TECHNICAL DOCUMENT

GRAVITY DRAINAGE SYSTEMS MADE OF THERMOPLASTIC MATERIALS

Technical document No. 442-01

Specifications applicable to all groups

Technical document: 442-01 rev. 00
21/12/2018

CENTRE SCIENTIFIQUE ET TECHNIQUE DU BATIMENT
84 avenue Jean Jaurès – Champs-sur-Marne – 77447 Marne-la-Vallée Cedex 2
Tel. +33 (0)1 64 68 82 82 – www.cstb.fr
MARNE-LA-VALLÉE / PARIS / GRENOBLE / NANTES / SOPHIA-ANTIPOLIS

CSTB
le futur en construction

CSTB (Centre Scientifique et Technique du Bâtiment), a public establishment supporting innovation in construction, has four key activities—research, expertise, assessment and dissemination of knowledge—organised to meet the challenges of ecological and energy transition in the construction sector. Its fields of expertise include construction materials, buildings and their integration into districts and towns.

With over 900 employees, its subsidiaries and networks of national, European and international partners, the CSTB group works for all the stakeholders in the construction sector to advance building quality and safety..

MODIFICATION HISTORY

Revision No.	Application date	Modifications
03	**21/12/2018**	**Update to the document layout and reference**

Table of contents

Note: all the diagrams and drawings referred to in this document come from CSTB.

Part 1 – MONITORING ARRANGEMENTS – GENERAL

1. TESTS

The tests are carried out in accordance with the standards cited in technical documents no. 442-02 to 442-07.

The examinations and tests are carried out during the audit in the presence of the auditor by the applicant in its laboratory or by the body responsible for the tests in a laboratory designated in Part 5 of the certification reference system.

The acceptance criteria, cases of retesting or cases where the test is declared non-compliant are described in the tables below.

FOR PIPES

Measurement or test	No. of pipes or specimens per type tested	Acceptance	Repeating tests	Non-compliant test
Mean external diameter	5 pipes	No measurements outside tolerances	If 1 value is outside tolerances, repeat testing on 10 other pipes	If more than 1 value is outside tolerances, with or without repeat testing
Appearance Marking Colour Length Any diameter Thickness Sockets (depth of groove)	5 pipes	On 5 pipes, 0 measurements outside tolerances (in each series of measurements), extra thickness accepted	If 1 value is outside tolerances (in each series of measurements): repeat testing on 10 other pipes, extra thickness accepted	If more than 2 values are outside tolerances, with or without repeat testing
Density	3 test specimens cut from 1 pipe	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
MFR EN ISO 1133	On raw material	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
TIO EN 728	On raw material (200 °C)	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
Tension and modulus of elasticity NF EN 6259-1-2-3	On raw material and on the final product	Average of 5 measurements compliant with specifications	-	Average of 5 measurements outside tolerances
Vicat softening temperature	2 test specimens cut from 1 pipe	Average of 2 measurements compliant with specifications	If the variance between the results obtained is > 2 °C repeat testing on 2 new specimens	Average of 2 measurements outside tolerances
Tensile characteristics (maximum stress and elongation at break)	Factory: For admission: 3 test specimens cut from 3 pipes For follow-up: 5 test specimens cut from 3 pipes Laboratory: 5 test specimens cut from 3 pipes	In factory: Average of 3 measurements compliant with specifications with the 3 individual values compliant	In factory: If average of 3 compliant measurements with 1 individual measurement outside tolerances, repeat testing on 2 new specimens	In factory: If average of measurements is outside tolerances (with or without repeat testing) or more than one individual value is outside tolerances
		<u>In laboratory:</u> Average of 5 measurements compliant with specifications with at least 4 individual values compliant	**<u>In laboratory:</u>** If average of 5 compliant measurements with 2 individual measurements outside tolerances, repeat testing on 5 new specimens	**<u>In factory:</u>** If average of measurements is outside tolerances (with or without repeat testing) or more than 2 individual values are outside tolerances
Tensile characteristics of the seam (maximum stress)	5 test specimens from 1 pipe	Average of the 5 measurements compliant with specifications, with at least 4 individual compliant values	If average of 5 compliant measurements with 2 individual measurements outside tolerances, repeat testing on 5 new specimens	If average of measurements is outside tolerances (with or without repeat testing) or more than 2 individual values are outside tolerances

Measurement or test	No. of pipes or specimens per type tested	Acceptance	Repeating tests	Non-compliant test
Impacts	See EN 744	**TIR ≤ 10%**	-	**TIR > 10%**
Impacts	See EN 1411	**H50 ≥ 1 m, one break max. and smaller than 0.50 m**	-	**H50 ≥ 1 m, more than one break smaller than 0.50 m**
Reversion at 150 °C	3 test specimens cut from 3 pipes	Result on each specimen compliant with specifications	If 1 measurement is outside tolerances, repeat testing on 3 new specimens taken from 3 pipes from the same batch	If 2 or more measurements are outside tolerances, with or without repeat testing, or average is outside tolerances, with or without repeat testing
Resistance to pressure – 140 hrs	1 specimen	Result on the specimen compliant with specifications	-	Result non-compliant with specifications
Resistance to pressure – 165 hrs	1 specimen	Result on the specimen compliant with specifications	-	Result non-compliant with specifications
Resistance to pressure – 1000 hrs	1 specimen	Result on the specimen compliant with specifications	-	Result non-compliant with specifications
Ring stiffness	3 test specimens spread over 1 pipe	Average value of 3 measurements compliant with specifications (with no non-compliant individual values)	If 1 individual value is non-compliant, retest 3 specimens	One individual value from the repeat test is non-compliant with specifications
Compression rate	3 test specimens spread over 1 pipe	Compliance of the 3 specimens with specifications	If 1 specimen is non-compliant, retest 3 specimens	One specimen from the repeat test is non-compliant with specifications
Ring flexibility	3 test specimens spread over 1 pipe	Average value of 3 measurements compliant with specifications	If 1 individual value is non-compliant, retest 3 specimens	One individual value from the repeat test is non-compliant with specifications
Leaktightness of elastomer sealing rings	1 assembly composed of 2 pipes	Compliance of the tested assembly with specifications	-	Does not meet specifications
Oven test	3 test specimens from 1 pipe	Each specimen is compliant with specifications	If 1 specimen is defective, repeat testing of 3 new specimens from the same batch	With or without repeat testing, from 2 specimens non-compliant with specifications

FOR FITTINGS

Measurement or test	No. of fittings or specimens per type tested	Acceptance	Repeating tests	Non-compliant test
Mean external diameter Any diameter	1 fitting per mould cavity	No measurements outside tolerances	If 1 value is outside tolerances, repeat testing on 5 other fittings per diameter	If more than 2 values are outside tolerances per diameter, with or without repeat testing
Sockets Appearance Marking Colour Assembly dimensions Thickness				If more than 1 value is outside tolerances per diameter, with or without repeat testing
MFR EN ISO 1133	On raw material	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
TIO EN 728	On raw material (200 °C)	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
Vicat softening temperature	2 test specimens cut from 1 fitting	Average of 2 measurements compliant with specifications	If the variance between the results obtained is > 2 °C repeat testing on 2 new specimens (fittings from the same batch)	Average of 2 measurements outside tolerances
Density	3 test specimens cut from 1 fitting	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
Oven test at 150 °C	For admission: 3 identical fittings For follow-up: 2 identical fittings	Each fitting compliant with specifications	If 1 fitting is defective, repeat testing of 3 new fittings from the same batch	With or without repeat testing, from 2 fittings non-compliant with specifications
Impact resistance at 0°C	See NF EN 12061: *5 fittings for DN ≤ 200 mm* *3 fittings for DN > 200 mm*	Result compliant with specifications	See NF EN 12061	Result non-compliant with specifications
Resistance to pressure – 140 hrs	1 specimen	Result on the specimen compliant with specifications	-	*Result non-compliant with specifications*
Resistance to pressure – 165 hrs	1 specimen	Result on the specimen compliant with specifications	-	*Result non-compliant with specifications*
Resistance to pressure – 1000 hrs	1 specimen	Result on the specimen compliant with specifications	-	*Result non-compliant with specifications*
Leaktightness of elastomer sealing rings	1 assembly composed of 2 pipes	Compliance of the tested assembly with specifications	-	Does not meet specifications
Mechanical strength or flexibility	1 fitting	Result compliant with specifications	-	Does not meet specifications
Watertightness NF EN 1053 (fabricated fittings)	1 fitting	Result compliant with specifications	-	Does not meet specifications

FOR ANCILLARY FITTINGS, INSPECTION CHAMBERS AND MECHANICAL SADDLES

Mesure ou essai	Nb d'assemblages testés	Acceptation	Cas de reprise	Non-conformité de l'essai
Vertical load resistance (mechanical saddles)	1 assembly	Result compliant with specifications		Result non-compliant with specifications
Vacuum required for resistance to external pressure of the ground and water	1 assembly	Result compliant with specifications		Result non-compliant with specifications
Watertightness of saddle branches with plug	1 assembly	Result compliant with specifications		Result non-compliant with specifications
Watertightness test (riser shaft seal)	1 assembly tested	Compliance of the tested assembly with specifications		Result non-compliant with specifications
Leak test on seal rings	1 assembly tested			
Quality of elastomer rings	Plate provided by the manufacturer + seal	Result compliant with specifications		Result non-compliant with specifications
Dimensional inspection	1 complete part / subfamily / process / material	Result compliant with specifications		Result non-compliant with specifications
Density	3 test specimens cut from 1 part	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
MFR EN ISO 1133	On raw material	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
TIO EN 728	On raw material (200 °C)	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
Tension and modulus of elasticity NF EN 6259-1-2-3	On raw material and on the final product	Average of 5 measurements compliant with specifications	-	Average of 5 measurements outside tolerances
Vicat softening temperature	2 test specimens cut from 1 part	Average of 2 measurements compliant with specifications	If the variance between the results obtained is > 2 °C repeat testing on 2 new specimens	Average of 2 measurements outside tolerances

FOR MANHOLES AND INSPECTION CHAMBERS IN VEHICULAR AND PEDESTRIAN AREAS AND DEEPLY BURIED SYSTEMS

Measurement or test	No. of assemblies tested	Acceptance	Repeating tests	Non-compliant test
Structural integrity of the base	1 assembly	Result compliant with specifications	-	Result non-compliant with specifications
Impact resistance of the base	1 assembly	Result compliant with specifications	-	Result non-compliant with specifications
Step of the ladder		Result compliant with specifications	-	Result non-compliant with specifications
Crushing strength of the dividing slab		Result compliant with specifications	-	Result non-compliant with specifications
Pull-off resistance of handling ring anchors for dividing slabs		Result compliant with specifications	-	Result non-compliant with specifications
Suitability for supporting loads		Result compliant with specifications	-	Result non-compliant with specifications
Dimensional inspection	1 complete part / subfamily / process / material	Result compliant with specifications		Result non-compliant with specifications
Watertightness test (riser shaft seal) of base-riser shaft and riser shaft-taper,	1 assembly tested	Compliance of the tested assembly with specifications		Result non-compliant with specifications
Leak test on seal rings	1 assembly tested			
Quality of elastomer rings	Plate provided by the manufacturer + seal	Result compliant with specifications		Result non-compliant with specifications
MFR EN ISO 1133	On raw material	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
TIO EN 728	On raw material (200 °C)	Average of 3 measurements compliant with specifications	-	Average of 3 measurements outside tolerances
Tension and modulus of elasticity NF EN 6259-1-2-3	On raw material and on the final product	Average of 5 measurements compliant with specifications	-	Average of 5 measurements outside tolerances

Summary table of testing parameters:

Tests / Technical Documents	TD2	TD3	TD4 & 5	TD 6 and 7
TIO **EN 728**	200°C	200°C	200°C	200°C
MFR **EN ISO 1133**	PP: 230°C / 2.16 kg PE: 190 °C / 5 kg	PP: 230°C / 2.16 kg Extruded / injection-moulded PE: 190 °C / 5kg Rotomoulded PE: 190 °C / 5kg	PP: 230°C / 2.16kg Extruded / injection-moulded PE: 190 °C / 5kg Rotomoulded PE: 190 °C / 2.16kg	PP: 230°C / 2.16kg Extruded / injection-moulded PE: 190 °C / 5kg
PRESSURE 140 hrs **EN ISO 1167-1-2**	PP: 4.2 MPa / 80°C	PP: 4.2 MPa / 80°C		PP: 4.2 MPa / 80°C
PRESSURE 165 hrs **EN ISO 1167-1-2**	PE: 4.0 MPa / 80°C	Extruded / injection-moulded PE: 4.0 MPa / 80°C Rotomoulded PE: 3.9 MPa / 60 °C		PE: 4.0 MPa / 80°C
PRESSURE 1000 hrs **EN ISO 1167-1-2**	PVC pipes: 10 MPa / 60 °C PP: 2.5 MPa / 95 °C PE: 2.8 MPa / 80°C	PVC pipes: 10 MPa / 60 °C PVC fittings: 6.3 MPa / 60 °C PP: 2.5 MPa / 95 °C Extruded / injection-moulded PE: 2.8 MPa / 80°C Rotomoulded PE: 3.2 MPa / 60 °C		PVC pipes: 10 MPa / 60 °C PVC fittings: 6.3 MPa / 60 °C PP: 2.5 MPa / 95 °C PE: 2.8 MPa / 80°C

1.1 INSPECTION CONDITIONS WHEN EXAMINING AN APPLICATION FOR THE RIGHT TO USE THE NF MARK

1.1.1 Type testing and taking samples

When examining an application for the right to use the NF mark, all testing for compliance with standards and complementary specifications is carried out under the conditions defined in article 1.1; type testing is carried out in the mark's laboratory. These are described in part no. 4 of each product group.

Samples for tests at the mark's laboratory are taken according to the instructions below, with reference to the sampling standards NF X 06-021 and NF ISO 2859-1.

a) Case of pipes

The table below gives the number of types of pipes to be sampled according to the number of types submitted for admission (sampled randomly).

Number of types submitted for admission (per family)	Number of types to be sampled (per family)
1	1
2 to 8	2
9 to 15	3
16 to 25	5
26 to 50	8
51 to 90	13
91 to 150	20

b) Case of fittings and products under TD4

The table below gives the number of types of fittings to be sampled according to the number of fittings submitted for admission (sampled randomly).

Number of fittings submitted for admission (per family, per category and per type)	Number of fittings to be sampled (per family, category and type)
1	1
2 to 8	2
9 to 15	3
16 to 25	5
$\geq$ 26	8

c) Case of products under TD5

The samples taken must enable testing of:

- Leaktightness of the different assemblies put together for each shaft DN,
- Suggested equipment (anchoring rings, ladder steps, dividing slab).

The samples taken are marked by the officer in charge of verification with a distinctive sign allowing them to be authenticated subsequently and sent by the applicant/holder and under its responsibility to the independent laboratory (see Paragraph 5.3 of this certification reference document) in charge of performing the test, unless the officer in charge of verification decides to take responsibility for them.

Part 2 - TEST PROCEDURES - GENERAL MONITORING ARRANGEMENTS - GENERAL

In addition to the test standards, this paragraph specifies the test procedures specific to products.

2.1 DENSITY (FOR THE PIPES)

Measurements are taken on 3 specimens cut according to the instructions in Standard NF EN ISO 1183-*1* Method A, on three generatrices at 120 °C.

- measure the density of the 3 specimens according to the instructions of standard NF EN ISO 1183-1 Method A, at 23 ± 2 °C;
- express the result by the average of the 3 values obtained.

Note: Other methods for structured-wall PVC (for example: sink-float method) may potentially be used by the applicants/holders, as a manufacturing quality check, provided that they are well defined (establishment of an operating procedure); the previous method makes reference to this.

Liquids other than water can be used (for structured PVC).

2.2 REVERSION

The tests are carried out in the laboratory of the mark according to Standard NF EN ISO 2505, referring to Method B (air over) including the following details:

- Test duration: The duration of the test must comply with the specifications established in the product standards in question.

In the event that the reversion test is performed using the air oven method:

- The specimen is a smooth piece of pipe of at least 200 mm;
- The 100 mm marks must be indicated in such a way that each mark is at least 10 mm away from the nearest end;
- The test specimen shall be suspended allowing free movement in the oven so that it touches neither the walls nor the base of the oven.

In case of dispute, only the reversion test performed according to the liquid bath method in Standard NF EN ISO 2505 (method A) will serve as the reference test.

In cases of quality assurance in production, the test method (either A or B) is left to the holder’s initiative.

If the reversion test is performed according to the liquid bath method (method A):

- The specimen is a smooth piece of pipe of at least 200 mm;
- The 100 mm marks must be indicated in such a way that each mark is at least 10 mm away from the nearest end;
- The distance between the liquid/air interface and the top mark must be at least 30 mm.

2.3 TENSILE STRENGTH

2.3.1 Smooth pipes

Evaluation of the stress at the yield point as well as the elongation at break:

The tests are carried out according to Standard NF EN ISO 6259-1 with the following specifications:

- Number of specimens subject to testing: 5;
- If a die is used for cutting after heating the samples, possible preheating of the bands can take place at a temperature from 125°C to 130°C for 1 minute per millimetre of thickness;
- To measure sections, it is recommended that a micrometre screw gauge be used, with flat cylindrical measuring faces 2 mm in diameter.

Assessing the modulus of elasticity under tension:

With the following additional specifications:

- The test speed equals 1 mm/min (see Standard NF EN ISO 527-2);
- The modulus is determined according to Standard NF EN ISO 527-1.

Summary table of key test data for evaluating tensile properties:

Thermoplastic material	Test specimens	Testing speed
PVC	5 specimens according to Standard NF EN ISO 6259-2.	Stress/elongation: 5 mm/min Module: 1 mm/min
PP and PE	5 specimens according to Standard NF EN ISO 6259-3.	Stress/elongation: 50 mm/min Module: 1 mm/min

NOTE: For Polyolefin material pipes with thicknesses > 12 mm, the specimens are type 3 as defined in Standard NF EN ISO 6259-3.

2.3.2 Corrugated pipes

The strength under stress value of the material of which the corrugated pipes are made must be declared by the manufacturer and verified by CSTB to enable sizing of the work in compliance with the provisions of leaflet 70.

This verification is completed by taking samples preferentially from the sides of the corrugation (structuring wall).

If the diameter prevents these samples from being taken, the test is carried out on a smooth-walled pipe specifically manufactured by extrusion using the same material.

Testing conditions: see § 2.3.1

Specifications

The minimum strengths under stress at the yield point are as follows:

- Polyethylene: 19 MPa
- Polypropylene: 23 MPa

2.3.3 Case of manholes and inspection chambers validated through calculation

Validation by calculating structural behaviour of the manhole or inspection chamber requires knowledge of the mechanical characteristics of the various materials of which the component is made.

Minimum characteristics are defined in Technical Document 5.

Higher characteristics can be taken into account to validate mechanical behaviour. These characteristics are declared by the manufacturer then validated through tests performed in the laboratory of the mark on the basis of the samples taken from the various components of the manhole.

Testing conditions: see § 2.3.1

Specifications:

The specifications relating to the tests performed as part of follow-up are the values used during the initial evaluation.

2.4 OVEN TEST

Test carried out according to Standard NF EN ISO 580 - method A with the following specifications:

- Test duration: The duration of the test must comply with the specifications established in the product standards in question.

2.5 VICAT TEMPERATURE MEASUREMENT

Measurement taken in accordance with the NF EN 727 standard; measuring specimens obtained by stacking is to be avoided if possible.

The VICAT temperature is expressed in degrees Celsius by rounding to the nearest whole number, using the half round up (0.5 °C) method. For example: If a result of 75.4 °C is obtained, the VICAT temperature value will be 75 °C; if a result of 75.5 °C is obtained, the VICAT temperature value will be 76 °C.

2.6 DIMENSIONAL CHARACTERISTICS

According to reference standards, with the following specifications for fittings: if possible, measure the assembly dimensions on the fittings, otherwise, proof of calculation and validation of these dimensions upon receipt of the moulds must be provided by the applicant/holder (calculation from the drawings of the fittings).

2.7 IMPACT TESTS

Tests performed in accordance with the NF EN 744 standard.

- Test temperature: 0°C;
- Diameter of the striker: 90 mm or 25 mm, according to the NF EN 744 Standard.

Note: The specific conditions of the NF EN 744 standard are used whenever possible. Otherwise, the applicant/holder may, for its own quality assurance, use a simplified method related to the NF EN 744 standard. In this case, it must define its own testing specifications in an operating procedure.

On an exceptional basis, the mass of the striker and its drop height may be converted into energy at the point of impact. This delivered energy complies with the technical documents and the product standards using different striker mass and drop heights.
For masses less than or equal to 1 kg, the striker material may be composed of plastic or any low density and sufficiently hard materials.

The masses of the striker and the drop heights must comply with the values in the standards listed in Part 2 of the certification reference system.

The speed of the impact equipment striker's fall must be calibrated (for example, using a measuring chain composed of fibre optics and a frequency meter).

All of the masses and heights specified in the product standards must be tested so that a specific correction can be applied per machine per mass or height.

These corrections must be calculated at 95.5% of the striker's theoretical speed of fall.

Interpreting the results:

The specification of the TIR must be ≤ 10% without taking into consideration the area on the curve; the test must be performed over 50 impacts and once a test on a specimen has started it must be completed: TIR ≤ 10%: batch compliant and validated in stock and TIR > 10%: non-compliant, non-validated batch.

The TIR is calculated using the following formula with a 90% level of confidence:

TIR = (Number of breaks/total number of impacts) x 0. 90

Table 3: Number of equidistant lines to be drawn on the test specimens

Nominal outside diameter d_n [1] (mm)	Number of equidistant lines to be drawn
$d_n \leq 40$	—
$40 < d_n \leq 63$	3
$63 < d_n \leq 90$	4
$90 < d_n \leq 125$	6
$125 < d_n \leq 180$	8
$180 < d_n \leq 250$	12
$250 < d_n \leq 355$	16
$355 < d_n$	24

1) For pipes whose nominal diameter is designated otherwise than by the d_n, the nominal dimension in millimetres shall be referred to instead of d_n.

2.8 LEAKTIGHTNESS TEST OF FITTING ASSEMBLIES

The testing conditions applicable to fittings are as follows:

The test is carried out according to the general conditions of the NF EN 1277 standard.

- The angular deflection is applied to the two seals while keeping the assembly fixed in front of the fitting.
- If, for dimensional or geometrical reasons, it is impossible to apply a 5% deformation of the DN to the fitting's socket, then only a 5% deformation of the DN will be applied to the pipe.

2.9 QUALITY OF THE ASSEMBLIES' ELASTOMER SEALING RINGS

The conditions and the testing parameters are defined in the standards EN 681 Parts 1 or 2, as the case may be.

The tests for which the manufacturer of the elastomer sealing rings is responsible are requested for each type of pipes or fittings used by applicants for / holders of pipes or fittings.

Application tests (pipes or fittings associated with the sealing ring: tests defined in technical documents no. 442-02 to 442-07) are requested by the applicant for / holder of pipes or fittings and processed in the same way as any application for extension.

2.10 LEAK TESTING ON ELASTOMER SEAL RINGS FOR BRANCHES ON MANHOLES AND INSPECTION CHAMBERS

The test is based on Standard NF EN 1277.

The spigot or socket of the manhole is not deformed; the deformation is limited to 5% on the only pipe connected.

The leak test is carried out using a class SN8 PVC pipe.

The test bench must support the base and possibly the spigot of the manhole in a way that limits stresses and deformation that could negatively impact the representativeness of the test.

2.11 EVALUATION METHODOLOGY FOR MOULDED MANHOLES WITH FLEXIBLE BEHAVIOUR, FINITE ELEMENT METHOD SIMULATION

COMPLETE METHOD:

This method takes into consideration the least favourable mechanical configuration.

2.11.1 Verification scheme

Transposing calculation rules from “Leaflet 70” concerning piping systems for inspection access chambers leads to completion of the following 3 analyses:

- Short-term elastic analysis aiming to verify that the loading stresses do not reach the elastic limit of the materials of which the manhole is composed (ULS);
- Long-term analysis of the buckling risk of the manhole under loads (ULS);
- Long-term elastic analysis to verify that the out-of-roundness of the manhole's shaft does not exceed the permitted limit (comfort of a person descending into the manhole) and that the deformation of the cunette does not make it unsuitable for ensuring proper flow of sewage (SLS).

2.11.2 Hypotheses and calculation procedures

Only the manhole is explicitly modelled in the approach. The backfill soil is implicitly taken into account by the force it transmits to the manhole.

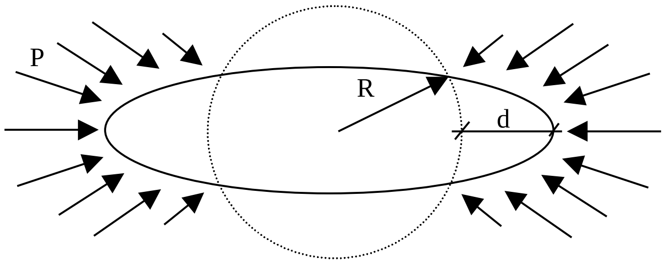
The following loads are taken into account:

- The weight of the earth;
- The hydrostatic pressure corresponding to the presence of a water table up to the natural surface of the ground.

The rolling loads formally adopted by Leaflet 70. For non-bearing manholes, these loads are applied to the centre of the dividing slab. The stresses produced in the ground by these loads are calculated according to the BOUSSINESQ model. For the short-term analyses, an increasing coefficient of 1.6 is applied to take into account the dynamic effects related to the loading speed.

It is specified that the manhole/backfill soil contact is considered perfectly smooth in the calculations. Consequently, the pressures applied to the manhole are normal at the wall. Under these conditions, the vertical walls of the manhole are subject to a horizontal radial pressure that corresponds partly to the hydrostatic pressure and partly to the weight of the earth and the traffic load multiplied by the earth pressure coefficient.

In accordance with Leaflet 70, the restoring forces that the backfill exerts on the manhole when the latter buckles are also taken into account. These forces are proportional to the normal part of wall displacement.



P = (Es/R).d

where Es is Young's modulus for backfill soil.

The evaluation of a manhole includes taking into account the 4 theoretical soil configurations, which cover all soil groups allowed under Leaflet 70.

Configuration	Earth pressure coefficient	Young's modulus (MPa)
1	0.15	0.6
2	0.35	1.2
3	0.5	3
4	0.6	7

The short-term elastic analysis consists of verifying that the stresses in the manhole do not exceed the elastic limit σ_c of the material. This analysis is conducted using the instantaneous elastic modulus. In the case of materials used to manufacture moulded manholes, the permanent deformations are the result of microscopic shifts that appear beyond a certain shear energy. The Von Misès yield criterion then appears appropriate for correctly reproducing the behaviour of these materials. The analysis therefore consists of verifying that the Von Misès stresses $\sigma_{VON\ MISÈS}$ occurring in the manhole do not exceed the material's elastic limit.

In this analysis, the partial factors of safety set out in Leaflet 70 are γa=1.25 for the actions and γm=1.32 for the material. The following verification is performed:

$$\sigma_{VON\ MISES} \leq \frac{\sigma_c}{\gamma_a \gamma_m}$$

The materials used to manufacture moulded manholes creep under long-term loads. Thus, the long-term apparent modulus is a quarter or fifth of the instantaneous modulus. Knowing the critical buckling load is proportional to the material's modulus, it appears to be sufficient to consider the minimum apparent modulus for evaluating the risk of buckling. Furthermore, rather than explicitly taking the viscoelasticity into account in the calculations, which would significantly slow down the process, the value of the long-term static modulus is taken into consideration. This measure makes the results all the safer as the typical time for material relaxation is increased (2 years on average). In fact, the method considers that the loads are continuously present, which is a correct hypothesis for the weight of the soil but, on the other hand, very safe for the water table and rolling loads. The same reasoning applies to the calculation of long-term deformation, also being safe.

The manhole's behaviour satisfying the necessary hypotheses, we find ourselves in the context of the linear buckling theory, which applies to elastic structures initially subjected to a self-balancing load (Euler buckling theory). Starting from an initial elastic calculation of the manhole subject to all the actions present in the previously described ground, the load factor corresponding to the first positive buckling mode for the structure is calculated. In this analysis, the overall factor of safety of 2.5 is required by Leaflet 70. Thus, a load factor at least equal to this value is necessary to ensure satisfactory behaviour.

The third and last analysis is the verification at the serviceability limit state, for which no factor of safety is required. We verify that the diametral compression of the manhole's shaft does not exceed 10% of the initial diameter at any point. Deformation of the bottom of the cunette is also observed in order to verify that the invert remains sufficiently sloped for proper sewage flow.

2.11.3 Characterisation of the materials

The mechanical characteristics needed for these analyses are as follows:

- The instantaneous elastic modulus (Young's modulus),
- Poisson's ratio,
- The elastic limit,
- The creep coefficient.

2.11.4 Calculation tool

The code for finite element analysis must allow:

- Inputting data on the manhole's geometry, loading and mechanical characteristics of the materials;
- Elastic and linear buckling calculation;
- Graphical application of results in order to offer their clear presentation to evaluation groups.

2.11.5 Digital description of the manhole

The wall of the manhole must be meshed with thin shell components in order to avoid stress-locking phenomena. Interpolation of motion fields must be at least quadratic to enable specific calculation of the stresses in manhole zones with complex geometry (particularly the cunette). Grid generation fineness must be "sufficient" (expertise of the modeller or ex post verification by using finer grid generation until results converge) for the gradients of the mechanical fields to be correctly taken into account.

It is important to specify that these verifications apply only to a manhole set up while ensuring the homogeneity of the backfill around its contours.

SIMPLIFIED METHOD:

When a complete study has been conducted on a manhole and a justification is requested for a similar product, there is, as a minimum, quasi-homothetic transformation of the geometry; the justification is provided through comparative analysis of the two products. This comparative analysis relies on writing proportionality rules between the two products concerning the stresses, load factors and displacements to justify the new product with respect to the ULS of strength, the ULS of buckling and the SLS of deformation. Apart from the homothety factor, these rules incorporate, as needed, the stiffnesses (SRS), strengths and depths claimed.

2.12 SIMPLE COMPRESSION TEST ON A DIVIDING SLAB

The simple compression test is conducted according to the following principle:

A length of shaft is inserted into the middle of a formed and packed sand bed 10 cm thick. The dividing slab is then placed horizontally on the sand bed such that the shaft is level with the location provided for the frame.

A rubber plate (60 DIDC) is inserted between the non-deformable steel plate to which the force is applied. The force is transmitted to the plate by means of a ball joint.

- The actuator has a minimum capacity of 400 kN. It is force-mode controlled.
- The load is transmitted to the proof body at a speed of 30 kN/min.
- The test is carried out on a slab with an age matching the provision wait time.

Specification: no collapse for a 300 kN load.

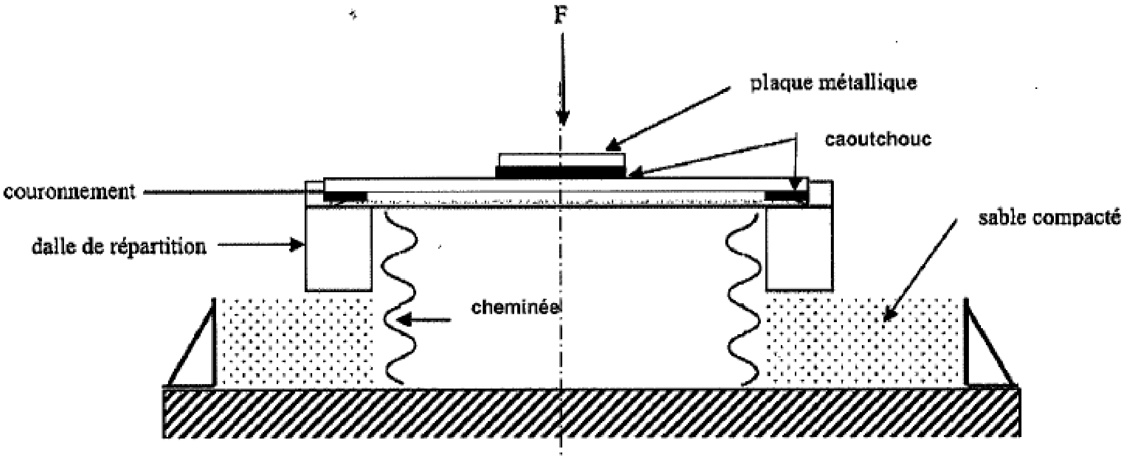


Figure 1: Example of an experimental assembly for the dividing slab compression test

2.13 TENSILE TEST ON ANCHORS

The tensile test is conducted according to the following principle:

The tensile stresses are transmitted by means of a manual hydraulic actuator equipped with a pressure gauge and a pedestal.

Tension is applied to the anchor by means of a ring which may be specific.

The minimum capacity required (F_{mini}) for the handling ring and its concrete anchoring is determined according to the following procedure:

Let:

P: Product weight in daN

n: Number of useful lifting points (n = 2)

k: Factor of safety on the concrete: k = 2.5

e: Sling angle factor (generally: e = 1.16, corresponding to an angle at the top of 60° slings)

d: Dynamic factor d = 2, corresponding to lifting and transport on flat and not very rugged terrain

$$F_{mini} = ked\ \frac{P}{n}$$

or when using two useful lifting points:

$$F_{mini} = 2.9\ P$$

Load increases occur in stages:

- 1st stage: increased to 1.5 times the weight of the slab then force maintained for 1 min - observation;
- 2nd stage: increased to 2.5 times the weight of the slab then force maintained for 1 min - observation;
- 3rd stage: increased to 2.9 times the weight of the slab then force maintained for 1 min - observation - then force increased up to the breaking point.

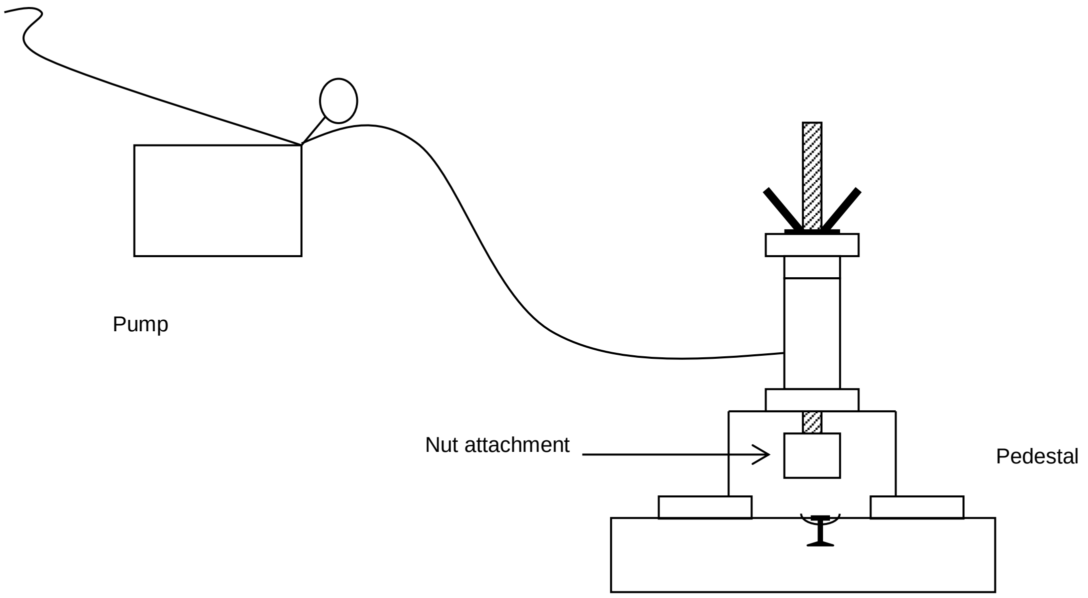


Figure 2: Example of an experimental assembly for the anchor tensile test

2.14 RESISTANCE TEST OF HANDLING RINGS FOR MANHOLES AND INSPECTION CHAMBERS

The test is conducted on the manhole or chamber with the greatest height.

Let P be the weight of the manhole (or the chamber).
Let n be the number of rings.

If necessary, join the various elements making up the component being tested.

Close off the orifices in the connection.

Add the amount of water needed to reach the equivalent mass matching the minimum force F such as Fmini = kedP, distributed across the n rings.

Raise the assembled and weighted component by about 10 cm using vertical slings and keep the assembly suspended for 1 minute.

Specification: no break

2.15 METHODOLOGY FOR EVALUATING THE STRESS AMPLIFICATION FACTOR ccσ FOR CORRUGATED, RIBBED OR SPIRALLY-FORMED STRUCTURED-WALL PIPES

Leaflet 70 considers the walls of the pipes to be homogeneous and isotropic. However, structured-wall pipes do not fit within the framework of this assumption, particularly where the evaluation of loading stresses is concerned.

The method involves performing:

- A study of the mechanical behaviour of structured-wall pipes for sewerage by numeric computing using the finite element method,
- An analysis of the results enabling them to be easily integrated into the existing computation rules.

2.15.1 Verification of the critical buckling pressure

The calculation of the pipe's inertia I, recognised by Leaflet 70, applies only to solid-wall pipes:

$$I = \frac{e^3}{12\left(1 - \nu_T^2\right)}$$

Where:

I: Moment of inertia

e: wall thickness

ν_T: Poisson's ratio for the material of which the pipe is made

However, the Leaflet's method authorises the experimental determination of the resulting SRS; this experimental determination of the ring stiffness takes into consideration the specific geometry of the structured walls and can be integrated into the analytical expression of Pcr (critical buckling pressure).

Verifying buckling and out-of-roundness for structured walls can therefore be carried out according to Leaflet 70's analytical method.

2.15.2 Verifying the ultimate limit state of strength

The approach used in Leaflet 70 involves deducting, within the framework of the strength of materials, the axial strain in stretched fibre of a homogeneous beam subjected to a bending moment. Doing so, Leaflet 70 considers a cut from the pipe as a circular beam. However, in the strength of materials context, the beam being considered equivalent to a line and the loads to an applied screw in one point, the Saint-Venant solution which describes the strain states in the section is only correct away from the points where force is applied.

This model only provides partial information on the stress states around the points where loads are applied.

For a homogeneous beam, the experiment and complementary calculations demonstrate that the axial strain in stretched fibre is indeed the most detrimental to the good performance of the structure.

Its relationship with the ultimate bending moment is: $\sigma_{\text{ult analytique}} = \frac{6Mu}{e^2}$

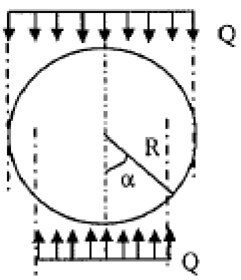
where:

e: is the thickness of the pipe's wall.

M_u: Bending moment *vis-à-vis* the ultimate limit state.

However, for structured walls incorporating geometric singularities and possibly materials with varied attributes, the profile of stresses is difficult to grasp using a simplified, strength of materials approach. Therefore, the more general continuum mechanics approach, implemented for the finite element method, is used.

In order to protect the method recommended in Leaflet 70, we will consider the ovalisation moment evaluated in the circular beam by the Bresse equation by taking into account the following conventional loading (which ignores, through simplification, the restraining action of the surrounding earth and an initial ovalisation):



Under these conditions, the bending moment is greatest at the base of the pipe; it is expressed as:

$$M = pv\frac{D^2}{4} \times K_\alpha$$

where:

D: calculation diameter corresponding to the distance between two diametrically opposed points on the neutral axis of the wall with respect to the pipe's axis.

pv: vertical pressure applied per linear meter of pipe (PV=Q/D)

Kα: moment coefficient, function of the conventional included angle 2α.

Using this expression of the bending moment, a wave or rib of the structured-wall pipe is modelled using the finite element method, in the framework of linear elasticity in small deformations, in a loading configuration compliant with the previous diagram. We put ourselves in the unique situation of a maximum conventional included angle 2α of 120°, which, for the same bending moment, leads to the greatest applied vertical pressure and, consequently, the greatest shear force. From here, the maximum value of the equivalent strain, according to Von Misès, in the pipe will be determined.

It is recognised that the experiment demonstrated that this strain is suitable for providing correct information on the risk of seeing the materials used in designing pipes leave their elastic range. At this stage, only calculating the stress amplification factor associated with the pipe remains, modelled by the relation:

$$Cc\sigma = \frac{2e^2.\sigma_{Von\ Mises}}{3pvD^2K_\alpha}$$

The Von Misès strain being homogeneous, the coefficient Ccσ is independent of the force of the actions inflicted and will apply to any bending moment value.

Note: for solid-wall and homogenous pipe, it will naturally be found that Ccσ = 1.

2.15.3 Verifying stresses

The stress amplification factor being calculated for a given structured-wall pipe, the ultimate stress for verification is calculated as follows:

$$\sigma_{ult} = Cc\sigma \times \sigma_{ult\ analytique} = Cc\sigma \times \frac{6Mu}{e^2}$$

where:

$\sigma_{ult\ analytique}$: ultimate strain calculated according the analytic method in Leaflet 70, considering M_u as the ultimate moment calculated according to Leaflet 70

e: the construction thickness of the wall of the structured-wall pipe.

All that remains is to verify that the maximumσ_{ult} stress calculated for the structured-wall pipe remains below the guaranteed characteristic stress $\sigma_{c,}$ for the product, less the coefficient γ_M, or:

$$\sigma_{ult} \le \frac{\sigma_c}{\gamma_M}$$

Note: The value guaranteed by the manufacturer as well as the out-of-roundness limits for calculation in accordance with Leaflet 70 are listed on the certificate.

2.16 EVALUATION METHODOLOGY FOR ASSESSING THE MECHANICAL BEHAVIOUR OF MANHOLE STEPS AND LADDERS

The assessment of the mechanical behaviour of steps and ladders with which manholes are fitted is based on Standards NF EN 13101 and NF EN 14396.

2.16.1 Steps

The testing parameters and requirements are as follows:

Vertical load:

- Applied load: 2 kN,
- Requirement: deformation ≤ 10 mm under load and ≤ 5 mm set.

Horizontal load:

- Applied load: 1 kN,
- Requirement: no pull-off.

2.16.2 Ladders with two stringers

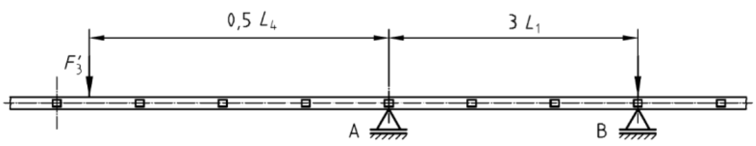
The testing parameters and requirements are as follows:

Vertical load on rungs (See Appendix B of Standard NF EN 14396)

A preload and a test load, distributed along a 100 mm length, are successively applied to a rung.

- Applied preload: 200 N for 1 minute and determination of the reference point after removal;
- Applied test load of 2.6 kN;
- Requirement: after removing the test load, the permanent deflection must not exceed 0.3% of the length of the rung. There may not be any visible cracks or damage.

Strength of ladder stringers (See Appendix C of Standard NF EN 14396)



A and B: fixing points

L1: distance between two rungs

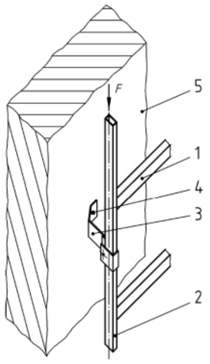
L4: distance between two fasteners

- Applied load: F'3 = 0.4 x γ (in kN)

With:

- y = 1.75 for steel and aluminium
- y = 4 for PRV composites
- Requirement: The permanent deflection must not exceed 0.3% of the 0.5 L4 length.

Strength of anchor points (See Appendix E of Standard NF EN 14396)



Vertical load:

- Applied load: 6 kN (20 N/s)
- Requirement: There may not be any visible cracks or damage.

Horizontal load:

- Applied load: 1 kN (minimum admissible value)
- Requirement: No displacement of the step, no visible cracks or damage to the anchors.

2.17 MANHOLE LEAK TESTING

2.17.1 Test conditions

The general testing conditions are based on Standard NF EN 1277 and the specifications in Standard NF EN 13598-2.

The deformations generated by the stresses during the test are not predictable. Depending on the design of the product and the method of manufacturing the component, the completion of the test may take place:

- In one go on the complete component,
- On the complete component using shims positioned to limit deformations related to the absence of soil during application of the various test pressures,
- In multiple stages, separating the tests focusing on different components and using devices to approximate the product's usage conditions, for example:
    - Specific props for bases resting on the cunette,
    - Provision of a riser shaft with welded cover,
    - Provision of an additional base for use as a blank cap,
    - Provision by the applicant of a specific blank cap,
    - Plugging the connection from inside the base.

For assemblies between the base and riser shaft (or riser shaft / riser shaft) achieved using seals and with vertical range, the test is completed without applying vertical force.

For base / riser shaft (or riser shaft / riser shaft) assemblies achieved using seals and with horizontal range, a compressive force equivalent to a maximum displacement of 1% of the height of the tested components is applied.

Where connections are concerned:

- Each assembly design is subject to a test.
- When measuring the leaktightness of spigot connections under angular deflection, keep in mind:

    - the initial vertical positioning of the manhole (take the slope of the cunette into account)
    - possible deflections observed when applying pressure or negative pressure.
- The 5% diametral deformation is applied to the connected pipe, at an L1 distance from the socket (or from the sleeve or manhole in the case of a female connection) as defined in Standard NF EN 1277.

2.17.2 Specifications

Compliance is based on the absence of leaks at the locations of the various connections. A leak related to a structural defect (cracking) appearing during application of the various pressures is considered a non-conformity.

2.18 LEAK TESTING OF MANHOLES OR INSPECTION CHAMBERS WITH BALL JOINTS

PREAMBLE: The ball joints are not intended to ensure a change of direction outside the manhole, but are intended to eliminate stresses at the junction between the manhole and header related to operating conditions.

Let α_d, value declared by the manufacturer, correspond to the nominal angular deflection permitted by the ball joint.

The angular deflection applied to the header during the leak test corresponds to the value α_d increased by the value α.

With:

- $\alpha = 2°$ for DN ≤ 315 mm
- $\alpha = 1.5°$ for 315 mm < DN ≤ 630 mm
- $\alpha = 1°$ for DN > 630 mm.

2.19 MECHANICAL STRENGTH AND FLEXIBILITY TEST OF WELDED FITTINGS

The mechanical resistance and flexibility tests are carried out on male-female assemblies with no sleeve inserted between the fitting to be tested and the pipe, enabling the test to be completed.

2.20 DEFINITION OF ATTESTATIONS OF CONFORMITY “TYPE 2.1” AND ACCEPTANCE CERTIFICATES “TYPE 3.1”

Attestation of conformity with the order “Type 2.1”

Document in which the producer declares that the products delivered comply with the requirements of the order, which does not include test results.

Acceptance certificate “Type 3.1”

Document in which the producer declares that the products delivered comply with the requirements of the order and in which it provides test results.

The quality control unit and the tests to perform are set out in the product specifications, official regulations and corresponding rules and/or in the order.

The document is approved by the producer’s authorised quality control representative, independent of the manufacturing services.

A producer must be permitted to enter, on its acceptance certificate 3.1, the applicable test results, obtained through a specific check on semi-finished products or products supplied that it uses, as long as the producer uses traceability procedures and can provide the corresponding control documents upon request.

The above definitions meet the specifications of Standard NF EN 10-204.

2.21 MANHOLES AND INSPECTION CHAMBER ADAPTERS FOR PIPES ADMITTED UNDER TD3

2.2.1 Dimensional characteristics

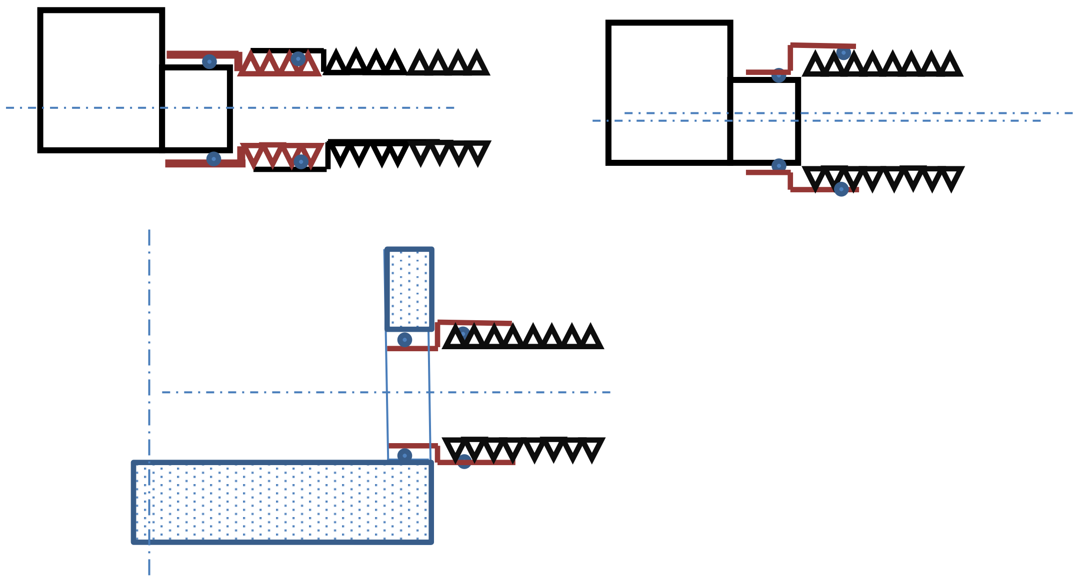
The adapter must allow the invert maintenance conditions to be met, as defined in Standard NF EN 476.

2.2.2 Leak test

If the manhole is fitted with spigots and sockets, the test is conducted on one diameter and both assembly types.

If the manhole is fitted with spigots or sockets, the test is conducted on one diameter.

The adapter is installed on the manhole following the manufacturer's instructions and then the pipe is connected to the adapter.



Examples of adapters

The deformation and angular deflection are applied simultaneously (Condition D of Standard NF EN 1277)

The deformation (5% DN) is applied to the pipe under the conditions of Standard NF EN 1277 (geometry of the tool, distance between the seal and the tool enabling the desired deformation to be obtained).

The angular deflection (function of the pipe DN) is applied to the whole connecting piece.

Part 3 – PACKAGING, PRESERVATION OF THE PRODUCT

When the applicant/holder packages its products and in addition to the requirements of the NF EN ISO 9001:2008 standard concerning the preservation of the product (chapter 8.5.4), this paragraph specifies the quality assurance methods specific to pipes packaged in a wooden frame.

Where fittings and inspection chambers are concerned, the requirements of chapter 8.5.4 "Preservation of the product" from the ISO 9001:2015 standard apply.

The packaging must be designed to preserve the quality and suitability for use of the products in the storage, transport and handling conditions defined (including stresses) by the applicant/holder and documented.

To do so, the audit body will verify that the applicant's/holder's quality assurance system includes the following:

3.1 CONTROL OF PACKAGING SUPPLY PURCHASES

Specifications regarding packaging supplies (wood, strapping, etc.).

Inspections on receipt of supplies.

3.2 PACKAGING DATA SHEET

Description and packaging methodology.

The technical description and the implementation of the packaging must be documented.

For all modifications or any new packaging, validation must be established by the holder.

3.3 PERIODIC INSPECTION OF IN-STOCK PACKAGED PRODUCTS

A record of the inspections must be documented. These inspections must take place at a predetermined frequency.

The verification must focus on the following points:

3.3.1 Compliance with the data sheet

3.3.2 Deterioration of the packaging, including:

- Sagging frames
- Sagging straps
- Broken wood
- Missing wood
- Sliding pipes (free pipes)
- Framework is parallel with regular spacing

3.3.3 Deterioration of products, including:

- Broken product

3.4 COMMUNICATION

On request, the applicant/holder provides its clients with the conditions under which the packaging enables storage, transport and handling of products.

3.5 ANALYSIS OF DISCREPANCIES FOR PARAGRAPHS 3.1 TO 3.4

Failure to respect the conditions in Part 3 will lead to a discrepancy that will be analysed by the mark committee.