SAINT-GOBAIN

mineRAL

DN 100 to DN 2000

DUCTILE CAST IRON PIPELINES FOR MINING
WATER SUPPLY AND SLURRIES

PIPELINE SOLUTIONS FOR THE FUTURE

PAM
SAINT-GOBAIN

SAINT-GOBAIN

66 countries

170.000 employees

12 research centers

3 activities hubs:

- Innovative materials (flat glass and high performance materials)
- Construction products (comprehensive pipe solutions, plaster products, sound and thermal insulation, wall facings, roofing)
- Building distribution (building materials)

PAM
SAINT-GOBAIN

IS A BRAND OF THE SAINT-GOBAIN GROUP

mineRAL

PIPELINES SOLUTIONS FOR MINING

TO KNOW MORE
SEE CHAPTER 3.4

TO KNOW MORE
SEE CHAPTER 2.2

TO KNOW MORE
SEE CHAPTER 3.2

mineRAL

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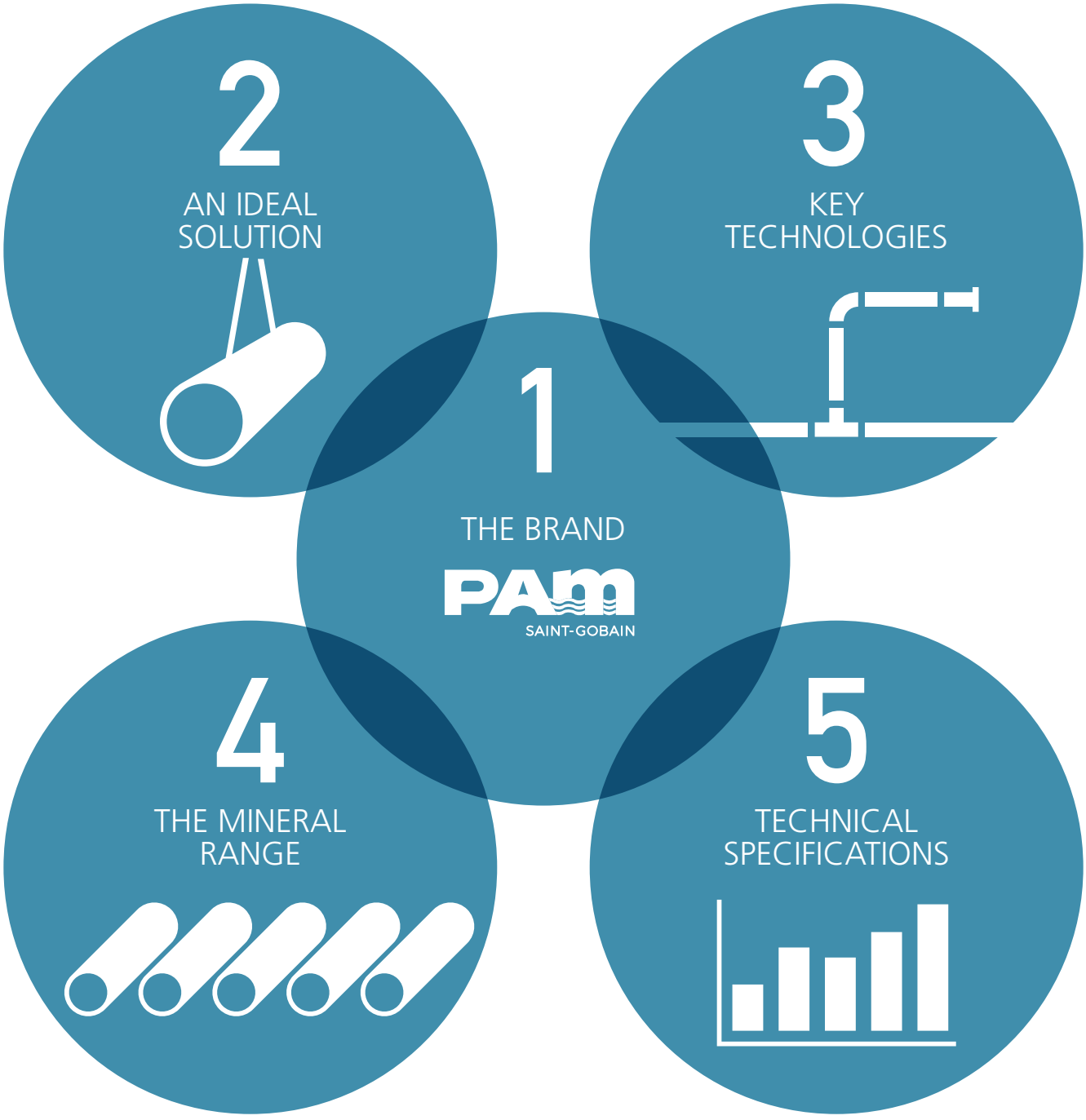


1

THE BRAND

1.1 160 YEARS' EXPERIENCE, 126 COUNTRIES

REFERENCES

1.1.1 INTERNATIONALLY ACKNOWLEDGED EXPERTISE

PAM has designed, produced and marketed pipe systems for potable water conveyance, sewers, untreated water and hydraulic fluids in industry and mines since 1856. Its reputation in pipes and fittings is founded on its considerable experience, on the reliability of its products and on their related services.

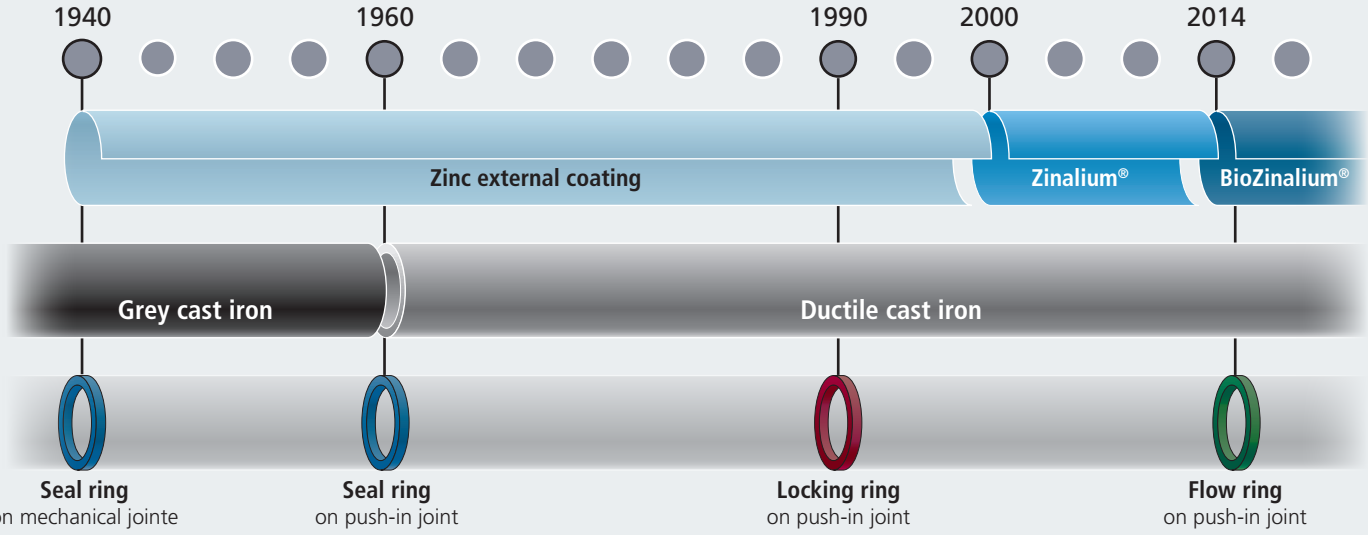
1.1.2 40,000 KM OF PIPES PER ANNUM

Leading industrialists all over the world put their trust in PAM pipes, for operations or for fire protection.

- KINROSS,
  Gold mine, tailings transport
- RIO TINTO,
  Costal project, water transport
- BHP Billington,
  Cupper mine, water transport
- SNIM,
  Iron ore mine, water transport
- LKAB, LULEÅ
  Iron ore mine, water transport
- NAMWATER / CGNPC
  Uranium mine
  Desalted water transport
- RWE Rheinbraun
  Lignite mine
  Drainage main
- OCP,
  Phosphate mine
  Drainage main
- ELF, TOTAL, ATOCHEM, DUPONT-NEMOURS, SHELL, EXXO, SOLVAY
- STATOIL,
  Firefighting system, disposal

INNOVATIONS THAT HAVE BECOME STANDARDS

PAM constantly improves the performance of its pipes, in particular the quality of the centrifugal ductile cast iron, the efficiency of the internal and external coatings and the reliability of the assembly systems. Its engineers and researchers have designed and developed more than 150 inventions that to date have generated 1,500 patents.



1.2 WITH YOU, TO THE ENDS OF THE REACH

SERVICES

1.2.1 AN INTERNATIONAL NETWORK

PAM has a global network organized to offer local service to operators, design and engineering firms and pipe-laying companies. PAM constantly strives to share with its customers and distributors its experience of numerous achievements throughout the world.

1.2.2 EACH STAGE OF THE PROJECT WITH CONFIDENCE

PAM local teams are close at hand throughout the project from elaboration to completion. They are supported by experts in soil and water analysis, abrasiveness phenomena, hydraulic calculations and civil engineering.

Soil survey and water analysis

Choice of product range

Engineering support

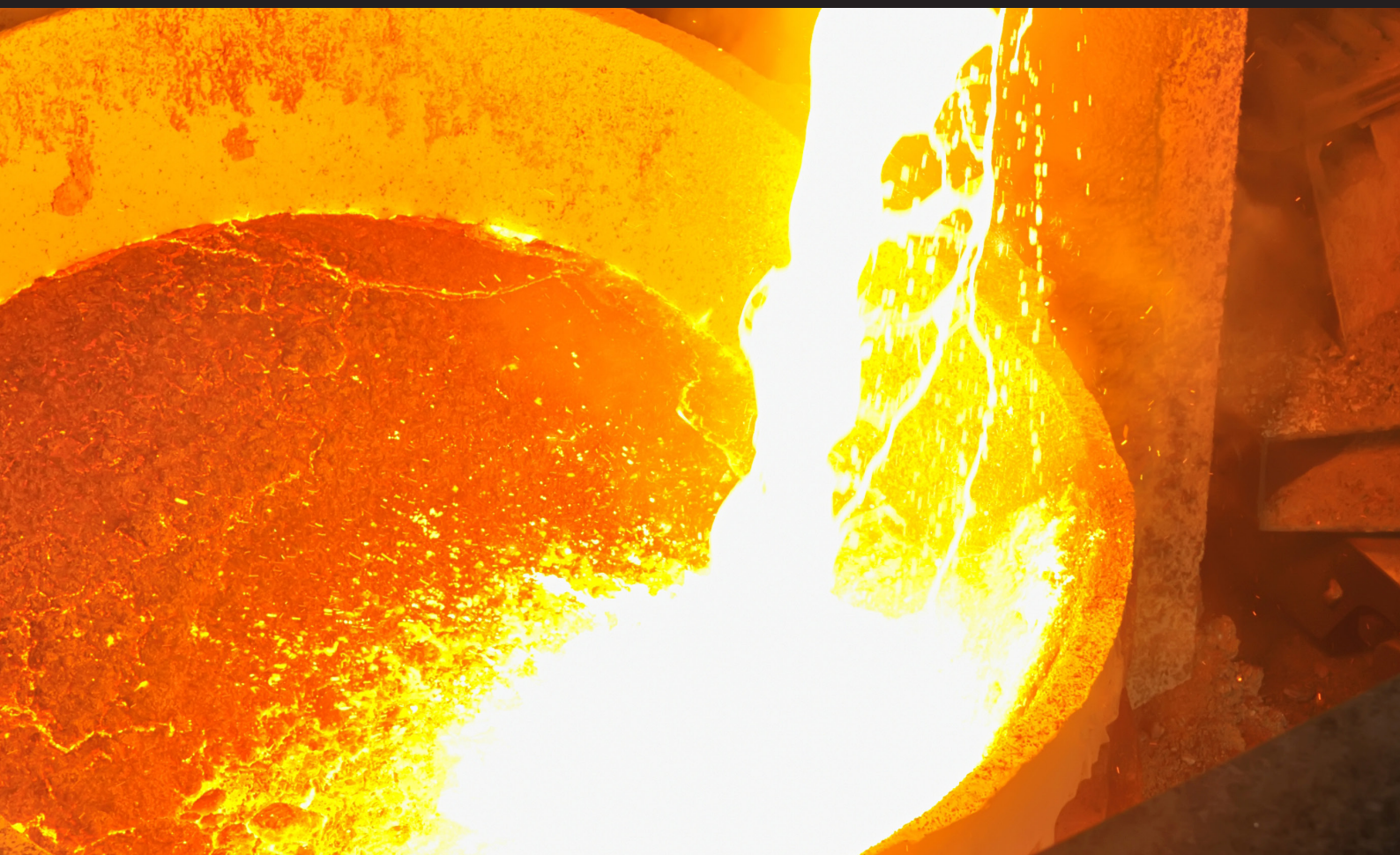
Implementation and training

Support for operations

INTERCONTINENTAL LOGISTICS

PAM conducts projects involving very long distances (hundreds of kilometres) and also those concerning more complex pipe systems on industrial or mining sites. PAM can take charge of the entire supply chain from the factory to the works site, charter lorries and trains, unload ships and handle containers at the best price and under optimal conditions of safety.

1.3 WATER, EARTH, FIRE ... AND DUCTILE CAST IRON

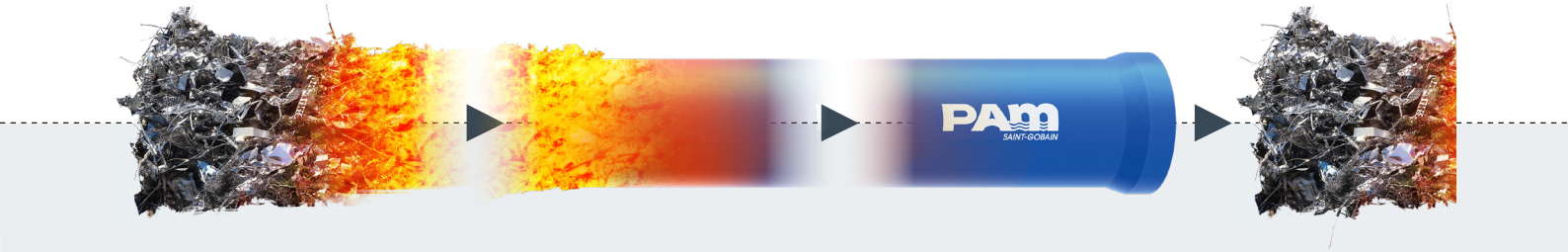


SAFETY AND THE ENVIRONMENT

1.3.1 PEOPLE AND SAFETY

Life safety is a central concern of PAM in its factories, during transport and on works sites. PAM provides haulage firms, laying firms and operators with detailed procedures to handle, store and assemble its products under optimal conditions of safety.

1.3.2 100 % RECYCLABLE INDEFINITELY



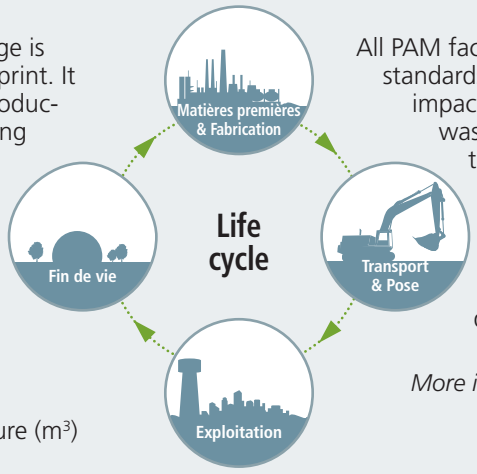
Ductile cast iron, mostly the product of deconstruction scrap, is 100 % recyclable, indefinitely and easily, thanks to the proximity of metal recovery sectors. The cast iron pipes are rigid and robust and do not require excessive compaction when laid in trenches. With the appropriate coatings, local backfill can be reused rather than materials imported from distant quarries.

PAM LCA CALCULATOR — CARBON FOOTPRINT IN A FULLY TRANSPARENT MANNER

The LCA PAM Calculator software package is designed to measure environmental footprint. It performs life cycle analysis (LCA) from production to recycling, including transport, laying and operation.

Compliant with standard EN 14044, for a given project this software evaluates:

- greenhouse gas emissions (CO_2 equivalent),
- fossil fuel consumption (MJ)
- the volume of water sourced from nature (m^3)



All PAM factories manufacture to ISO 14001 standards, in order to minimize their ecological impact, prevent pollution incidents and control waste management and water consumption.

Thanks to its new industrial processes, PAM has reduced its energy requirements by an average of 30 % to manufacture a pipe of the same diameter.

More information in the "technical specifications" chapter with 2 LCA calculation examples.


PAM
MINERAL
M100

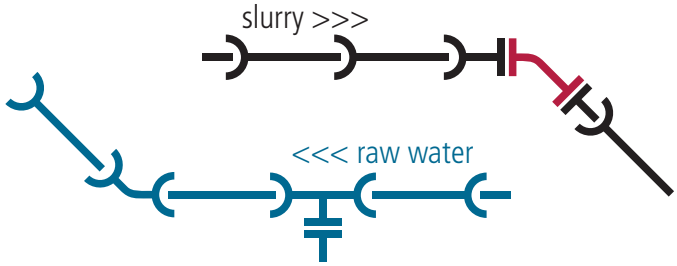
2

AN IDEAL SOLUTION

2.1 INGENIOUS AND SIMPLE

EASE OF DESIGN

2.1.1 SOCKETS OR FLANGES, 100 % COMPATIBLE



With 50,000 references from DN 80 to DN 2000, PAM pipes and fittings system facilitates the design networks of any size and complexity in any environment.
With standardized components equipped with 100 % compatible socket or flange joints, the PAM system considerably facilitates the work of engineers in charge of designing networks.

PAM provides a library of digital images that can be integrated into the main software packages for design firms.

2.1.2 QUALITY ASSURANCE AND CERTIFICATION

PAM designs, manufactures and markets its products in accordance with ISO 9001 quality assurance system requirements. The quality assurance is regularly audited by independent organizations that issue certificates of compliance.

All PAM products are compliant with current European standards (EN) and international standards (ISO).

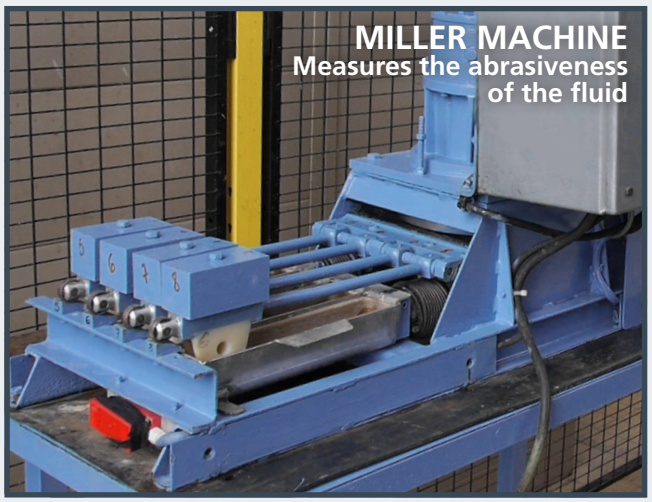
More information on standards and certificates in the "technical specifications" chapter.

PAM SAINT-GOBAIN SOLUTION

AN ABRASION EXPERTISE CENTRE AT YOUR DISPOSAL

On request, PAM's Centre of Expertise can characterize the chemical and mechanical aggressiveness of a sample of slurries. A report is issued for each requested analysis.

In addition, the centre has an abrasion loop for full-scale testing of the behaviour of linings, and it carries out tests in situ on mining sites.



2.2 TIME IS MONEY

RAPID INSTALLATION

2.2.1 ROBUST COMPONENTS

PAM designs efficient and robust parts that can be transported by lorry, train and boat, and can be stacked and handled roughly on works sites.

2.2.2 HIGH RATE LAYING

1. Excavating **2.** Laying **3.** Assembling **4.** Backfilling

Lay, align, push-in! No welding in situ, no re-coating, no ultrasonic or X-ray inspection required... No other material can match the speed of assembly of ductile cast iron socket pipes. No need to budget for specialized machinery, no waiting time while assemblies dry or cool. Nothing equals the flexibility of site management (stoppages, resumption and progress) with PAM technology.

Deserts or forests, marshes or mountains, sunshine or snow, the pipes and fittings, their protection and assembly are designed for all climates and situations. No waiting time, whatever the temperature and humidity.

More information on assembly times in the "technical specifications" chapter.

PAM SAINT-GOBAIN SOLUTION

IN TRENCHES OR ON SUPPORTS, WITHOUT EXPANSION JOINTS

IN TRENCHES: an excavator for straight lines at high rates, simple hand winches at the bottom of inaccessible trenches!

ON THE SURFACE: supports easy to make in the workshop, easy to install on site: the flexible joints adjust to any misalignment of the supports and act as thermal expansion joints.

IN TUNNELS: Short pipe lengths (6 and 8 metres) facilitate access in tunnels and the push-in joints enable weld-free assembly without any bulky equipment.

ON THE GROUND: pipes secured to the ground with locked joints, removable when DN and pressure permit.

2.3 WATER, 24/7

RATIONAL OPERATION

2.3.1 WATERTIGHT AND RELIABLE

Water is essential for mining operations. An interruption in the water supply can cause serious delays in mining. A leak detected too late can cause very costly environmental pollution.

- Cast iron is a sturdy material that withstands high service pressures and external mechanical accidents.
- The joints with flexible sockets can handle excess pressure caused by soil movements.
- The coatings protect enduringly the pipes against corrosion and/or abrasive fluids.

2.3.2 SCALABLE AND SUSTAINABLE

PAM pipes with flexible sockets adapt easily to routing changes and soil movements: they are particularly suited to constantly changing mining sites and industrial sites.

Their design factors in a safety margin that can confidently withstand increases in pressure and flow rate, as well as increases in surface loads (roads, buildings, live loads, etc.).

International statistics on buried drinking water systems show that ductile iron pipes and fittings have a service life longer than 100 years.

PAM LCA CALCULATOR

PAM SAINT-GOBAIN SOLUTION

INVEST TO SPEND LESS

An investment in reliable pipes reduces the risk of shutdown of operations.

Pumping costs and water losses or accidental pollution during the lifetime of a network are considerably higher than its initial cost of purchase.

The TCO PAM calculator software package is designed to assess the total cost of ownership (TCO). It highlights the immediate costs of the investor and the deferred costs of the operator.

The calculation method factors in:

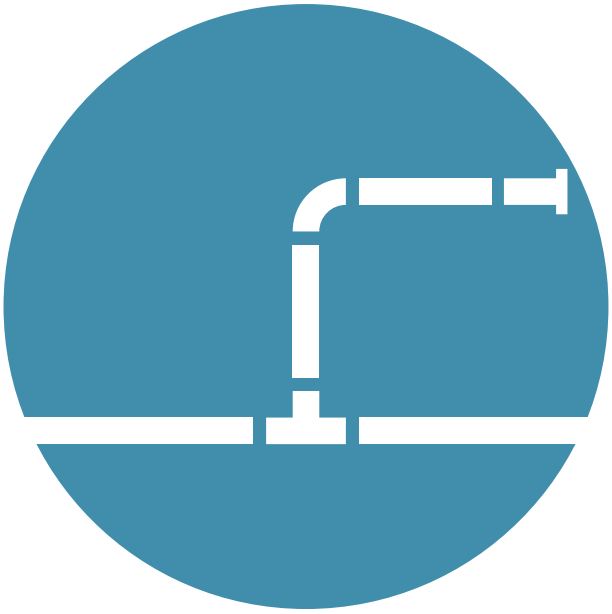
- Acquisition costs (pipes, laying, loans, etc.).
- Operating costs (maintenance, water losses, pumping energy).
- End-of-life costs (removal, recycling).

More information in the "technical specifications" chapter with 2 TCO calculation examples.

MINERAL PIPE DN 200 OVER 100 YEARS

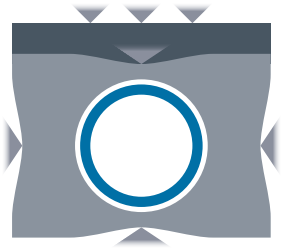
3

KEY TECHNOLOGIES



3.1 STRENGTH AT THE CORE OF THE MATERIAL

DUCTILE CAST IRON



3.1.1 SOLID UNDER LOADS

In underground conditions, the ductile cast iron pipe has a semi-rigid behaviour: it offers an excellent compromise between mechanical stress in the wall (small DN) and ovality (large DN). It can be laid with deep or shallow cover, and easily in soft soil. The "soil/semi-rigid pipe" system offers optimal mechanical stability over time, without risk of buckling in large diameters.

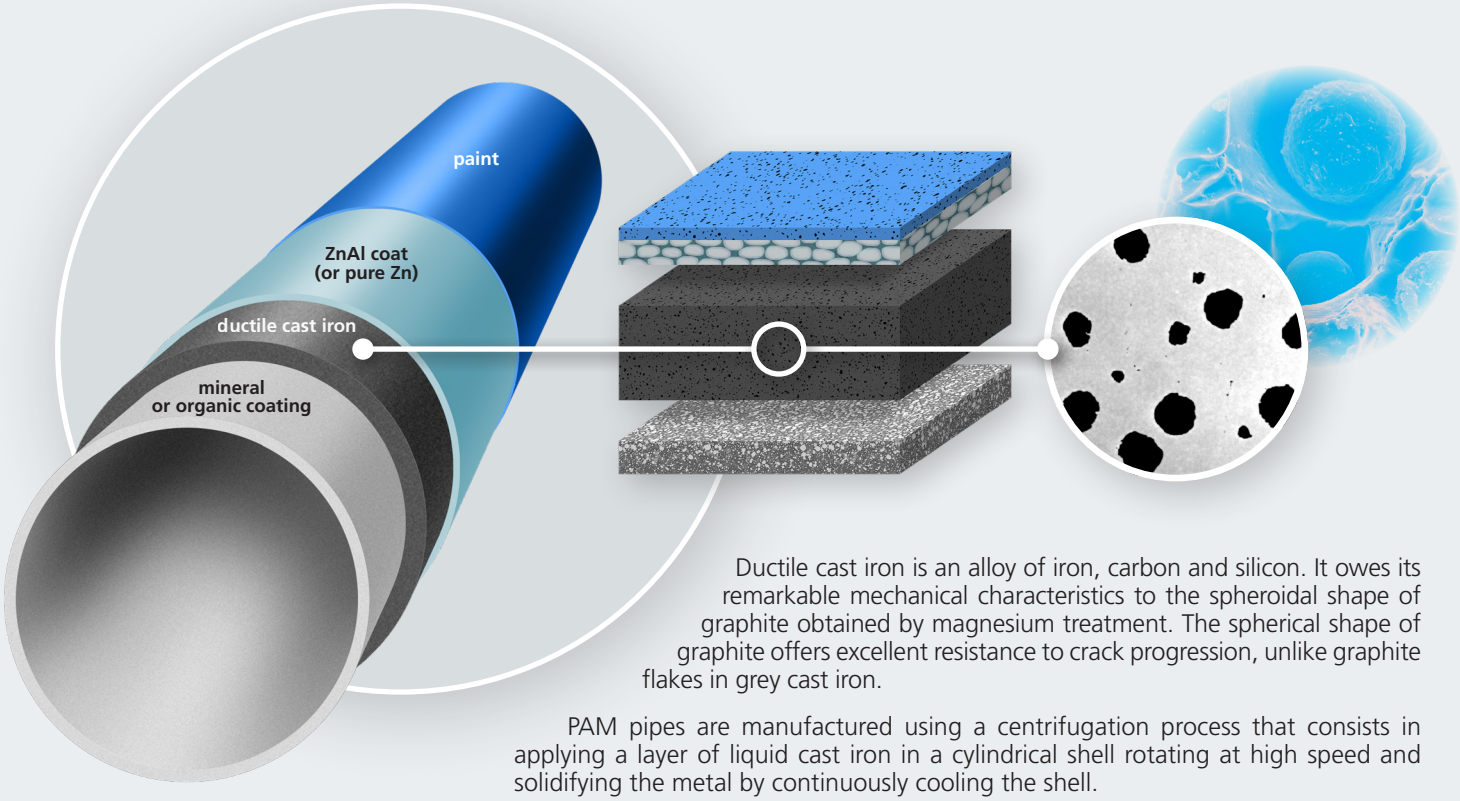
3.1.2 PRESSURE RESISTANCE

Wall thicknesses are calculated with a safety factor of 3 in relation to maximum service pressure. This safety margin is very useful considering impacts during installation, accidental overpressure and mechanical fatigue in service.

3.1.3 INSENSITIVE TO IMPACTS

The ductile cast iron structure has a high elastic deformation ratio and high resistance to crack initiation: it results in an excellent impact resistance.
The cast iron pipes are perfectly suited to transport conditions over long distances (lorry, train or ship), handling conditions on sites and to different backfilling methods.

PAM SAINT-GOBAIN TECHNOLOGY



Ductile cast iron is an alloy of iron, carbon and silicon. It owes its remarkable mechanical characteristics to the spheroidal shape of graphite obtained by magnesium treatment. The spherical shape of graphite offers excellent resistance to crack progression, unlike graphite flakes in grey cast iron.

PAM pipes are manufactured using a centrifugation process that consists in applying a layer of liquid cast iron in a cylindrical shell rotating at high speed and solidifying the metal by continuously cooling the shell.

More information on PAM ductile cast iron in the "technical specifications" chapter.

3.2 MASTERING WATER AND ABRASION

LININGS
MINERAL OR ORGANIC

3.2.1

GRADED PROTECTION OFFER

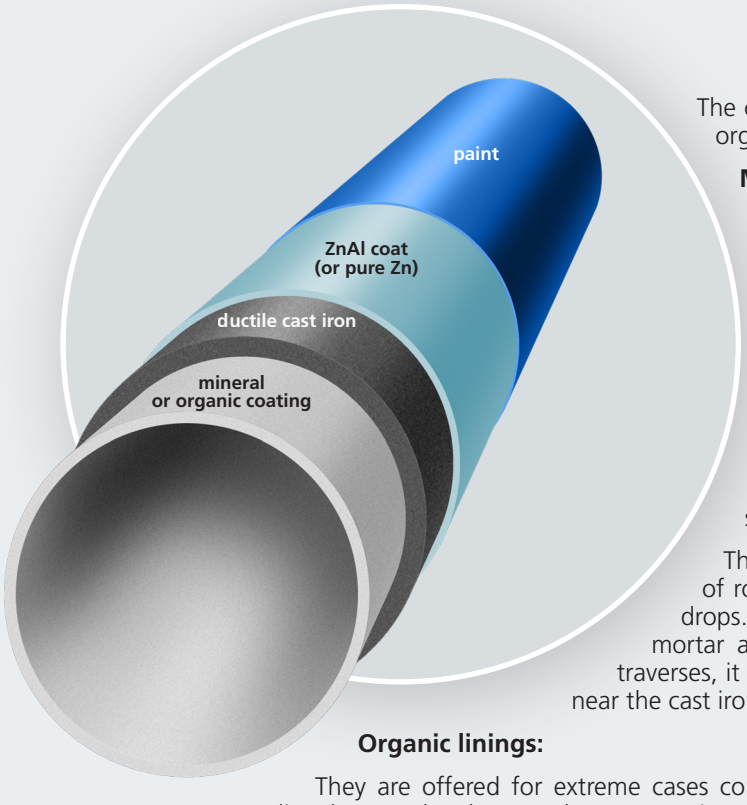
The MINERAL range coatings are suitable for the abrasiveness and salinity of the water and slurries generally found in mines. They are classified by 3 performance grades and their references begin with the letter M, as shown in the table below:

	ABRASION	FLUID	LININGS			FLOW RING
			GRADE 100	GRADE 200	GRADE 300	
WATERS	NO ABRASION	• Drinking water • Raw waters • Salted waters, brines • Soft water after desalination	M100 M110 M150 M160			NO
	LOW & MEDIUM ABRASION	• Recycled waters • Waste waters, sewage • Waste slurries • Ore concentrates		M200 M210		YES
SLURRIES	HIGH ABRASION	• Waste slurries • Ore concentrates			M350*	YES

**in progress*

More information on the abrasiveness of charged waters and slurries in the "technical specifications" chapter.

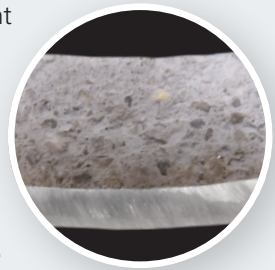
PAM SAINT-GOBAIN TECHNOLOGY



The coatings in the MINERAL range are developed with mineral or organic materials

Mineral linings:

They mainly comprise cement mortars. Rigorous selection offers different grades according to the levels of abrasion while covering a wide pH range (4 to 12 at 20° C).



All PAM mortars are applied by high-speed centrifuging under vibration. This process produces a coat that adheres to the cast iron wall, a compact layer whose structure is inspected.

This results in excellent hydraulics, very good bending and out of roundness behaviour, and total resistance to transient pressure drops. In a pipe filled with water, the water impregnates the cement mortar and traverses it until it reaches the cast iron. As the water traverses, it is enriched with alkaline elements that render it non-corrosive near the cast iron wall.

Organic linings:

They are offered for extreme cases combining chemical attack and very high erosion due to flow disturbance. They have undergone precise and thorough tests in the PAM research centre and are applied by projection or centrifuging in pipes and by moulding in fittings.

More information on PAM internal coatings in the "technical specifications" chapter.

3.3 WITHOUT CATHODIC PROTECTION

EXTERNAL COATING
PURE ZINC OR ZINALIUM®

3.3.1 LONG-LIFE PROTECTION

The MINERAL pipes are available with a Zinc-based coating comprising 2 layers:

1. A metallic layer (pure zinc or an 85-15 alloy of zinc and aluminium) of at least 400 g/m^2,
2. A coat of synthetic paint (semi-permeable), at least 100 microns thick.

These coatings are compliant with standards EN 545 and ISO 8179.

Unlike electrically continuous welded metal pipelines, cathodic protection is not necessary on ductile cast iron pipe systems protected in this manner.

3.3.3 PROOF AGAINST WORK SITES

Adhering perfectly to the surface of the cast iron, the metallic zinc-based coating is malleable and deformable, and absorbs impacts in transit or on site without breaking.

The pipe sockets and spigot flanges are factory-coated, so that after the joints are assembled there is no need to touch up the coating on site.

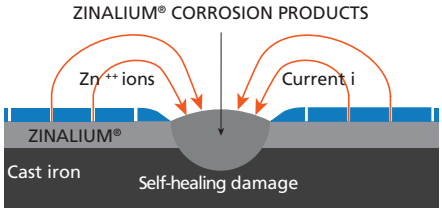
3.3.2 FOR CORROSIVE SOIL

The uses of zinc-based coatings are specified in European standard EN 545: 2010 (appendix D.2.2.). PAM's teams carry out soil surveys on request. Special coatings are available for extreme cases of corrosiveness.

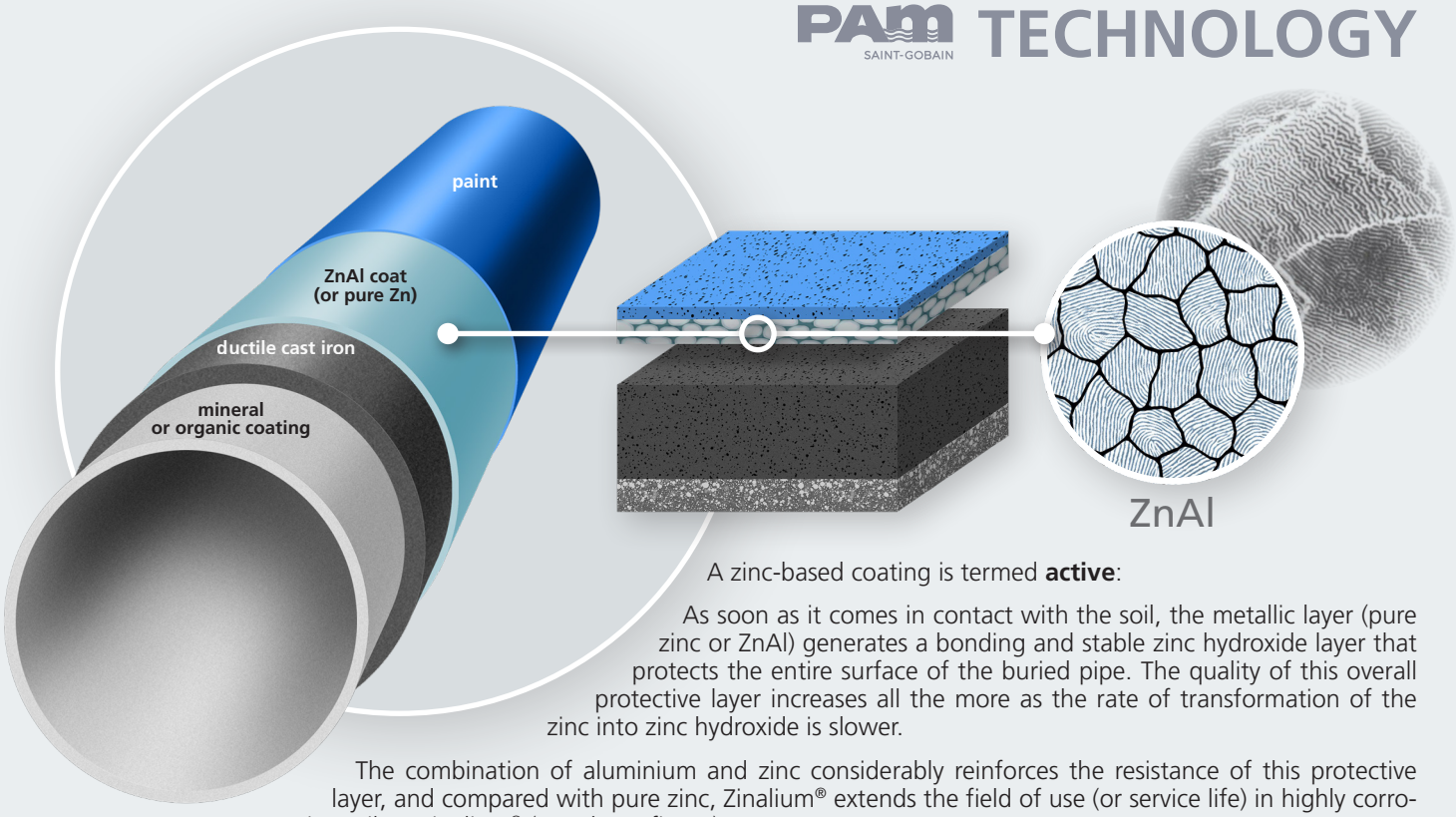
More information on uses in different types of soil in the "technical specifications" chapter.

3.3.4 SELF-REPAIRING

A zinc-based coating (pure zinc or Zinalium®) restores the continuity of the protective layer at points that have suffered limited damage, by galvanic effect between the exposed cast iron and the zinc near the damaged area (impacts in transit, scraping during backfilling).



PAM SAINT-GOBAIN TECHNOLOGY

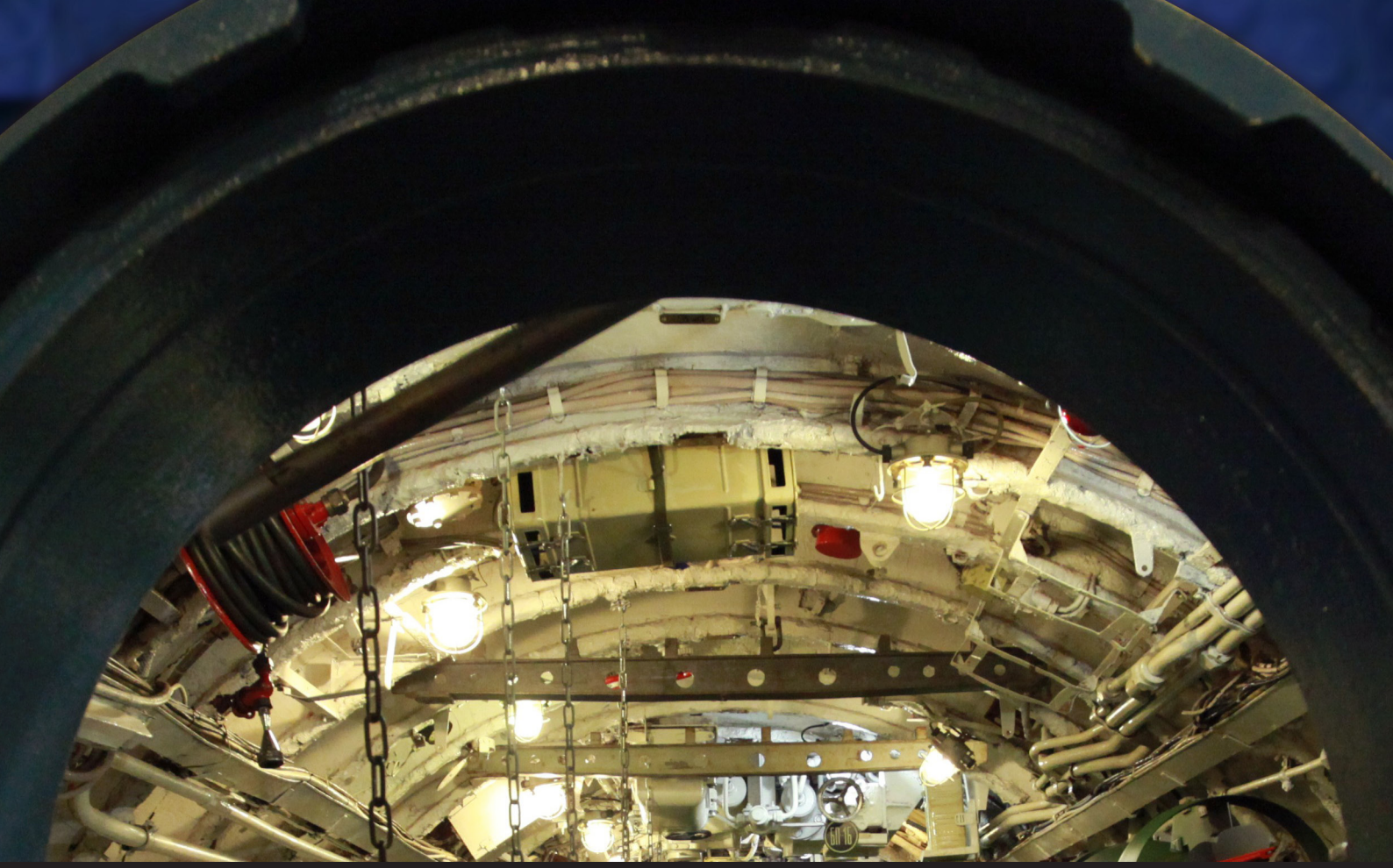


A zinc-based coating is termed **active**:

As soon as it comes in contact with the soil, the metallic layer (pure zinc or ZnAl) generates a bonding and stable zinc hydroxide layer that protects the entire surface of the buried pipe. The quality of this overall protective layer increases all the more as the rate of transformation of the zinc into zinc hydroxide is slower.

The combination of aluminium and zinc considerably reinforces the resistance of this protective layer, and compared with pure zinc, Zinalium® extends the field of use (or service life) in highly corrosive soil. In Zinalium® (see above figure):

- the coat of semi-permeable paint limits but does not prevent transfers with the surrounding damp soil;
- the ZnAl 85-15 alloy traps the zinc-rich phase in an aluminium skeleton, which slows down the transformation of zinc into zinc hydroxide and confines the latter in the metal layer.



3.4 THE GREATER THE PRESSURE, THE MORE IT IS WATERTIGHT

THE “PUSH-IN” JOINT

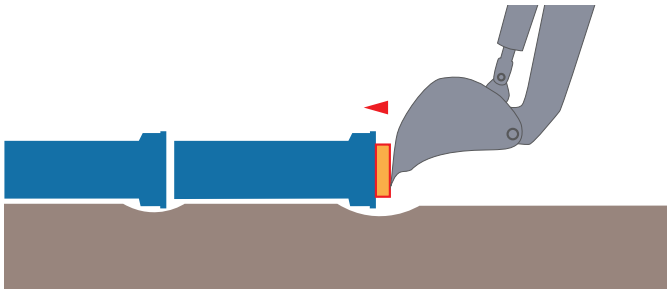
The “push-in” joint has been the preferred assembly system of pipeline contractors for 60 years.

3.4.1 QUICK AND SELF-SEALING

The watertightness of the STANDARD push-in joint results from radial compression of the sealing ring (1), by simply inserting the spigot ends into the socket. It does not require any tightening of bolts or a welding process.
The STANDARD “push-in” joint is ideally suited for laying in trenches or overhead, irrespective of weather conditions.

3.4.2 NO WELDING OR REWORKING

No welding on site, no repair of coatings. As an example, it takes only 8 minutes to create a watertight junction at 25 bar on an DN 1000 ductile cast iron pipe!



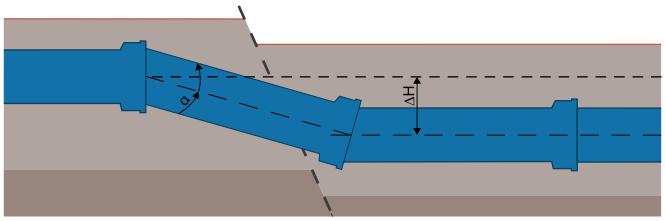
3.4.3 EASY DISMANTLING

The “push-in” joints are by definition removable. PAM provides a dismantling/reassembly procedure that factors in the time elapsed since the pipe was brought into service, the replacement of the elastomer ring and the cleaning of the socket and spigot flange.

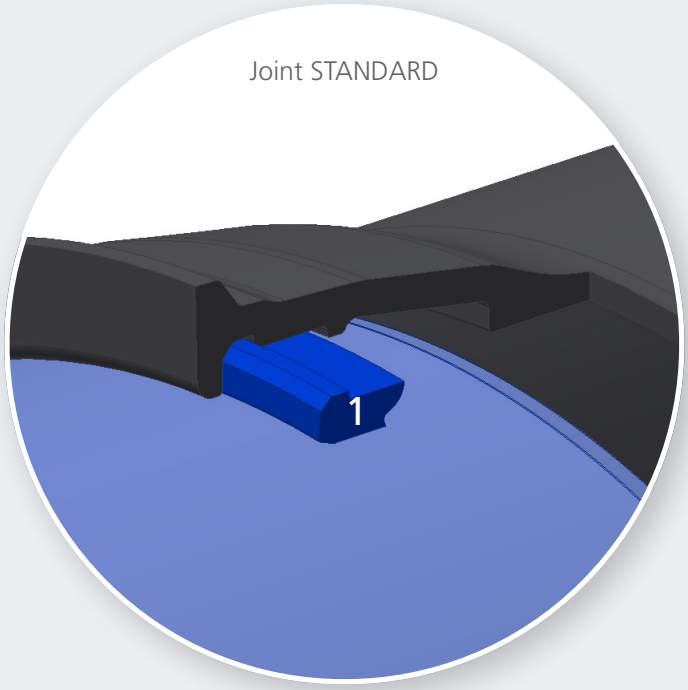
3.4.4 FLEXIBLE

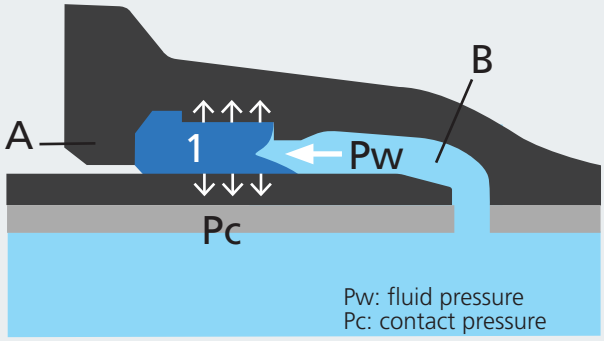
The angular deviation and axial displacement capacity gives the pipeline a chain-like behaviour in unstable soil. It allows the actual routing of the pipeline to be corrected easily according to obstacles encountered.

More information on PAM joints in the “technical specifications” chapter.



PAM SAINT-GOBAIN TECHNOLOGY

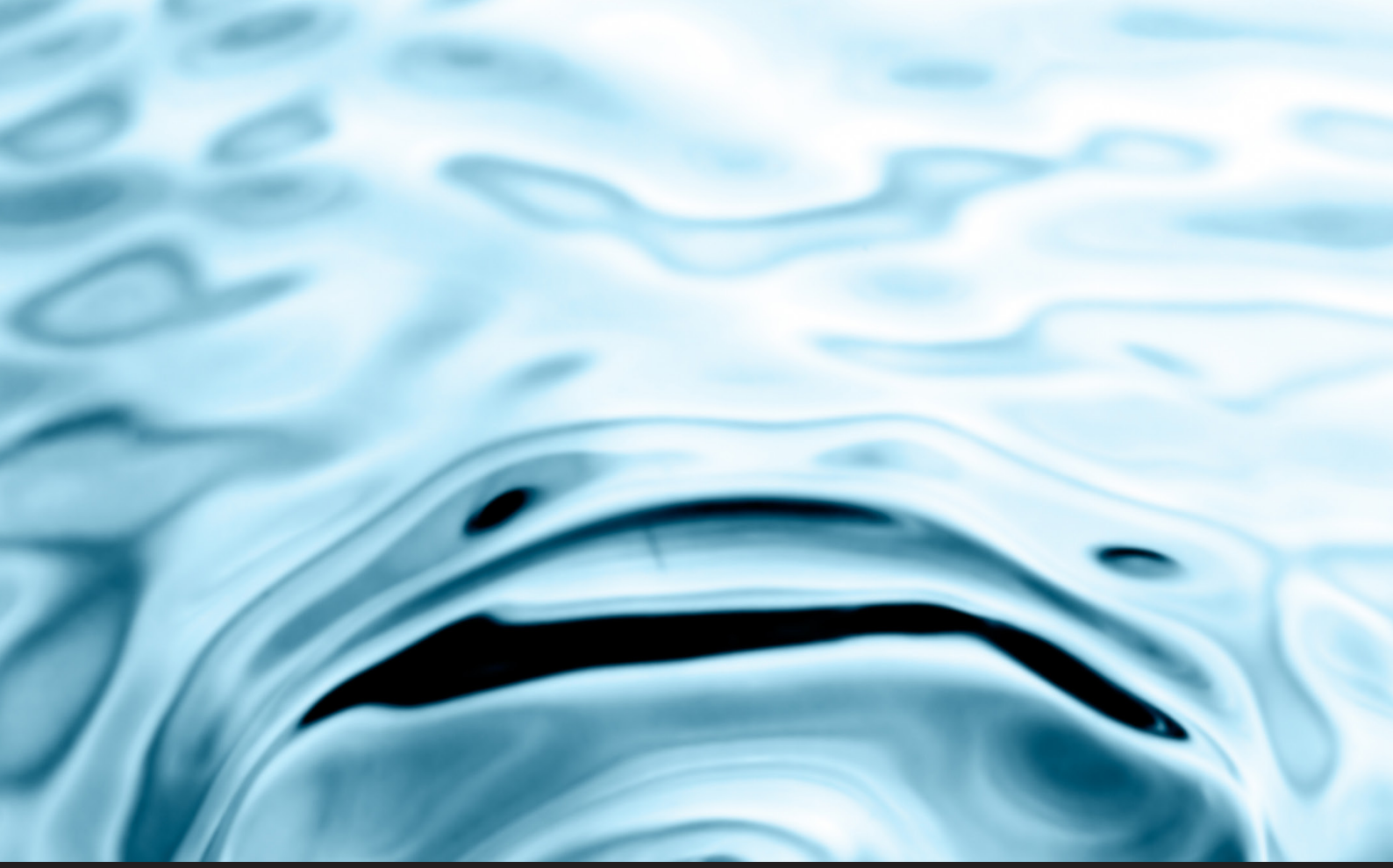




More information on the performance of the joints in the “technical specifications” chapter.

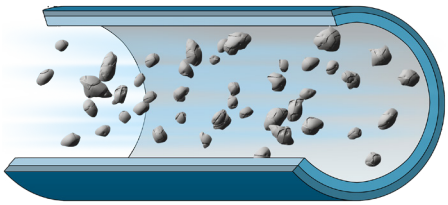
The STANDARD joint is self-sealing: the greater the water pressure (Pw), the greater the contact pressure (Pc) between the elastomer ring and the metal. This property is obtained thanks to the shape of the sealing ring (1) and to the physical characteristics of the elastomer. The heel (A) of the socket prevents blow out of the joint, and the cavity (B) allows angular deviation, even at high pressure.

The sealing ring is made of EPDM or NBR elastomer. Rigorously selected, it maintains its physico-chemical characteristics (creep and elaxation) over a very long period of time.



3.5 CONTINUOUS FLOW

THE FLOW RING



3.5.1 AN ANTI-TURBULENCE DEVICE

The flow ring regulates flow at the point of assembly and in its immediate extension in the direction of flow. This therefore considerably reduces abrasion phenomena in these zones.

3.5.2 PATENTED EFFICIENCY

The flow ring has been designed and developed at PAM's research centre and is protected by an international patent.

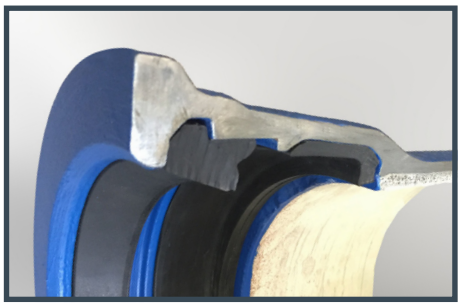
It is the fruit of a study of hydraulic phenomena perpendicular to and downstream of the socket, of the position of pipe elements (aligned, deviated, off-centre, etc.), and also of an analysis of the behaviour of several elastomers subjected to abrasion.

In parallel, tests have been conducted at high flow rates on the abrasion loop of the PAM expertise center and in situ in mines.

3.5.3 RAPID INSTALLATION

The flow ring is suitable for STD, STD Vi and STD Ve joints. It does not modify the ease of fitting, the push-in movement or the angular deviation capacity.

It also acts as a shock absorber when pushing in, in case of lack of control of the push-in effort.



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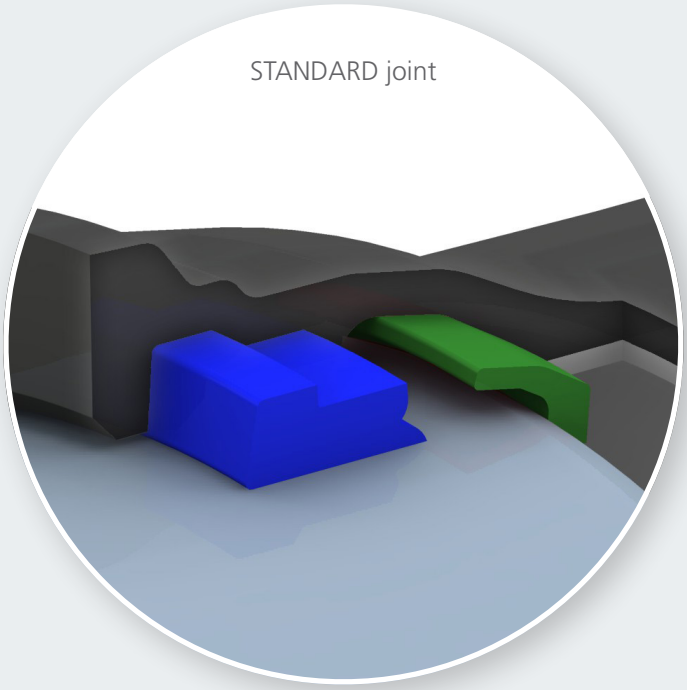
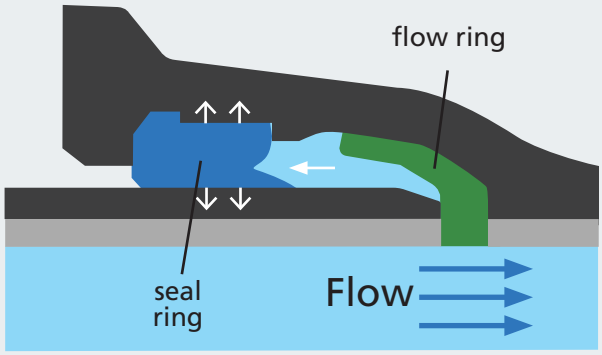




More information on the main parameters involved in erosion in the "technical specifications" chapter.

Abrasive hydraulic fluids tend to attack pipe walls in zones of turbulence (when they are stable and homogeneous), or in the bottom section (when they are sensitive to settling at low speed). The elastomer flow ring is lodged at the bottom of the socket. Its design ensures it stays firmly in place and helps improve the continuity of the lining between pipes.

3.6 LOCKING IS BETTER THAN WELDING

THE LOCKING RING

3.6.1 A LOCK FOR EACH CONFIGURATION

Locking the joints enables absorption of the axial hydraulic forces while maintaining its angular deviation capacity. It eliminates the need to construct anchor blocks, which are costly for large diameters.
PAM offers several locking techniques for different DNs and service pressures:

- Locking with metal inserts lodged in the seal ring (without a weld bead) is normally reserved for reduced axial force (the case for small or medium DNs at low pressure)
- Locking with a ring + weld bead withstands axial forces (the case for large DNs, or small DNs at high pressure).

3.6.2 RAPID PROGRESS

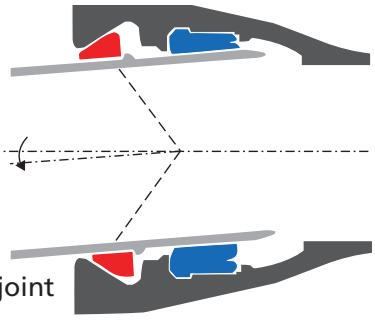
Locking enables the final pressure tests to be carried out in situ as soon as possible after the pipes have been laid. It is particularly convenient for reducing disruption caused by laying works in operating zones.

Compared with welding processes (on PE or steel pipes), the locking system of ductile cast iron pipes removes the need for the contractor to hire certified personnel and immobilize equipment and specified sources of electrical energy.

3.6.3 HIGH TENSILE STRENGTH

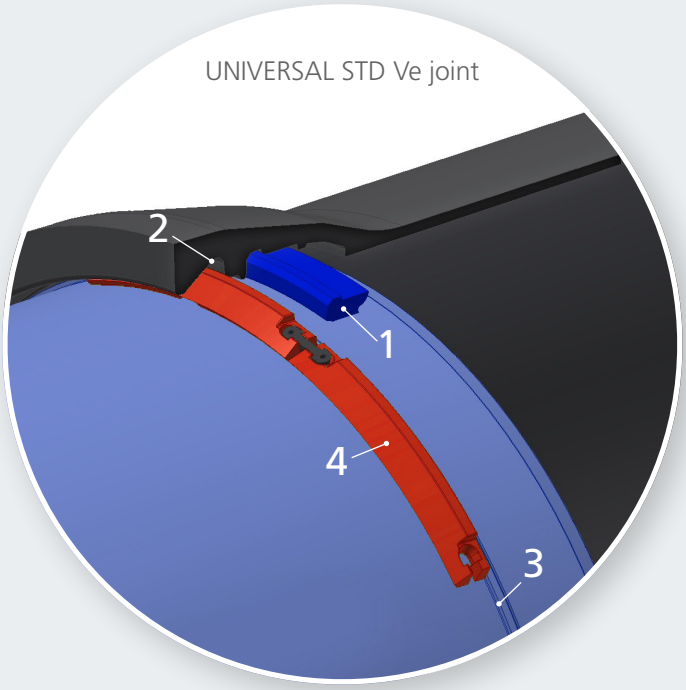
High tensile strength without foregoing angular deviation!

In many cases, locking is a simple and easy solution: pulling through a casing under a roadway, trenchless directional drilling, installation on steep incline (the case for small hydroelectric power plants in the mountainous areas), securing in unstable terrain, pulling a floating pipeline before immersing it, etc.



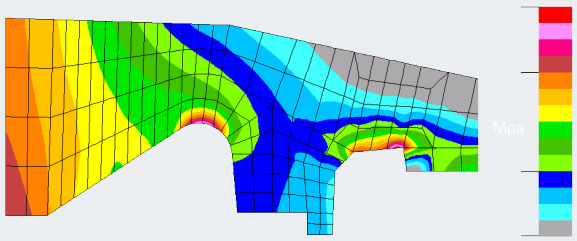
UNI STD Ve joint

PAM TECHNOLOGY



There are several locking techniques:
STANDARD Vi or Ve, UNIVERSAL STD Vi or Ve and PK.

FINITE ELEMENT MODELLING



With the UNI STD Ve technique (opposite), sealing is achieved with a STANDARD seal ring (1). The axial hydraulic forces are taken up by a system comprising:

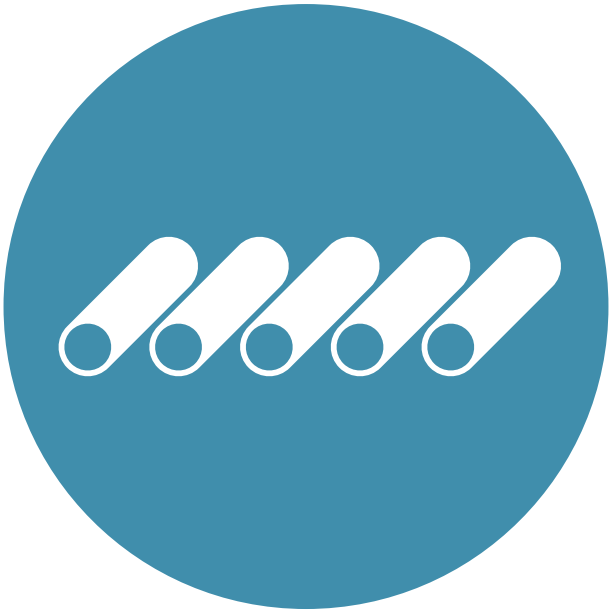
- an UNIVERSAL socket with a dual chamber (2),
- a factory-welded bead (3) on the pipe's spigot flange,
- a single-block locking ring (4) with a spherical external profile, which rests on the weld bead.

PAM locking systems are designed using finite element calculations supplemented by behaviour tests in the most extreme conditions. They support angular deviations and pipe out-of-roundness without reducing their axial resistance capacity in any way.

More information on joint performance levels and the choice of locking devices in the "technical specifications" chapter.

4

THE MINERAL RANGE

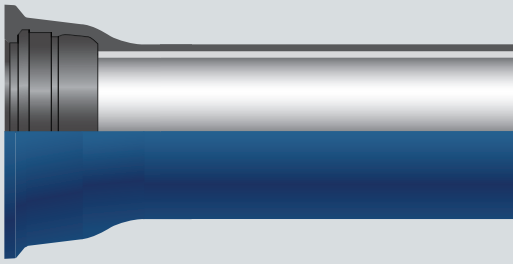


4.1 PIPES AND JOINTS

ASSEMBLY VIDEOS

CHOICE OF LOCKING DEVICES

More information in the "technical specifications" chapter.



Protective coatings:

Internal coating: select grade according to level of fluid abrasiveness. More information in § 3.2.1

external pure zinc or ZnAl alloy coating

Other available classes of pipe:

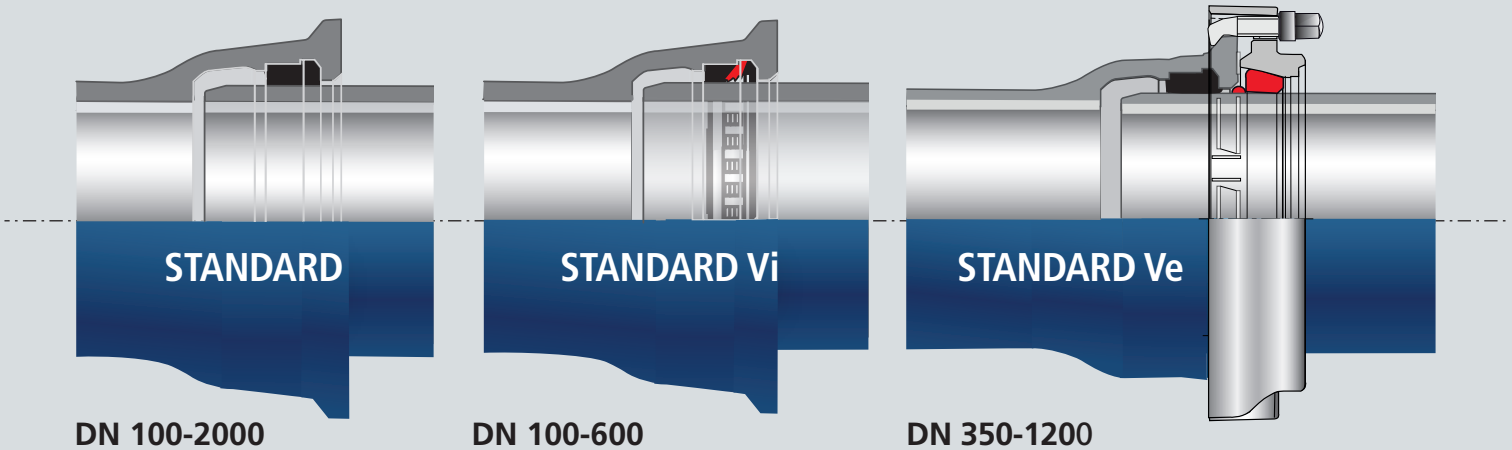
- C25 from DN 350 to 600 on request
- C20 from DN 700 to 2000 on request
- For larger classes, contact us

PFA: Allowable operating pressure

STD: standard joint not anchored
STD Vi: standard Vi joint anchored
STD Ve: joint standard Ve anchored
UNI STD Vi: UNIVERSAL std Vi joint anchored
UNI STD Ve: UNIVERSAL std Ve joint anchored
PK: PAMLOCK joint anchored

(1): Unit length
(2): Weight calculated with STD socket
(3): Under development

DN		Coatings	
		Internal	External
mm	inches	Grade	
100	3.94	100 200 300 (3)	
150	5.90		
200	7.87		
250	9.84		
300	11.81		
350	13.78	100 200 300 (3)	
400	15.75		
450	17.72		
500	19.68		
600	23.62		
700	27.56	100 200 300 (3)	
800	31.50		
900	35.43		
1000	39.37		
1100	43.31	100 200 300 (3)	
1200	47.24		
1400	55.12		
1500	59.05		
1600	62.99		
1800	70.87		
2000	78.74		

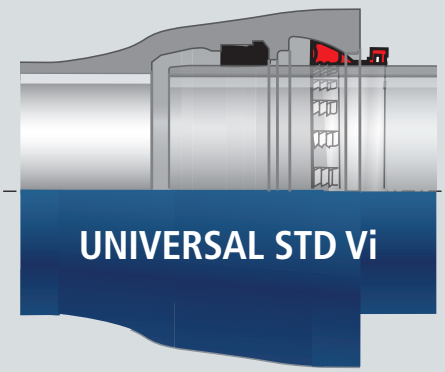


DN 100-2000
Self-sealing, not locked
RAPID, FOR ALL DN!

DN 100-600
Seal ring with locking inserts
LAST-MINUTE FITTING!

DN 350-1200
Locking with ring abutting on the weld bead maintained by an added companion flange
FOR STANDARD JOINT WITH FLANGE RING!

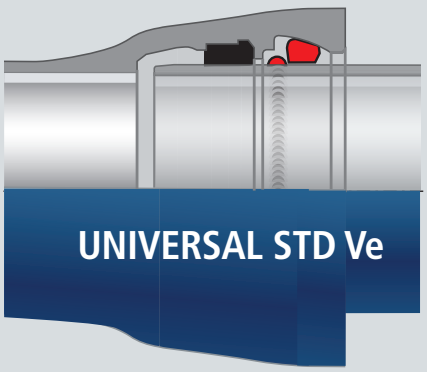
MINERAL®		Pipes		Joint				Pipes		Joint				
DN mm	Lu (1) m	Thickness class	Mass (2) kg/m	STD PFA bar	STD Vi PFA bar	STD Ve PFA bar	PK PFA bar	Thickness class	Mass (2) kg/m	STD PFA bar	STD Vi PFA bar	UNI STD Vi PFA bar	STD Ve PFA bar	UNI STD Ve PFA bar
100	6.00	C40	14.9	40	16			C100	17.3	100	56	56	64	64
150	6.00	C40	22.2	40	16			C64	25.7	64	25	48	55	60
200	6.00	C40	30.2	40	16			C64	33.5	64	56	43	46	52
250	6.00	C40	42.2	40	16			C50	47.4	50	20	39	35	46
300	6.00	C40	55.6	40	16	30*		C50	63.9	50	20	34	37	41
350	6.00	C30	68.8	30	16	27*		C40	74.5	40	20	25	30	38
400	6.00	C30	79.4	30	16	25		C40	91.3	40	20	20	30	35
450	6.00	C30	93.8	30	13*	23		C40	111.3	40	20	16	30	32
500	6.00	C30	111.2	30	11	22		C40	131.7	40	18	16	30	30
600	6.00	C30	150.6	30	10	20		C40	180.6	40	16	16	27	30
700	6.00	C25	186.2	25	10	20		C30	203.8	30			16-22	27*
800	6.00	C25	229.0	25		16-20		C30	256.3	30			16-23	25*
900	6.00	C25	276.2	25		16-20		C30	310.9	30			16-24	25*
1000	6.00	C25	330.6	25		16-20		C30	371.4	30			16-25	25*
1100	8.19	C25	395.4	25		16-20		C30	447.6	30			16-25	
1200	8.19	C25	461.3	25		16-20		C30	521.0	30			16-25	25*
1400	8.17	C25	634.3	25			25*							
1500	8.16	C25	720.3	25			25*							
1600	8.16	C25	807.5	25			25*							
1800	8.15	C25	995.1	25			16*							
2000	8,13	C25	1210,0	25			16*							



DN 400-600

Locking with insert rings housed in a chamber adjoining the sealing chamber

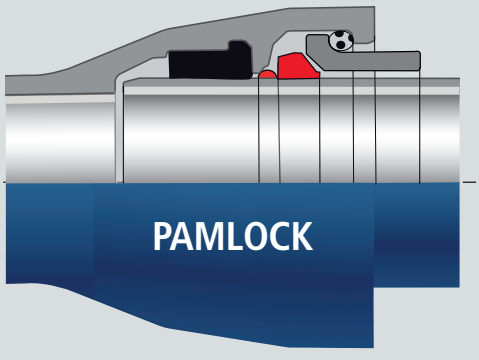
NO WELD BEAD!



DN 400-1400

Locking with ring and weld bead housed in a chamber adjoining the sealing chamber

HIGH PRESSURE, NO BOLTS!



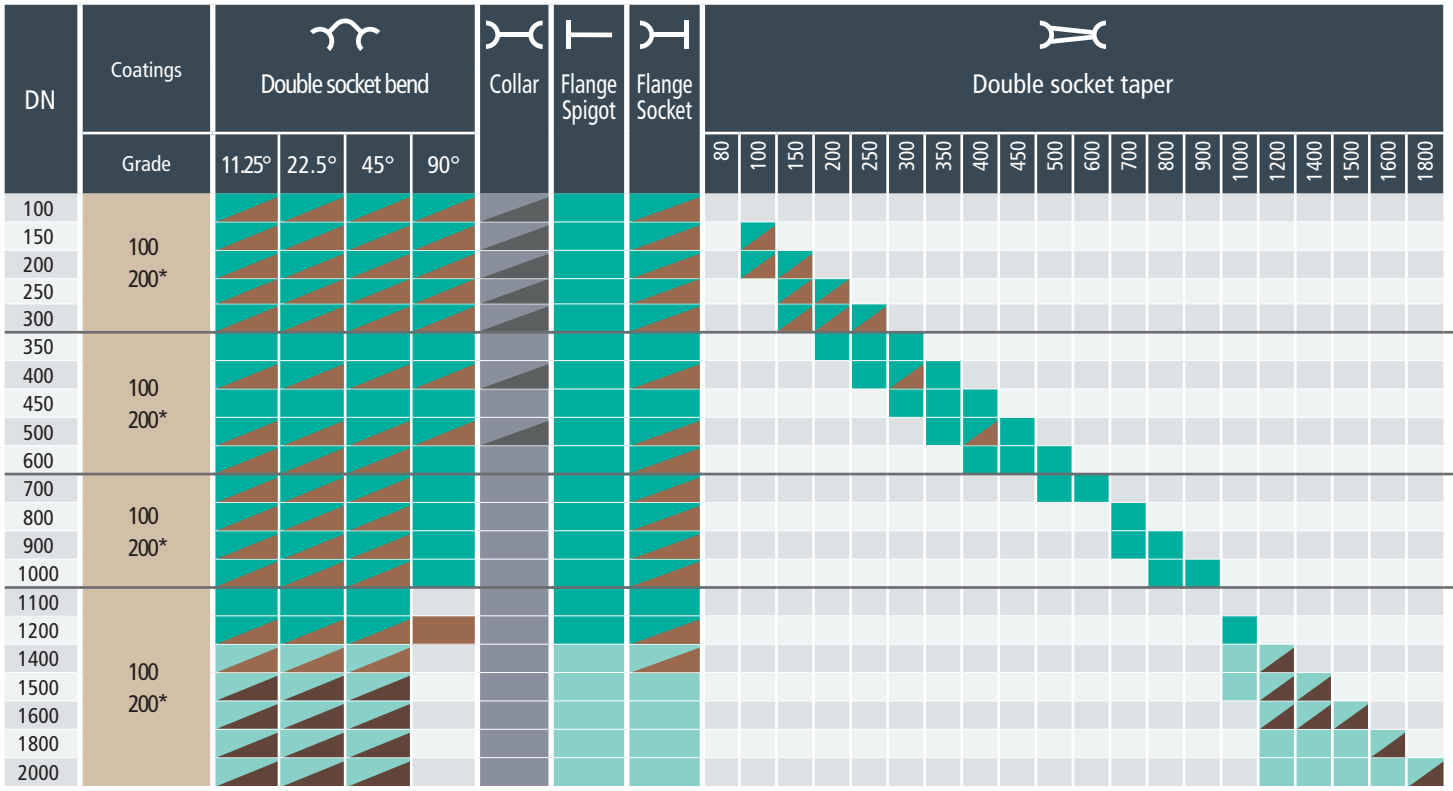
DN 1400-2000

Locking with shrinkage block, ring and weld bead housed in a chamber adjoining the sealing chamber

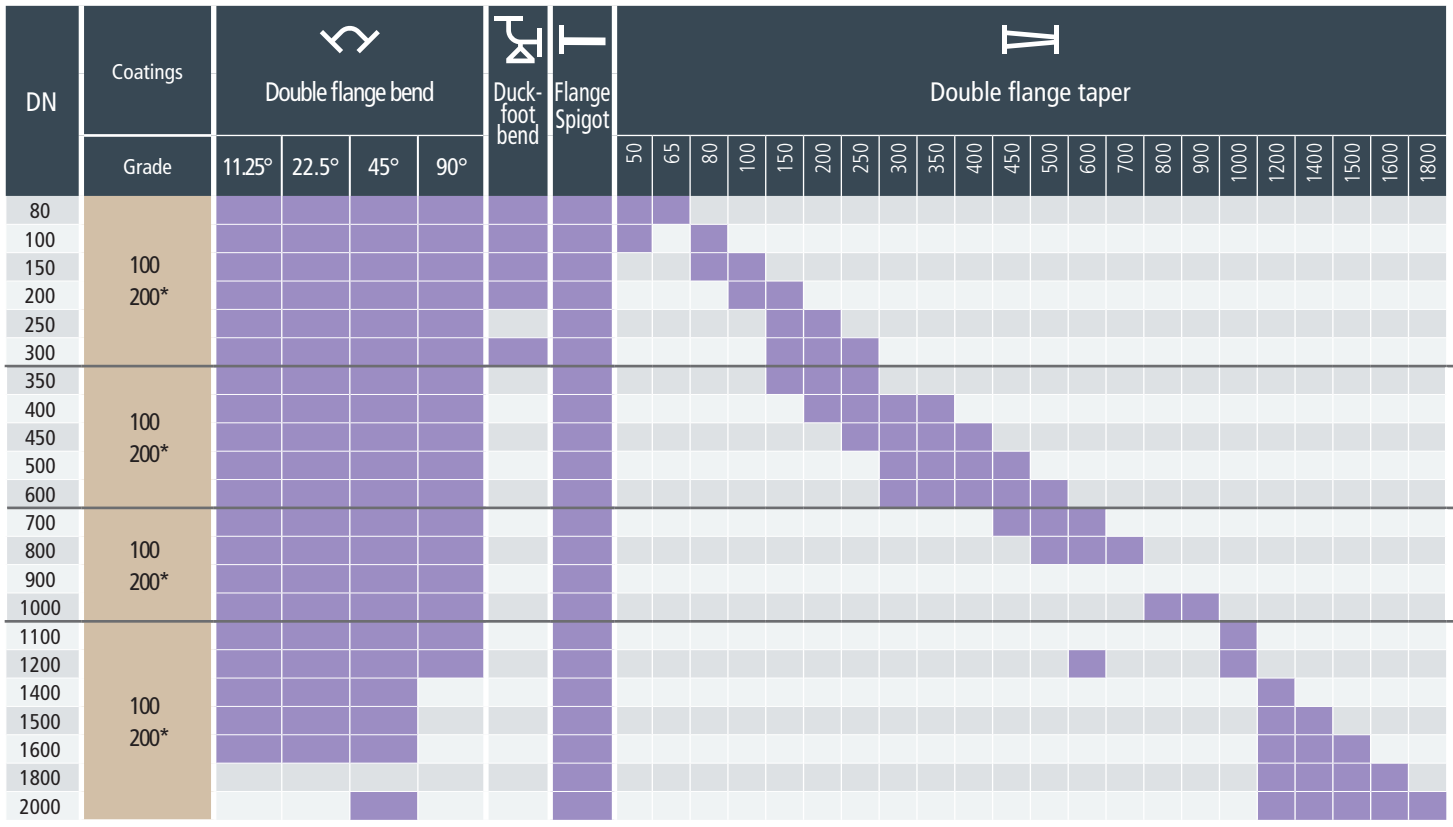
HIGH PRESSURE AND LARGE DN!

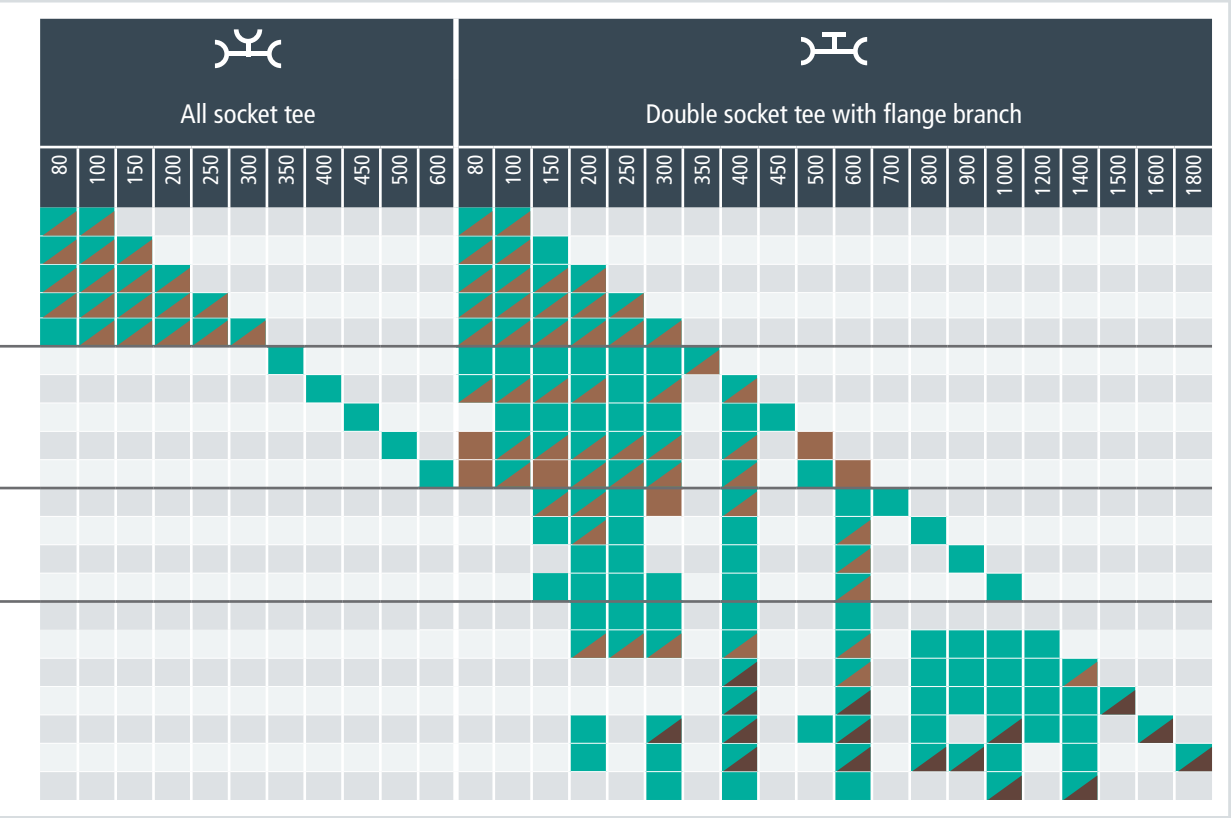
4.2 FITTINGS

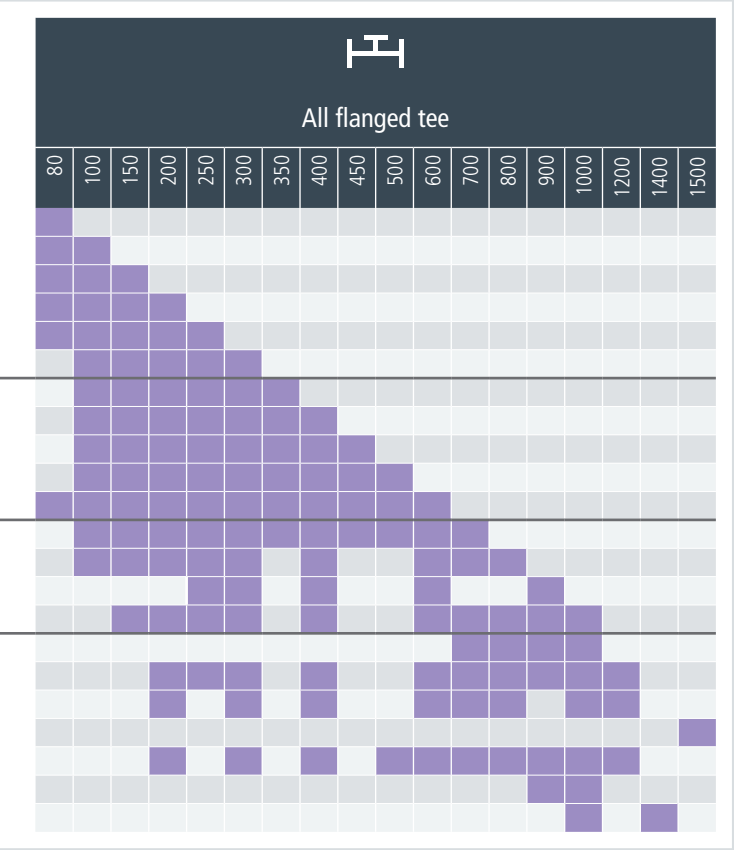
SOCKET FITTINGS



FLANGE FITTINGS







Joints :

- STD joint
- STD ou STD Ve joint
- UNI STD Ve joint
- PK joint
- EXP (Express) joint
- Locked mechanical joint
- Fixed flange gasket

PN available for flanged parts:

- DN ≤ 300 :
  PN 10-16-25-40
- DN 350 to 2000 :
  PN 10-16-25. *For PN 40 flanges, contact us.*

Coatings :

Select grade according to fluid abrasiveness level.
More information in § 3.2.1

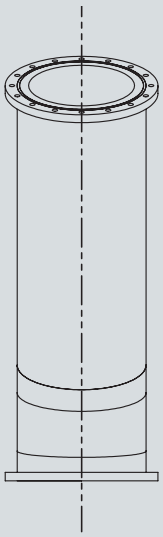
(*) Grade 200, only for certain fluids.
Contact us.

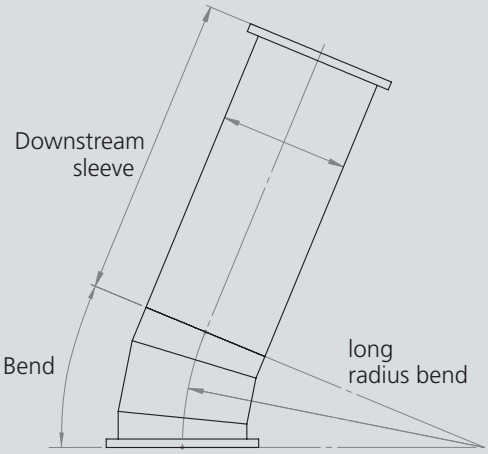
Flanged pipes and flanged anchoring pipes with puddle flange are available on request

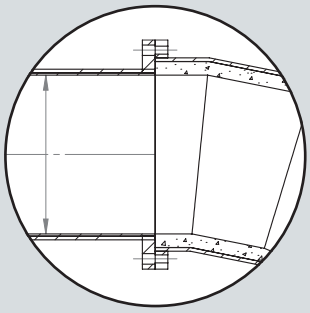
4.2 FITTINGS SPECIAL

Made-to-order fittings, very high erosion resistance

DN	Coatings		PN
	Internal Grade	External	
100 to 1600	200 and 300		10 to 64





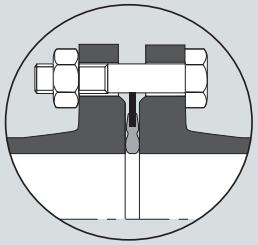


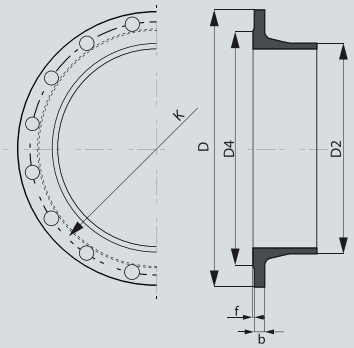
extra thick coating perfectly adjusted

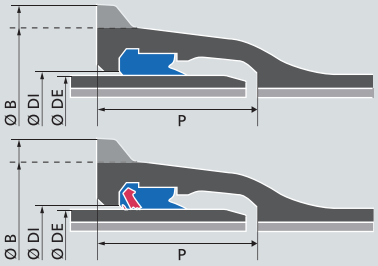
4.3 JOINTS FOR FLANGES

PN 10							PN 16				PN 25			
DN mm	D mm	D2 mm	D4 mm	K mm	b mm	f mm	D4 mm	K mm	b mm	f mm	D4 mm	K mm	b mm	f mm
80	200	98	132	160	16	3	132	160	16	3	132	160	16	3
100	220	118	156	180	16	3	156	180	16	3	156	190	16	3
125	250	144	184	210	16	3	184	210	16	3	184	220	16	3
150	285	170	211	240	16	3	211	240	16	3	211	250	17	3
200	340	222	266	295	17	3	266	295	17	3	274	310	19	3
250	400	274	319	350	19	3	319	355	19	3	330	370	21,5	3
300	455	326	370	400	20,5	4	370	410	20,5	4	389	430	23,5	4
350	505	378	429	460	20,5	4	429	470	22,5	4	448	490	26	4
400	565	429	480	515	20,5	4	480	525	24	4	503	550	28	4
450	615	480	530	565	21,5	4	548	585	26	4	548	600	30,5	4
500	670	532	582	620	22,5	4	609	650	27,5	4	609	660	32,5	4
600	780	635	682	725	25	4	720	770	31	4	720	770	37	4
700	895	738	794	840	27,5	5	794	840	34,5	5				
800	1015	842	901	950	30	5	901	950	38	5				
900	1115	945	1001	1050	32,5	5	1001	1050	41,5	5				
1000	1230	1048	1112	1160	35	5	1112	1170	45	5				
1100	1340	1152	1218	1270	37,5	5	1218	1270	48,5	5				
1200	1455	1255	1328	1380	40	5	1328	1390	52	5	Consult us			
1400	1675	1462	1530	1590	41	5	1530	1590	55	5				
1500	1785	1565	1640	1700	42,5	5	1640	1710	57,5	5				
1600	1915	1668	1750	1820	44	5	1750	1820	60	5				
1800	2115	1875	1950	2020	47	5	Consult us							
2000	2325	2082	2150	2230	50	5								

PN 40: consult us

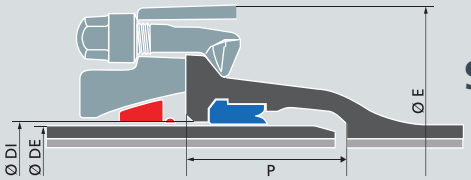






STD

STD Vi

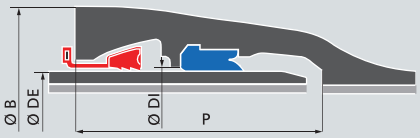


STD Ve

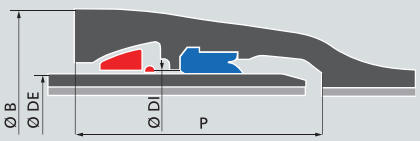
DN mm	Ø DE mm	Ø DI mm	P mm	Ø B mm
100	118	121	94,5	170
150	170	173	100,5	224
200	222	225	106,5	277
250	274	277	105,5	334
300	326	329	107,5	393
350	378	381	110,5	464
400	429	432	112,5	516
450	480	483	115,5	574,2
500	532	535	117,5	629
600	635	638	132,5	738,5
700	738	741	192	863
800	842	845	197	974
900	945	948	200	1082
1000	1048	1051	203	1191
1100	1152	1155	225	1300
1200	1255	1258	235	1412
1400	1462	1465	245	1592
1500	1565	1568	265	1710
1600	1668	1671	265	1816
1800	1875	1878	275	2032
2000	2082	2085	290	2259

* UNI STD Vi joint unavailable for these DNs

DN mm	Ø DE mm	Ø DI mm	P mm	Ø E mm
350	378	381	110,5	570
400	429	432	112,5	618
450	478,6	483	115,5	671
500	532	535	117,5	734
600	635	638	132,5	840
700	738	741	192	958
800	842	845	197	1100
900	945	948	200	1218
1000	1048	1051	203	1306
1100	1152	1155	225	1417
1200	1255	1258	235	1547



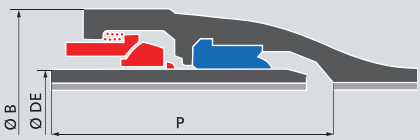
UNI STD Vi



UNI STD Ve

DN mm	Ø DE mm	Ø DI mm	P mm	Ø B mm
400	427,4	431,9	176	510
450	478,6	483,0	190	570
500	530,5	535,0	200	625
600	633,3	638,2	209	740
700	736,6	741,7	250	855
800	840,4	845,8	261	980
900	943,2	948,9	280	1087
1000	1046,0	1052,0	279	1191
1200	1252,3	1260,0	279	1415
1400	1458,9	1468,5	330	1640

** UNI STD Vi joint unavailable for these DNs



PAMLOCK

DN mm	Ø DE mm	Ø DI mm	P mm	Ø B mm
1400	1458,9	1467,9	300	1620,1
1500	1561,7	1571,1	315	1757,3
1600	1664,5	1674,2	325	1868,0
1800	1871,6	1881,5	350	2075,3
2000	2077,7	2088,8	394	2307,0

5

TECHNICAL SPECIFICATIONS

5.1 STANDARDS AND CERTIFICATES

The MINERAL range® components meet the requirements of the following standards with the exception of internal coatings designed for abrasive fluids, which meet PAM's in-house specifications.

Compliance certificates are supplied on request.

Environmental and Quality standards:	EN Standards	ISO Standards
Environmental management systems	EN ISO 14001	ISO 14001
Quality management systems	EN ISO 9001	ISO 9001
Water supply - Requirements for systems and components outside buildings	EN 805	

Product standards:	EN	ISO
Technical specifications of ductile cast iron pipelines	EN 545, EN 598	ISO 2531, ISO 7186
External zinc-based coating	EN 545	ISO 8179
Reinforced epoxy coating of fittings	EN 14901	
Polyurethane coating on fittings	EN 15655	
Polyethylene sleeve	EN 545	ISO 8180
Joint rings. Specification for materials	EN 681.1	ISO 4633
Flange dimensions	EN 1092 - 2	ISO 7005 - 2

Implementation standards:	EN	ISO
Calculation methods for laying buried pipelines	EN 545	ISO 10803
Pressurization test on site	EN 805	ISO 10802

Standards compliance certificates:	Issued by:
Compliance with standard ISO 140001	Veritas
Compliance with standard ISO 9001	Veritas
Compliance with standard 8179	Veritas
Compliance with standard 14901	Veritas
Compliance with standard 681-1	Veritas

Assembly performance certificates:	Issued by:
EN 545 type test on STD joint	Veritas
EN 545 type test on STD Vi joint	Veritas
EN 545 type test on STD Ve joint	Veritas
EN 545 type test on UNI STD Ve joint	Veritas
EN 545 type test on UNI STD Vi joint	Veritas

5.2 PAM DUCTILE CAST IRON

MECHANICAL PROPERTIES

Elastic limit (*), Rp 0.2	300 MPa
Tensile strength, Rm	420 MPa
Ultimate elongation, A	10 % pour DN 60 à 1,000, 7 %pour DN 1,100 à 2,000
Modulus of elasticity	1,7 x 10^5 N/mm^2
Thermal expansion coefficient	1.1 x 10^{-2} mm/m °C
Density	7.05 g/cm^3

(*) 270 MPa when A >= 12 % for DN 40 to 1,000 or A >= 10 % for DN > 1,000

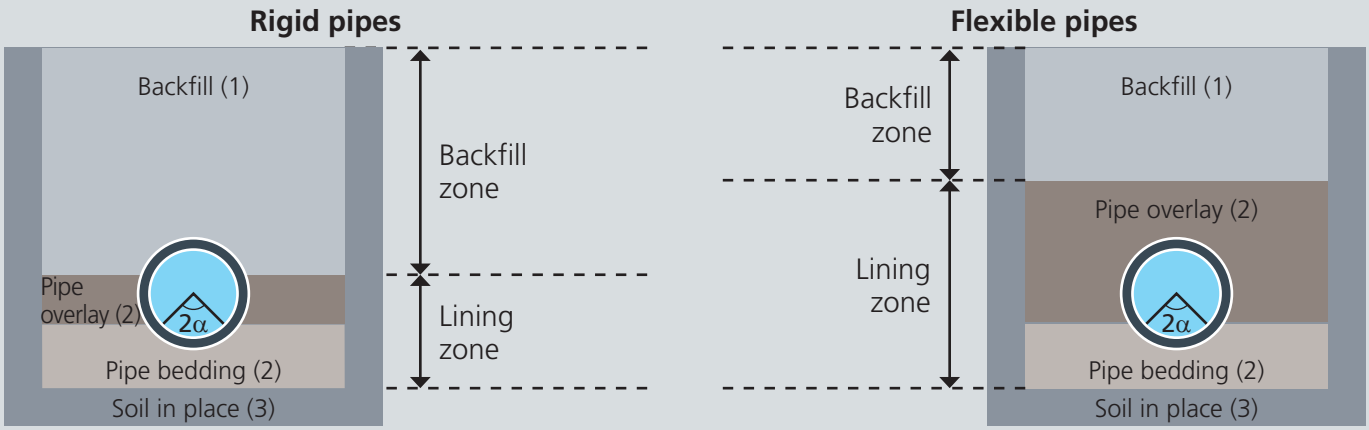
DEPTH OF COVER

Minimum and maximum cover depths depend on the pipe's specifications and trench laying conditions (nature of the soil and backfill).

They have been established using the following assumptions:

- pipe resistance and distortion criteria compliant with standard EN 545 (wall stress and vertical out-of-roundness), without the risk of pipes buckling
- computation model based on standard EN 1295 B.2.5, "structural design of buried pipelines under various condition of loading", without a water table

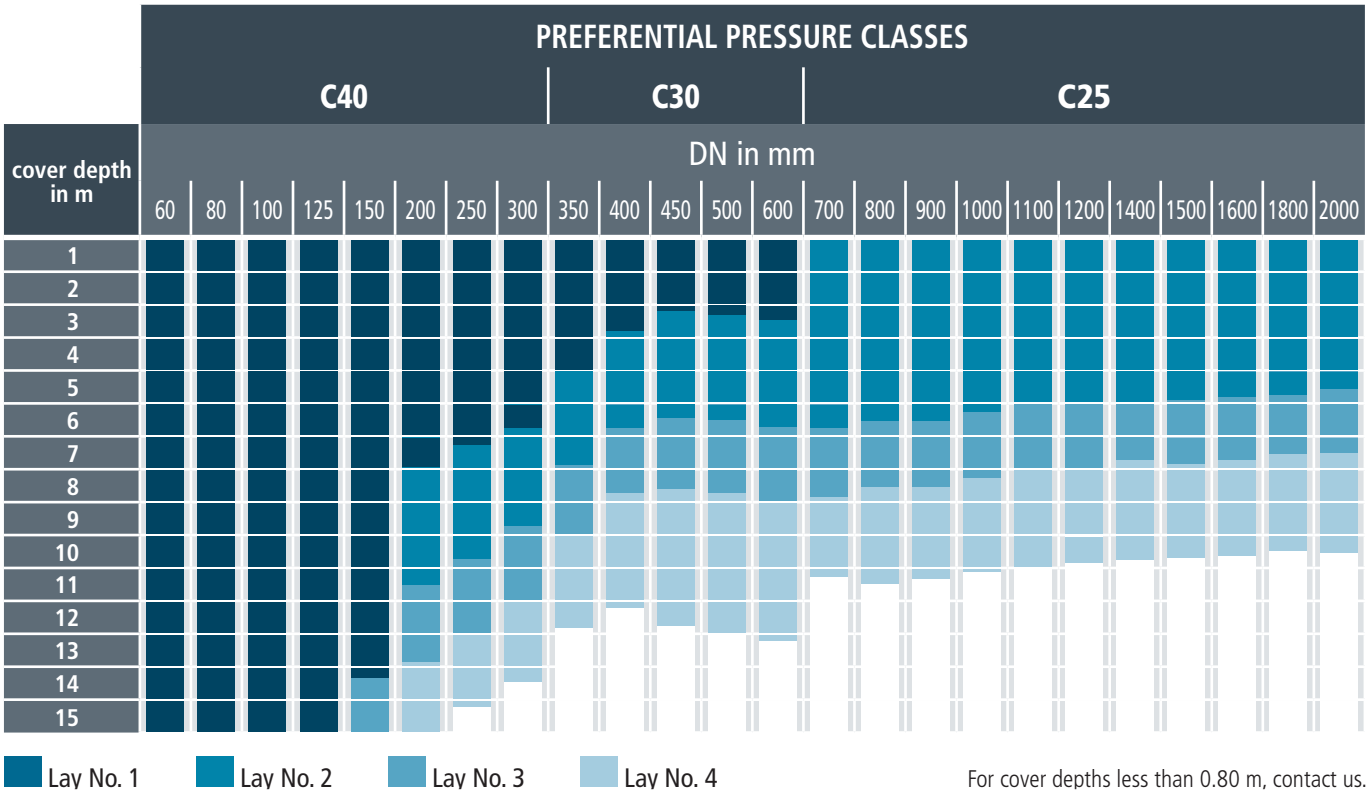
4 types of laying (standard practice) are represented. In all other cases, contact PAM



Soil group	Brief description
1	Clean or slightly silty sand and gravel (particle size under 50 mm)
2	Sand, gravel, silty or moderately clayey
3	flint clay and millstone grit clay. Rubble. Moraine, decomposed rock, coarse alluvium with a high percentage of fines
4	Silt, fine sand, coarse sand, clay, more or less malleable marl (Ip < 50)
5 a (*)	Very malleable clay and marl (Ip > 50). Organic materials, soluble or polluting
5 b (**)	Sedimentary rock: chalk, sandstone, shale, etc. Composite soils (millstone grit and flint clay, rubble, moraine, decomposed rock, coarse alluvium, with particle sizes that can exceed 250 mm. Clean gravel, non-sedimentary rock with particles sizes > 50 mm.

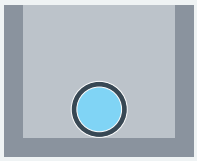
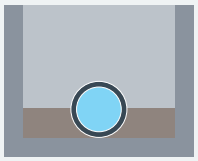
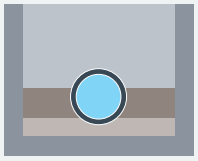
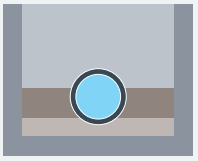
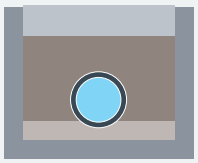
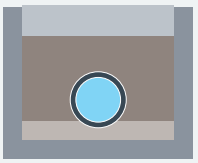
(*) These materials cannot be used in the lining or backfill layers (1).
(**) These materials, unusable in the lining layer, can sometimes be used in the backfill layer (1).

Maximum and minimum cover depths with moving load



For cover depths less than 0.80 m, contact us.

Definition of four laying cases

Laying method	No. 1	No. 2	No. 3	No.4
	DN ≤ 600	DN ≤≥ 600 à 2000	DN ≤≥ 1400	DN ≤ 600
				
			DN > 1400	DN > 600
				
Pipe bedding (2)	Level excavation floor	Level excavation floor	Seating in selected materials	Seating in selected materials
Backfill (2)				
• soil group	4	3	2	1
• compaction	Not compacted	Controlled compaction	Controlled compaction	Controlled compaction
• Es (bar)	3	10	12	20
• 2α (°)	60	90	90	90
Choice of materials	The lining materials used (selected or not) directly in contact with the pipe must be free of rocky or corrosive materials.			

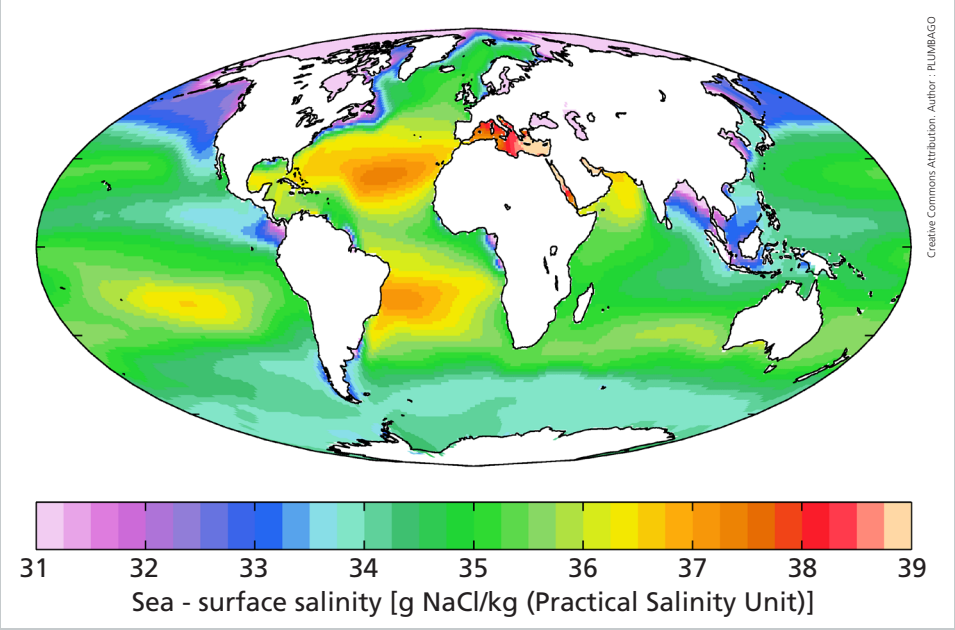
5.3 PAM LININGS

The systems of linings of the MINERAL range are either mortars developed from carefuly choosen cements (sulfato-resistant, modified by a mineral or polymeric component), or organic linings with anti-wear polyurethane. They are selected by the experts of PAM according to the expected performances.

AGGRESSIVENESS OF RAW AND/OR SALTY WATERS

The aggressiveness of a water on the lining depends on one of the following main factors :

Parameter	Influence
Conductivity	The conductivity (µS/cm) of the water varies from pure water to brackish waters and brine. Several families of waters can de defined : demineralized, soft, mid-soft, hard, very hard and salty waters. Conductivity governs the phenomena of metal corrosion, gives information about the compatibility of cement mortar or organic linings. One risk is the extraction of certain minerals or organic compounds, according to the types of linings which will be exposed and the conditions of use of the pipeline
pH	The pH is an important factor. Iron corrodes rapidly at low pH values but is usually protected at high values. The internal linings, minerals and organics, shall be adapted to the pH to provide protection. In some case, the pH can also affect the formation or solubility of protective films. For seawaters, the pH is also dependent on the concentration of dissolved CO_2.
Mineralization	For cement based materials, it is essential to take into account the calcium-carbonate balance of the water. Total Hardness and Total Acidity precizely provides information about the agressivness of the fluid against the lining. Seawaters from surface are generally more agressive than deep water . The role of chlorides, oxygen, sulphates is determinant on the corrosion of metals and alloys and the attack of some cement mortars. Chemical analyses of the waters is necessary to determine both the effects on the durability of the linings in contact with the water, and the change of quality of conveyed water which can appear along the pipeline.
Temperature	The temperature effects are complex and depend on the water chemistry and type of materials present in the pipeline. There are three basic effects of rising temperature on corrosion rates. • First, (generally speaking) increasing the rate of the chemical reactions, • Second, reducing corrosion by precipitation of $CaCO_3$. (protecting film) • third changing the entire nature of corrosion. (eg: causing uniform corrosion or ageing the polymers of organic coating).
Dissolved oxygen	The dissolved oxygen concentration is near the equilibrium saturation concentration with atmospheric oxygen at the surface water at a given temperature (6 ppm in the Tropics, 11 ppm in the Arctic…).
Pollutants	H2S may be high in polluted waters (estuaries, harbors…). Ammonia may be high in inshore waters and harbors.

Parameter	Influence
Salinity	Concerning seawaters, the temperature of surface water in the open ocean varies in the range of -2 to 35 °C depending of the latitude, season, currents and so on. For open sea, the salinity varies between 32 and 36 ‰ (g.l-1) - see next figure for North hemisphere during summer. To complete, some indicatives values of salinity for: • Mediterranean Sea 38-40‰ • Baltic Sea 17‰ • Red Sea 43-45‰ • Dead Sea 270‰. 
Biological	Some biological organisms such as bacteria form bacterial films (slime), weeds grow from pores, and adhesion of animals (e.g. barnacles, tube worms, hydroids…) could play a role in corrosion.

ABRASIVENESS OF CHARGED WATERS AND SLURRIES

An hydraulic slurry is a mixture of water combined with some solid particles. The combination of the type, size, shape and quantity of the particles together with the nature of transporting water determine the exact characteristics and flow properties of the slurry.
Slurries can be broadly divided into the two general groups of non-settling or settling types:

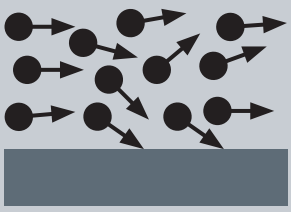
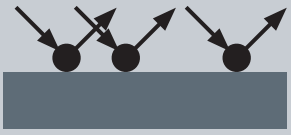
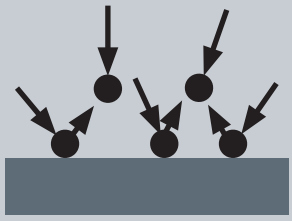
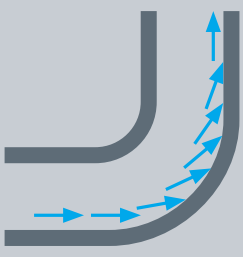
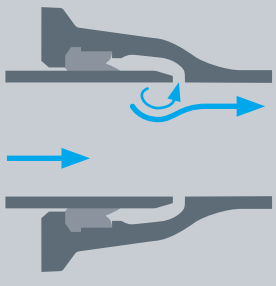
Non-settling slurries	They entail very fine particles which can form stable homogeneous mixtures exhibiting increased apparent viscosity. These slurries usually have low wearing properties but require very careful consideration when selecting the correct pump and drive, because they often do not behave in the manner of a normal liquid (ex: non-newtonien behaviour).
Settling slurries	They are formed by coarser particles and tend to form an unstable mixture and therefore particular attention must be given to flow and power calculations. These coarser particles tend to have higher wearing properties and form the majority of slurry applications. This type of slurry is also referred to as being heterogeneous (or pseudohomogeneous).

5.3 PAM INTERNAL LININGS

Wear can be defined as an « undesirable mechanical or chemical process leading to consumption of material from a surface» and can be a combination of abrasion, erosion and corrosion.

Wear process	Comments
Abrasion	Abrasive wear occurs when hard particles are forced against and move relative to a solid surface. There are 3 major types of abrasion: gouging, high stress and low stress grinding. This does not really concern pipes and fittings.
Erosion	This form of wear involves the loss of surface material by the action of particles entrained in the fluid. Erosion implicates a transfer of kinetics energy to the particles which does not occur in abrasion. 3 basic types of erosion can be defined as detailed below.
Corrosion	The wear of pipelines transporting backfill slurries is often seen to be only an erosion problem. The role played by corrosion is frequently not understood and often ignored. Nonetheless, the corrosion contribution to wear rates has been examined in steel pipes transporting slurries, finding that corrosion constitutes a significant part of the total wear rate. One solution to reduce the corrosion is to treat the slurry for passivation. It is difficult to maintain its efficiency on a long distance and sometimes the combination of erosion and corrosion, working together, makes things complicated. Another solution consists in lining the pipes with coatings having a good resistance to corrosion (and erosion).

THE 3 TYPES OF EROSION

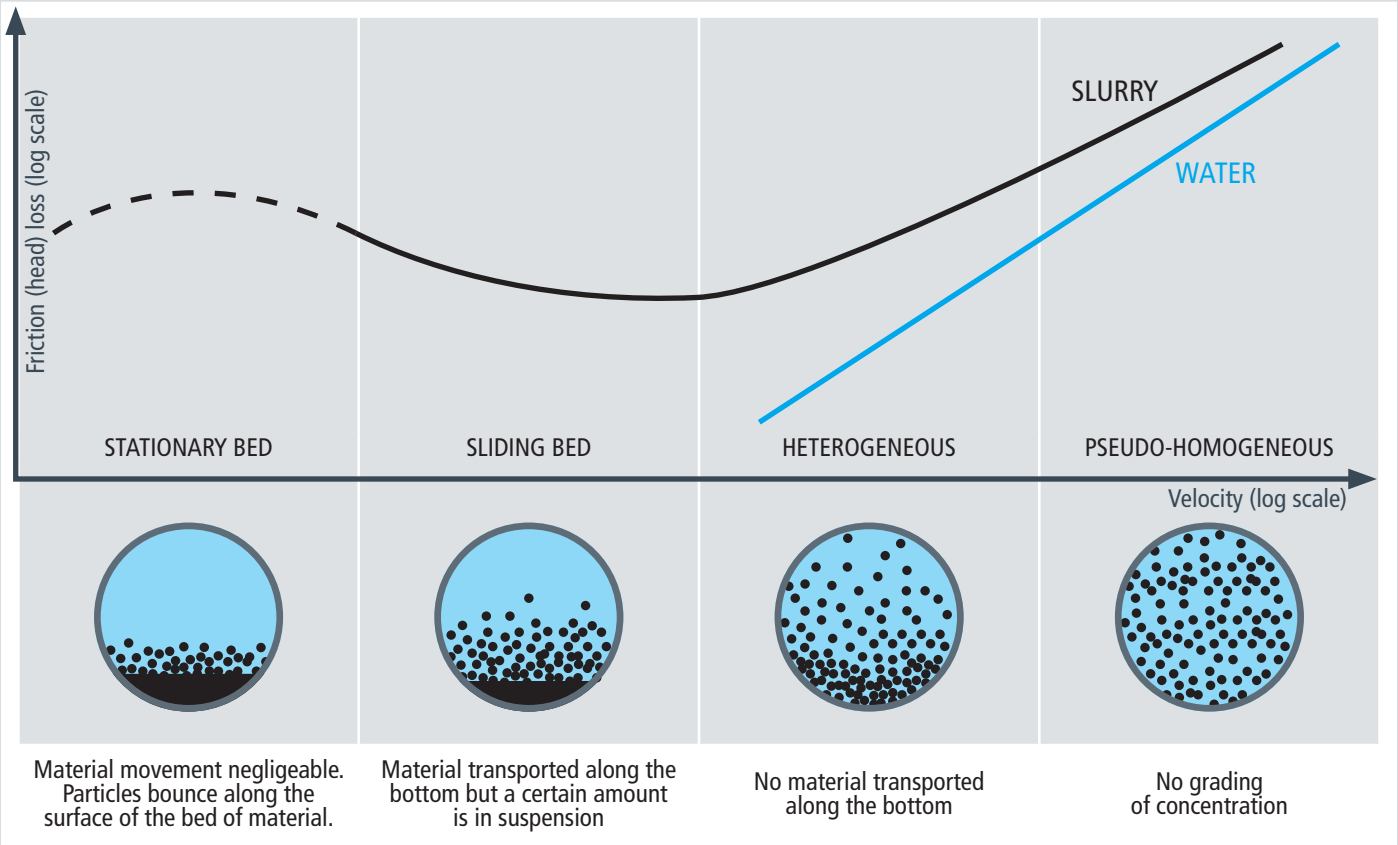
1. sliding bed	2. directional impact	3. random impact
		
		

PRINCIPAL PARAMETERS PLAYING A ROLE IN EROSION

Particles	size, size distribution, profile characteristics, hardness
Liquid	pH-value, density, viscosity, temperature
Flow	velocity, laminar or turbulent, heterogeneous or homogeneous
Pipe	pipe material or pipe lining material, configuration (bends, slopes…), diameter

Miller number is a relative measure of the abrasiveness of a slurry. This figure can give a good approach of combined factors like size and profile of particles, concentration of solids parts…

Suspension or decantation : The smaller are the particles, the lower is the risk of settling. When high percentages of fine-sized solids particle (of less than 100 µm) are mixed with water (concentrate of ore…), they usually form slurries, which do not behave like Newtonian fluids and in which the solids do not settle. There exist various types of non-Newtonian fluids, one is the Bingham fluids which have a behaviour close to a jelly. Suspensions frequently contain both small particles as well as coarse particles. So the dispersion, the concentration and the velocity play a major role in the behaviour of the flow (turbulent, heterogeneous…) and in the wear phenomenon, all along linings or locally such as bends…



HEADLOSS

The processes of centrifugation of mortars lead to regular and smoother surfaces. The headlosses are reduced and the hydraulic performances are guaranteed long-term.

For the transport of waters: the coefficient of roughness Colebrook of an isolated pipe has for value k=0,03 mm. PAM recommends to use the average value k=0,10 mm which takes into account singular points (tees, bends, valves...).

For the transport of slurries: the initial roughness of mortars can evolve because of the abrasion phenomena. However, it affects only the low part of the hydraulic section for linear sections or the sections after bends. For the whole pipe, the evolution of headlosses remains low.

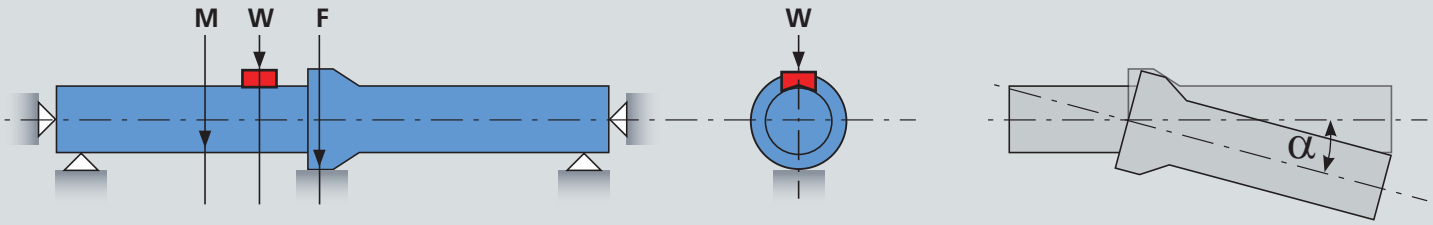
5.4 PAM JOINTS

ANGULAR DEVIATION OF THE PAM JOINTS

DN	Min. required ISO 2531 on non-locked joints	Maximum admissible α on PAM joints						
		not locked		locked				
		STD	TYT	STD Vi	STD Ve	UNI STD Vi	UNI STD Ve	PAMLOCK
100	3,5	5	5	5				
150		5	5	5				
200		5	4	4				
250		5	4	4				
300		5	4	3	4			
350	2,5	4	3	3	3			
400		4	3	2	3	3	3	
450		4	3	2	3	3	3	
500		4	3	2	3	2	2	
600		4	3	2	3	2	2	
700	1,5	4	2		2		2	
800		4			2		2	
900		4			1,5		1,5	
1000		4			1,5		1,2	
1100	1,5	4			1,5			
1200		4			1,5		1,1	
1400		3					1,1	1
1500		3						1
1600		3						1
1800		2,5						0,8
2000		2						0,8

TESTS IN EXTREME CONDITIONS

All PAM joints are qualified in extreme pressure and angular deviation conditions as specified by standard EN545 in a temperature range of 0 to 50° C. Contact us for temperatures outside this range.



Setting up the standard test according to EN 545

Performance	Test pressure	Stresses on joint	Acceptance criteria
pressure tightness (service and overpressure)	Positive internal P	Maximum deviation α Shearing force W Duration 2 hours	1.5 PFA + 5 bar
Negative pressure tightness (accidental negative pressure)	Negative internal P		-0.9 bar (cavitation)
Performance in fatigue (proximity of pumps)	Cyclical internal P		PMA +/- 5 bar 24,000 cycles
Water ingress tightness from the outside (empty pipe)	Positive external P		2 bar (20 m of water)

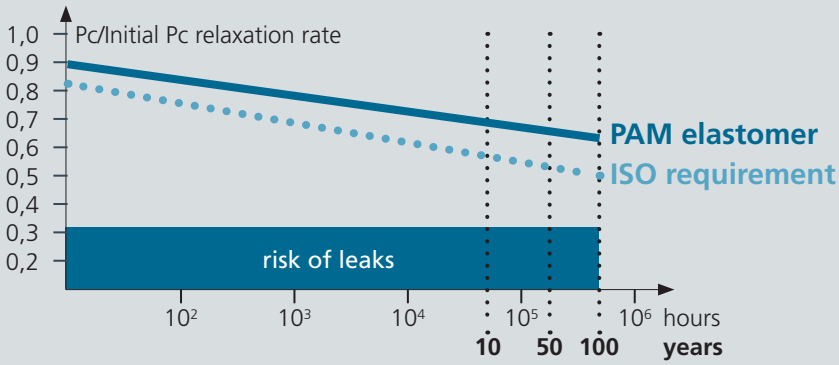
CHOICE OF LOCKING TECHNIQUES

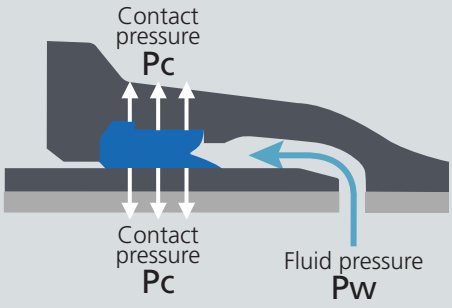
Contact PAM to determine the pipe lengths to be locked (at singular points, on slopes, etc.) and to calculate the number of locked joint pipes required.

Typology	DN range		Pressure range	Locks	Benefits
Connected water networks	100 - 300		16 bar	STD Vi	Last-minute fitting without welding
Mains water pipes	400 - 1000	medium pressure high pressure	10 - 20 bar 20 - 35 bar	STD Vi, UNI STD Vi STD Ve, UNI STD Ve	Mechanical, powerful, with or without bolts
Transportation in large DNs and over long distances	1200 - 2000		16 - 25 bar	UNI STD Ve, PAMLOCK	No specialized machinery, quick to lay, ideal when access is difficult

PERFORMANCE OF PAM ELASTOMER

Behaviour of PAM elastomer over time





The relaxation rate under stress (Pc/initial Pc) indicates the capacity of EPDM elastomer to withstand pressure. The above graph shows that the elastomer ring is capable of fulfilling its sealing function during the entire service life of the pipeline.

ASSEMBLY TIMES

Absolute assembly times for STANDARD joints	With power shovel	With cable and hand winch
DN	minutes per joint	minutes per joint
300	4	7
400	4	8
600	5	10
800	6	14
1000	8	16
1200	12	18
1400	12	20
1600	12	20
1800	12	20

Note: The above values are given as a rough guide for normal laying conditions. They are in no way contractually binding.
It is the installer's responsibility to adjust them on the basis of his precise knowledge of site access of execution conditions

5.5 PAM EXTERNAL COATINGS

ZINC AND ZINALIUM®: USE IN SOIL

Performances in the soils:	Conventional zinc Pure zinc 200g/m² + bituminous varnish	ZINALIUM® ZinAlu alloy 400 g/m² + synthetic paint
Resistivity greater than (see EN 545:2010 D.2.1): - 2500 ohm.cm below water table - 750 ohm.cm outside water table	X	X
Resistivity greater than (see EN 545:2010 D.2.2): 500 ohm.cm below water table		X
Regeneration of the protection on coating damage	X	X

Field of use according to standard EN 545

Basic coating with pure zinc

The ductile cast iron pipes coated with a pure zinc metal layer (minimum 200 g/m²) and a layer of bituminous varnish can be buried in contact with many different types of soil, which may be identified by in-situ soil surveys except for**:

- soil with low resistivity, under 1,500 Ω.cm above the water table or under 2,500 Ω.cm below it;
- mixed soil, i.e. comprising two or more types of soil;
- soil with a pH of less than 6 and a large reserve of acidity;
- soil containing waste, ash or slag, or soil contaminated by certain types of industrial waste or effluents.

Coating with zinc and aluminium alloy

The ductile cast iron pipes with a minimum zinc and aluminium alloy coating of 400 g/m² with a top coat can be buried in contact with most soils, except for**:

- peaty and acid soil;
- soil containing waste, ash or slag, or soil contaminated by certain types of industrial waste or effluents;
- soil situated below the marine water table with a resistivity less than 500 Ω.cm.

(**) In these types of soil identified by in-situ surveys, and in the event of stray currents, we recommended additional protection (such as polyethylene sleeving) or other types of suitable external coatings (see EN 545, D.1, D.2.2 and D.2.3).

ELECTRIC LINES AND CATHODIC PROTECTION

Proximity of electric lines:

"The electrical resistance of each elastomer ring is sufficient to consider that the ductile cast iron pipeline is not an electrically continuous structure. This is because the elastomer ring insulates the pipe and neutralizes the magnetic induction phenomenon. In most cases, when pipelines are coated with metallic zinc and buried, they may be considered as "earthed" over their entire length, which prevents all induction phenomena over great lengths."

Source: Effect of overhead AC power lines paralleling DI pipelines 1996 (R.W. Bonds/DIPRA Research)

Cathodic protection:

Unlike electrically continuous welded metal tubes, cathodic protection is not necessary on ductile cast iron pipelines assembled with elastomer sealing rings and protected with anti-corrosion coatings adapted to the terrain traversed.

5.6 EXAMPLES OF TCO-LCA ASSESSMENT

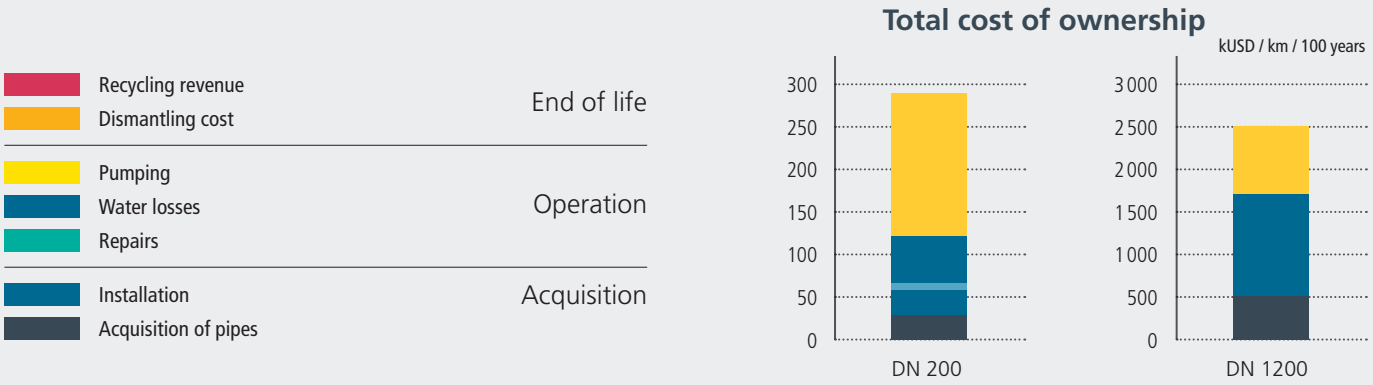
Hypotheses of calculations performed with LCA-TCO PAM calculator:

- For Mineral pipes DN 200 and 1200
- Laid in trenches under standard conditions
- Transported over 13000 km by ship
- Technico-economic data of the year 2014 for Asia/Middle East areas
- Service life 100 years

The values below, based on hypothetical cases and average data, are proposed for information.
They are not contractual in nature.

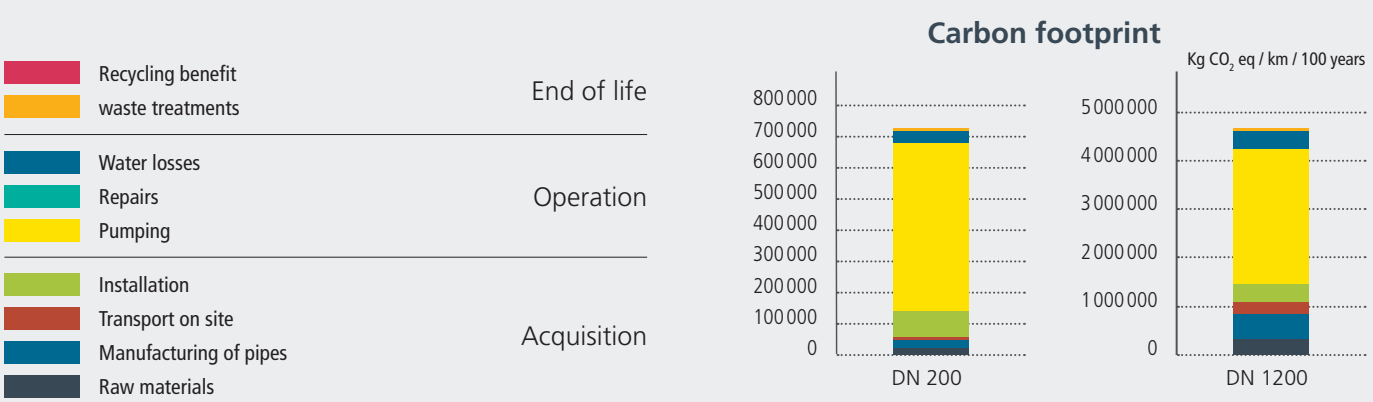
TCO ANALYSIS (TOTAL COST OF OWNERSHIP)

PAM TCO CALCULATOR



LCA ANALYSIS (LIFE CYCLE)

PAM LCA CALCULATOR



Contact PAM to assess your project.

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