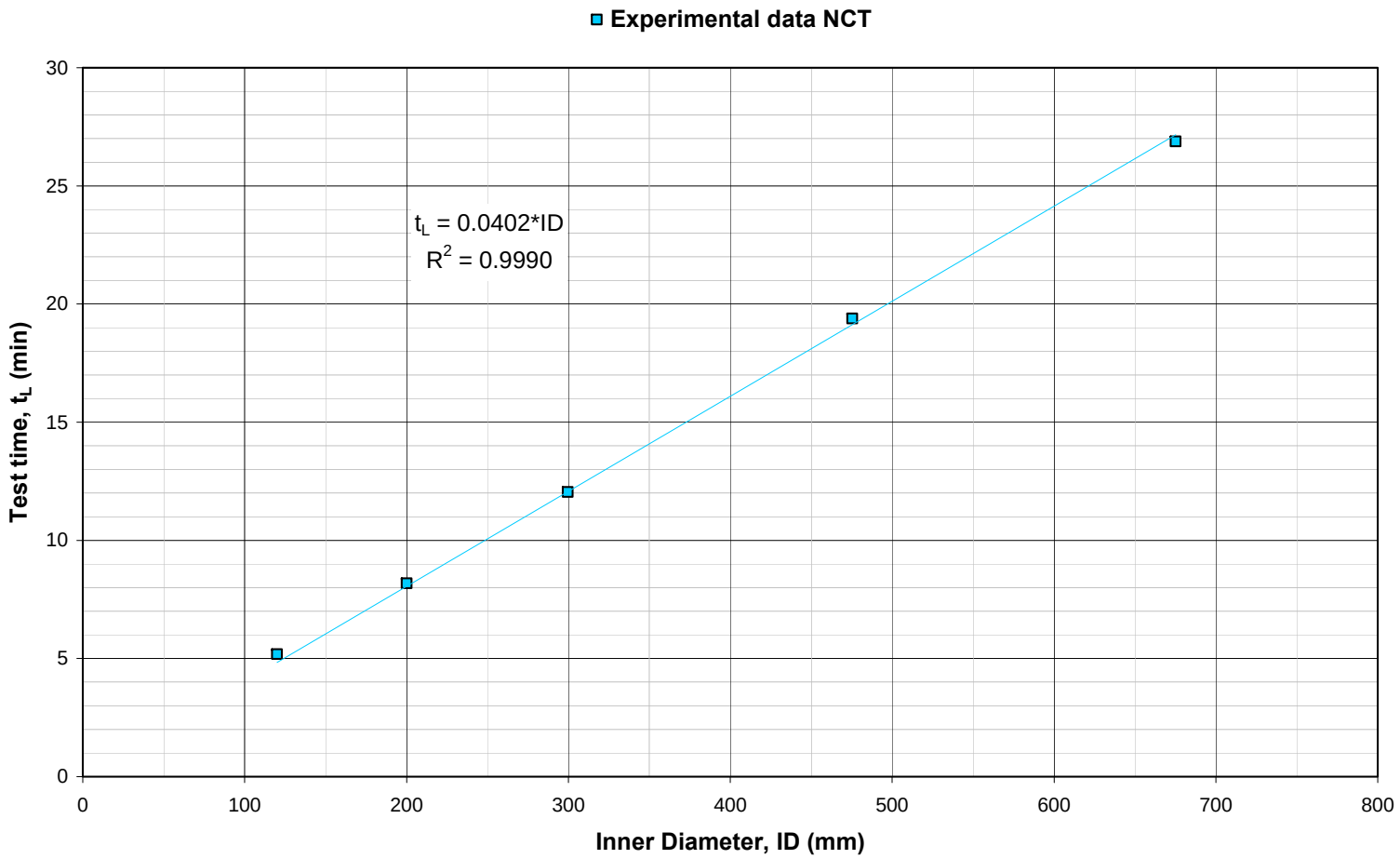
Test Number	TEST METHOD	
	AIR ("LD")	WATER ("W")
	Test result	Test result
#1 – DN125	$\Delta p/\Delta p_{amm} = 1$	$w/w_{amm} = 0,96 \cong 1$
#2 – DN200	$\Delta p/\Delta p_{amm} = 1$	$w/w_{amm} = 1,01 \cong 1$
#3 – DN315	$\Delta p/\Delta p_{amm} = 1$	$w/w_{amm} = 0,97 \cong 1$
#4 – DN500	$\Delta p/\Delta p_{amm} = 1$	$w/w_{amm} = 0,98 \cong 1$
#5 – DN710	$\Delta p/\Delta p_{amm} = 1$	$w/w_{amm} = 0,96 \cong 1$

⇓

In all cases
the method "LD" and method "W"
are EQUIVALENT TO EACH OTHER!

EXPERIMENTAL RESULTS

Method "LD" – Experimental regression curve t_L-ID



EXPERIMENTAL RESULTS

Comparison between test time values by UNI EN 1610:1999 and test time values by Equivalence criteria

Material	Test method	p_0	Δp	Test time (min)						
		mbar (kPa)		DN100	DN200	DN300	DN400	DN600	DN800	DN1000
Soaked concrete pipes and all other material	LD UNI EN 1610:1999	100 (10)	15 (1,5)	1,5	1,5	2,0	2,5	4,0	5,0	7,0
	LD Equivalence criteria	200 (15)	15 (1,5)	4.0	8.0	12.1	16.1	24.1	32.2	40.2

EXPERIMENTAL RESULTS

Comparison between test time values by ÖNORM B2503:2009 and test time values by Equivalence criteria

DN (mm)	p_0 (mbar)	Δp (mbar)
	200	15
	Test time, t_L (min)	
	ÖNORM B2503:2009	Equivalent criteria
100	5,0	4,0
150	7,5	6,0
200	9,0	8,0
250	10,0	10,1
300	11,0	12,1
350	12,5	14,1
400	14,0	16,1
450	15,0	18,1
500	17,5	20,1
600	20,0	24,1
700	22,0	28,1
800	25,0	32,2
900	30,0	36,2
1000	35,0	40,2

Thanks for

your kind attention!