

HYDRO PAM

Comprehensive solution
for Hydro Power Stations

Ductile iron pipe
for renewable
energy

PAM commitment
for sustainable
development



Comprehensive pipe systems

PAM
SAINT-GOBAIN

Water, fire, iron and energy

HYDROPAM

Hydraulic energy produced by the force of water flowing downwards inside a pipe is transformed by a turbine connected to a generator into electricity; this can be rapidly transported and does not produce any waste or pollution. Today, hydroelectricity is still the cheapest form of energy in terms of production costs, and ranks high among the renewable energies.

Compared with traditional fossil fuel power plants, a 1MW hydroelectric power station can supply around 630 homes with electricity and prevents the emission of around 2,500 t of CO2 into the atmosphere each year.

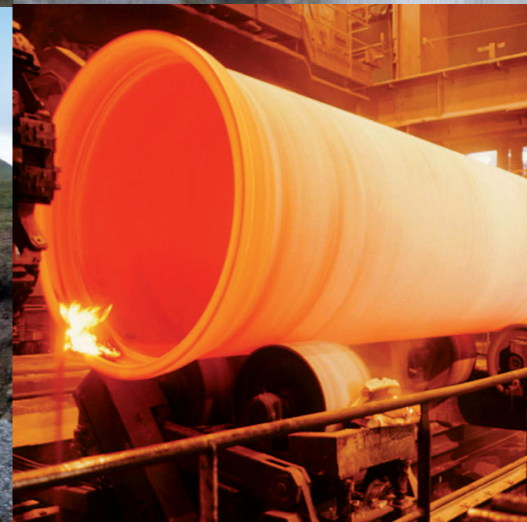
Many European countries are investing in hydraulic technologies to meet the 20% target set by the European Union for 2020.

For decades, SAINT-GOBAIN PAM has been a major player in the development of the hydroelectric sector, supplying ductile iron mains for penstock pipelines.

Starting from an upstream reservoir, HYDROPAM passes water to the turbine installed downstream. Depending on the difference in height and the flow rate, the pipeline can be subjected to high pressures at the lowest point.

The robustness of ductile iron, combined with its exceptional resistance to pressure and abrasion, make HYDROPAM mains the ideal solution, boasting an excellent service record that goes back over a century.

Available in DN 60 to 2000, built to last and 100% recyclable, HYDROPAM mains are laid directly in trenches and have a life cycle that often exceeds a hundred years.

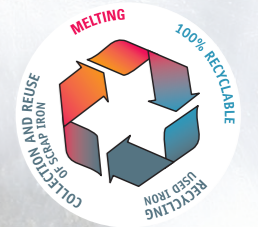


QUALITY ASSURANCE AND ENVIRONMENT

ISO 9001

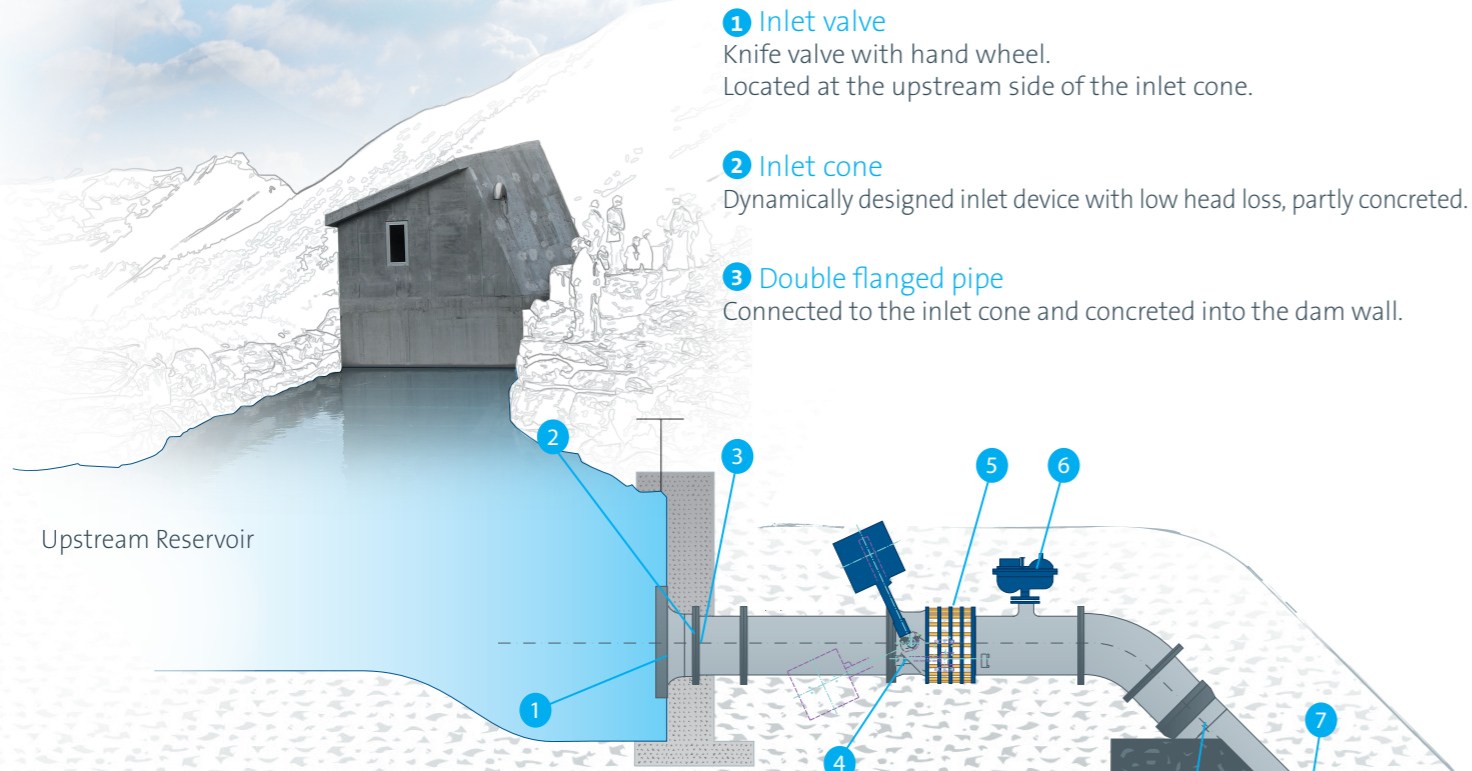
The quality management system introduced by PAM has been certified as complying with EN / ISO 9001 by the independent third party (Bureau Veritas Certification). This involves specific internal rules concerning the design, manufacture and sale of ductile iron products in accordance with high quality standards.

A ductile iron pipe system is a 100% recyclable product.



ISO 14001

The PAM's environmental management system complies with ISO 14001 Standard



- 1 Inlet valve**
Knife valve with hand wheel.
Located at the upstream side of the inlet cone.
- 2 Inlet cone**
Dynamically designed inlet device with low head loss, partly concreted.
- 3 Double flanged pipe**
Connected to the inlet cone and concreted into the dam wall.

HYDROPAM concept

HYDROPAM is a comprehensive concept which provides a full set of solutions dedicated to hydraulic power stations

- pipes, fittings, joints and accessories.
- valves, air valves, needle valves.
- advice and technical support.

- 4 EUROSTOP emergency valve**
A counterweighted butterfly valve installed to prevent damage caused by pipeline failure. This safety device works without any external energy supply and shuts down when the maximum allowable flow rate is exceeded. The flow rate can be detected by a paddle system supplied on request.
- 5 Self-restrained dismantling joint**
Dismantling joint for adjustment, easy installation and dismantling.
- 6 Automatic air valve (triple function VENTEX)**
The air valve ensures safe filling of the pipe and exhausts entrapped air to the atmosphere. The valve prevents negative pressure in the pipeline when the water is drained out. A gate valve upstream of the air valve is an option for servicing the air valve, even if a gate valve is already present in the body.

- 7 Ductile iron pipes**
The pipes are in different pressure classes with or without self anchoring joints, depending on the static pressure and the slope.
- 8 Anchoring device**
Anchor for clamping the pipeline to stable soil.
- 9 Needle valve for draining**
Safety needle valve used for controlled draining or synchronous discharge of pipelines under high pressure without cavitation.
- 10 EUROSTOP butterfly valve**
Keeping the valve closed prevents any static pressure building up on the guide blades of the turbine as well as any leakage.

The properties of ductile iron pipes, fittings and accessories are in conformity with EN 545 Standard.



Main properties of ductile iron

Yield tensile (*), Rp 0.2	300 MPa
Tensile strength, Rm	420 MPa
Elongation after fracture, A	10 % for DN 60 to 1000, 7 % for DN 1100 to 2000
Modulus of elasticity	1,7 x 10 ⁵ N/mm ²
Coefficient Thermal expansion	1,1 x 10 ⁻² mm/m °C
Density	7,05 g/cm ³

(*) 270 MPa when A >= 12 % for DN 40 to 1000 or A >= 10 % for DN > 1000

■ **Stable mechanical properties over time:**

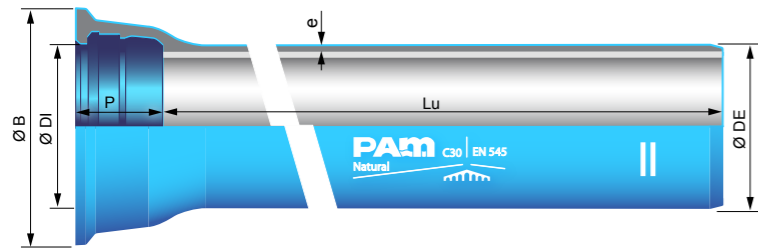
These mechanical characteristics remain constant throughout the service life of the buried pipeline. A high stiffness level makes ductile iron pipe less dependant on the quality of soil embedment. Ductile iron pipes have a high capacity to withstand poor laying conditions.

■ **Impact and point loading:**

Although pipeline laying procedures require avoiding or limiting as much as possible impacts with the pipe, zinc coated ductile iron is well known to be the most resistant and suitable for transport over long distances and for rocky environments. This would explain its extensive use in mountainous areas, limestone areas, etc. Any damage can easily be repaired.



PAM offers a complete range of pipe diameters from DN 60 up to DN 2000 completed by a comprehensive range of fittings and accessories. See the Pam catalogue "Water mains".



The STANDARD joint has been used for many decades all over the world. Assembly is easy, safe and quick. As the assembly operation needs no welding and coating repair, this push-fit joint is greatly appreciated by contractors when environmental conditions are difficult: winter time, presence of water in the trench bottom, no access for digger, limited time for working, etc. Ductile iron pipe joints are fully tested in accordance with the requirements of EN 545 against positive internal and external pressures, negative pressure, and cyclic pressure.

Pipes and fittings with STANDARD joint

DN	Lu m	Angular deflection	PFA bar	PFA bar	PFA bar	PFA bar	PFA bar	PFA bar	PFA bar	PFA bar	PFA bar	PFA bar		
60	6,00	5	c40	64	k9	85	k10	85	k11	100	k12	*	k13	*
80	6,00	5		64		85		85		100		*		*
100	6,00	5		64		85		85		100		*		*
125	6,00	5		64		85		85		100		*		*
150	6,00	5		62		79		85		97		100		100
200	6,00	5		50		62		71		80		90		99
250	6,00	5		43		54		61		70		78		86
300	6,00	5		40		49		56		63		70		78
350	6,00	4	c30	35	k9	45	k10	51	*k11	58	*k12	65	*k13	71
400	6,00	4		32		42		48		55		61		67
450	6,00	4		30		40		45		52		57		63
500	6,00	4		30		38		44		49		55		60
600	6,00	4		30		36		41		46		51		56
700	6,96	4		-	k9	34	k10	38	*k11	43	*k12	48	*k13	53
800	6,95	4				32		36		41		46		50
900	6,95	4				31		35		40		44		48
1 000	6,96	4*				30		34		38		43		47
1 100	8,19	4				29		32		37		41		
1 200	8,19	4				28		32		37		41		
1 400	8,17	3				28		31		35		39		
1 500	8,16	1				27		30						
1 600	8,16	3				27		30						
1 800	8,15	2,5				27		30						
2 000	8,13	2				26		29						

PFA = Allowable operating pressure
please refer to next section «design safety factor» for pressure definitions

*= please consult PAM

Pipes are delivered with the following protections systems:

Coating: a layer of metallic zinc (ZINALIUM for NATURAL pipe range), applied by electric arc spray gun, and covered with a pore sealer layer. High resistance to impact from transport, handling, storage and backfill.

Lining: a layer of cement applied by centrifugal process, (blast furnace cement for potable water or high alumina cement for sewage). The mortar is spun at high speed, giving good lining compaction, then cured to optimum mechanical strength.

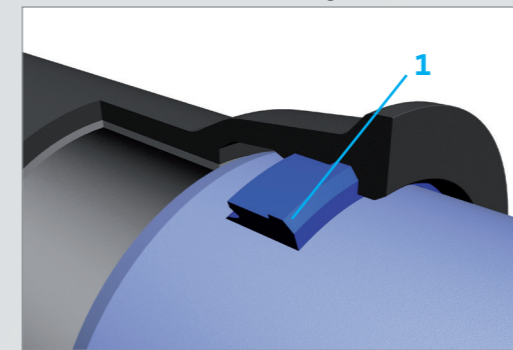
The spinning process has the advantage of producing a smooth internal surface layer consisting of very fine particles, giving:

- Excellent abrasion resistance against raw waters with solid particle content (e.g. sand)
- Excellent resistance against mechanical and chemical cleaning operations
- Very good resistance to longitudinal bending and ovalisation .

Fields of application are in accordance with EN545 annex D and E.

PAM can supply special coating for specific applications: please refer to the PAM catalogue

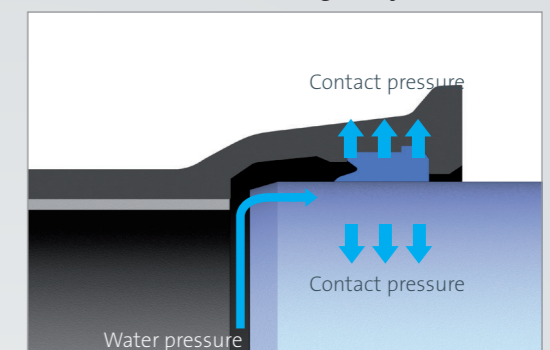
STANDARD joint



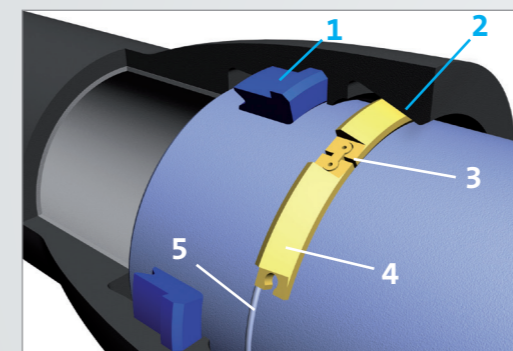
STANDARD joint:

The STANDARD joint is a flexible push-in joint. The seal is provided by radial compression of the EPDM rubber gasket (1). Contact pressure between gasket and metal increases as the water pressure increases.

A self water tightened joint



UNIVERSAL Ve joint



UNIVERSAL Ve joint:

Leak tightness is ensured by an EPDM rubber gasket (STANDARD joint) (1) in one chamber. The anchoring (axial force transmission) takes place through a mechanical arrangement comprising:

- weld bead (5) on the pipe spigot (factory applied), segmented anti-slippage locking rings (3+4), (with a curved external profile)
- second chamber (2) in pipe socket (with spheroidal internal profile)
- self anchoring function is obtained by confining the locking ring between the external chamber of the socket and the weld bead (5) present on the spigot of the pipe

The UNIVERSAL Ve joint combines the advantages of a flexible socket joint and a welded joint:

- self tightening design: the contact pressure between gasket and metal increases as the water pressure increases
- high resistance to traction stress
- fully rotational locking system: the UNIVERSAL Ve joint is designed to accept angular deviation even under axial tension: the curved exterior of the locking ring (3+4) acts like a pivot on the spheroidal internal profile of the second chamber (2). Suitable for ground movements

Ductile iron pipe joints make the laying operations cheaper and easier:

- simple and fast assembly on site (even when difficult trench or bad weather conditions)
- use of standard field equipment on site: crowbar, mechanical winches or digger bucket, according to diameter or accessibility in the trench
- flexible joint, suitable for ground movements
- no coating repair after assembly
- no welding operation, no sophisticated equipment
- avoids installation of concrete anchor blocks (for bends, tapers, tees, blank flanges)

PAM's technical teams are ready to assist the client at any stage of the project, from information on our ductile iron products and their use through to technical assistance at the beginning of pipe laying.

PAM experts can support customers, consultants and contractors for:

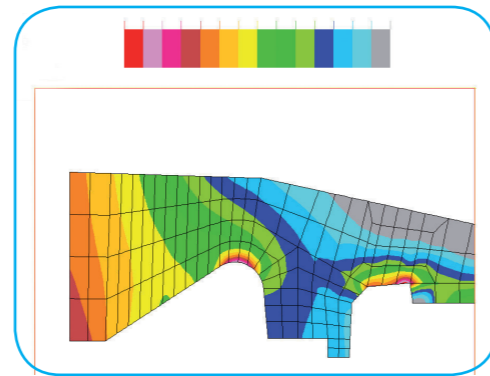
- Soil survey analysis and corrosion protection
- Hydraulic design and buried pipe engineering
- Pipe system designing
- Laying operations
- Logistic arrangements (transportation by ship, truck, storage, etc.)

PAM is also represented by local distributors that can propose equipment and immediate services during pipeline installation (pipe cutting, on-site logistics arrangements, after sales services, etc.)

■ Design Safety Factor

Long term safety of buried pipelines will be achieved if, at the design stage, it is possible to know with a fair degree of confidence:

- the properties of the pipe material and of the pipe itself, as laid down in the standards and guaranteed by the manufacturer;
- the loads which the pipeline will be subjected to, as determined by adequate design methods.



• Resistance against pressure:

Ductile iron Pipes are designed to withstand pressure according EN545 STANDARD annex A:

PFA = calculated with the minimum tensile strength divided by 3 (safety factor 3)

PMA = 1,2 PFA

PEA = PMA+ 5 bar

Where:

- PFA = (Allowable operating pressure) internal pressure, excluding water hammer, that a component can safely and continuously withstand under permanent hydraulic service
- PMA = (Allowable maximum operating pressure) maximum internal pressure, including water hammer, that a component can safely withstand during service
- PEA = (Allowable test pressure) maximum hydrostatic pressure that can be applied onsite to a newly laid component.

• Resistance against earth loads:

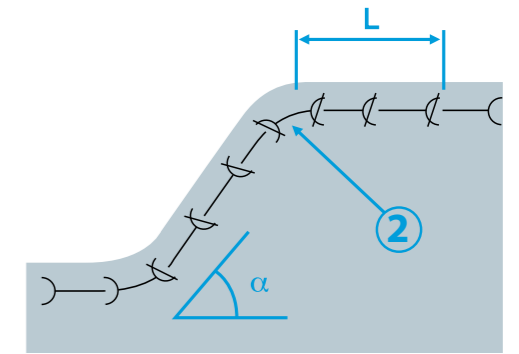
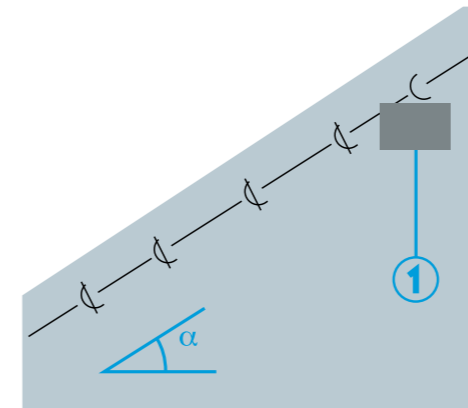
S = Typical stiffness for ductile iron pipes are set out in EN545 standard, Annex C, Table C.1. They clearly explain why the laying conditions are not so critical for ductile iron pipes compared to other materials.

Minimum Stiffness for ductile iron pipe EN545 K9

DN	S
400	72 000 N/m ²
800	30 000 N/m ²
1200	20 000 N/m ²
2000	16 000 N/m ²

■ Steep inclines

Beyond a certain angle, the friction between a pipeline and the ground is insufficient to hold the pipeline in position: a buried main needs to be anchored when the incline exceeds an angle dependent on pipe dimension, soil characteristics and laying conditions. The longitudinal gravitational movement then has to be counteracted by the use of concrete anchor blocks for each pipe, or better, by the use of anchored joints or by a combination of both techniques.



In addition, a section of self-anchored pipes should be anchored either by an anchor block situated behind the socket of the leading pipe ① or by an additional self-anchored length (L) installed in the flat section behind the uppermost bend ②.

The maximal axial force is supported by the first self-anchored joint. This force is a function of the gradient and the length of the anchored section. The maximum permissible length is therefore defined by the strength limit of the self-anchored joint.

The main should be laid downhill starting from the highest point, so that the self-anchoring system is fully engaged and tensioned.

Please contact the technical department of PAM or refer to PAM tools.



■ Hydraulic flow capacity

The equivalent surface roughness, k, of a pipeline depends not only on pipe wall smoothness, but also and more importantly on the number of bends, tees and branches, pipeline profile irregularities, and the development of internal bio film.

Experience has shown that k=0.1 mm is a reasonable value (whatever the internal lining) for distribution mains, and slightly less (0.06 to 0.08 mm) for large mains with a small number of fittings per kilometre.

Any comparison of flow capacity of pipe material based on a different roughness coefficient would be a very theoretical speculation.

The reason is the following; head loss is the sum of 3 effects:

- a) Water friction to itself (linked to the water viscosity = $2.51/Re^{1/2}$)
- b) Water friction on the pipe wall (linked to the roughness = $k / 3.71 D$)
- c) Local changes to flow (bend, joints, etc)

Internal water friction (term a) is the main part of the head loss. Water friction on the pipe wall (term b), depending only on material roughness, is much less (evaluated at 7% max of term a for a cement-lined ductile iron pipe).

The actual internal diameter of the pipe is the most important parameter: for a given flow rate, each 1% less in diameter is 5 % more head loss, and for a given head loss (gravity main) each 1% less in diameter is 2.5 % less in the resultant flow rate

Therefore, special attention has to be paid to the influence of the hydraulic internal diameter of the pipe.

PAM uses software to evaluate the different cases. Please contact PAM.



PAM proposes a selection of documentation and software for the attention of consultants and contractors:

■ Library



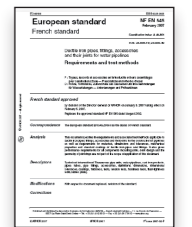
A 450-page "User's Guide" or CD ROM providing clear information and detailed application procedures for PAM products.



A series of teaching and operational instruction sheets to be used on site

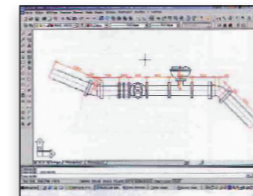


"Self-anchoring solutions for ductile iron pipes": a comprehensive guide to explain the concept of anchor joints and the different existing technologies.



A full experienced, coherent and recognised European Standard System, EN545

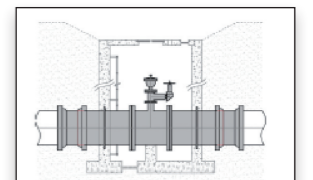
■ Software



PAMCAD: design and dimensioning software to make the work of designers and consultants easier, providing the range of PAM product software for dimensioning of:

- butterfly safety valves
- needle valves
- air valves

PAMKIT: design software to design standardized solution for air release, drainage and shutoff, and to provide logistic benefits. Reference shall also be made to the relevant national regulations and standards when applicable.



PAMTC: assistance using in-house calculations tools dedicated to :

- Pipe laying in steep incline
- Dimensioning concrete blocks
- Dimensioning self-anchored length
- simulating Head losses

■ Reference shall also be made to the relevant national regulations and standards when available.

Comprehensive solution
for Hydro Power Stations

Ductile iron pipe
for renewable
energy

PAM commitment
for sustainable
development



REFERENCES

Every year, over 100 projects are manufactured by SAINT-GOBAIN PAM for hydraulic power stations and delivered in Europe and worldwide.



SAINT-GOBAIN PAM worldwide

ALGERIA

SAINT-GOBAIN PAM ALGERIE

Z.I. Sidi Abdelkader-Ben Boulaid - BP 538
09000 - BLIDA - Algeria
Phone: + 213 (0) 25 36 00 60

ARGENTINA

SAINT-GOBAIN PAM ARGENTINA

Bouchard y Enz
1836 - LAVALLOL - BUENOS AIRES - Argentina
Phone: + 54 11 42 98 9600

AUSTRALIA

SAINT-GOBAIN PAM

15 Edgars Road
THOMASTOWN VIC 3074 - Australia
Phone: + 61 (0) 3 9358 6122

AUSTRIA

SAINT-GOBAIN GUSSROHRVERTRIEB

ÖSTERREICH GmbH

Archenweg, 52
A-6020 - INNSBRUCK - Austria
Phone: + 43 512 341 717-0

BELGIUM

SAINT-GOBAIN PIPE SYSTEMS

Raatshovenstraat, n°2
B-3400 - LANDEN - Belgium
Phone: + 32 11 88 01 20

BRAZIL

SAINT-GOBAIN CANALIZACAO LTDA

Praia de Botafogo 440 7º andar
22250-040 - RIO DE JANEIRO - RJ - Brazil
Phone: + 55 21 2128 1677

CHILE

SAINT-GOBAIN PAM CHILE

Antillanca Norte 600
Parque Industrial Vespucio, Comuna de Pudahuel
SANTIAGO DE CHILE - Chile
Phone: + 562 444 13 00

CHINA

SAINT-GOBAIN PAM CHINA (SHANGAI)

1812 Ocean Tower
550 Yan'An East Road - SHANGAI 200001 - China
Phone: + 86 21 6361 2165

SAINT-GOBAIN PAM CHINA (XUZHOU)

Dong Jiao Yangzhuang
PC 221004 - XUZHOU - Jiangsu Province - China
Phone: + 86 516 8787 8107

SAINT-GOBAIN PAM CHINA (MAANSHAN)

Hua Gong Road Cihu
PC 243052 - MAANSHAN Anhui Province - China
Phone: + 86 555 350 8040

COLOMBIA

SAINT-GOBAIN PAM COLOMBIA

Terminal terrestre de carga de Bogota
Etapa 1, Bodega 9, Modulo 3
Km 3,5 costado sur autopista - Medellin
COTA CUNDINAMARCA - Colombia
Phone: + 57 (1) 841 5832

CZECH REPUBLIC

SAINT-GOBAIN PAM CZ s.r.o.

Pořernická 272/96
108 03 Praha 10 - Czech Republic
Phone: + 296 411 746

FINLAND

SAINT-GOBAIN PIPE SYSTEMS OY

Nuijamiestentie 3A
FIN-00400 - HELSINKI - Finland
Phone: + 358 207 424 600

FRANCE & DOM-TOM

SAINT-GOBAIN PAM (HEAD OFFICE)

91 Avenue de la Libération
54076 NANCY CEDEX - France
Phone: +33 3 83 95 20 00

SAINT-GOBAIN PAM

(France Commercial Department)
CRD - Chemin de Blénod - B.P. 109
54704 PONT A MOUSSON CEDEX - France
Phone: +33 3 83 80 73 00

SAINT-GOBAIN PAM

(Europe and International Commercial Departments)
21 avenue Camille Cavallier
54705 - PONT A MOUSSON CEDEX - France
Phone: + 33 3 83 80 67 89

SAINT-GOBAIN PAM

(Local Agency of The Antilles)
Rue Alfred Lumière - ZI de Jarry - BP 2104
97122 - BAIE MAHAULT - Guadeloupe
Phone: + 33 590 26 71 46

GERMANY

SAINT-GOBAIN PAM DEUTSCHLAND

Saarbrucker Strasse 51
66130 - SAARBRUCKEN - Germany
Phone: + 49 681 87 010

GREECE

SAINT-GOBAIN SOLINOUREGIA

5 Klissouras Str.
GR 14482 - METAMORFOSI - ATHENS - Greece
Phone: + 30 210 28 31 804

HONG KONG

SAINT-GOBAIN PIPELINES

H15/F Hermes Commercial Centre - 4-4A Hillwood Road
TSIM SHA TSUI - KOWLOON - Hong Kong
Phone: + 852 27 35 78 26

INDIA

SAINT-GOBAIN PAM

Grindwell Norton Ltd
5th Level, Leela Business Park - Andheri-Kurla Road
MUMBAI - 400059 - India
Phone: + 91 22 402 12 121

ITALY

SAINT-GOBAIN PAM ITALIA SPA

Via Romagnoli n°6
I-20146 - MILAN - Italy
Phone: + 39 02 42 431

JORDAN

SAINT-GOBAIN PAM REGIONAL OFFICE

Abu Zaid Center - Office # 8
35 Saad Bin Abi Waqqas St, - PO BOX 831000
11183 AMMAN - Jordan
Phone: + 962 6 551 4438

MOROCCO

SAINT-GOBAIN MAROC DEVELOPMENT

2 allée des Figuiers - Ain Sebaâ
CASABLANCA - Morocco
Phone: + 212 522 66 57 31

MEXICO

SAINT-GOBAIN PAM MEXICO

HORACIO 1855-502 - Colonia Los Morales - Polanco
11510 - MEXICO D.F. - Mexico
Phone: + 52 55 5279 1657

NETHERLANDS

SAINT-GOBAIN PIPE SYSTEMS

Markerkant 10-17
1316 - AB ALMERE - Nederland
Phone: + 31 36 53 333 44

NORWAY

SAINT-GOBAIN PAM NORWAY

Brobekkveien 84
N-0614 OSLO - Norway
Phone: + 47 23 17 58 60

PERU

SAINT-GOBAIN PAM PERU

Avenida de los Faisanes N° 157 - Chorillos
LIMA 09 - Peru
Phone: + 511 252 40 34/35

POLAND

SAINT-GOBAIN CONSTRUCTION PRODUCTS POLSKA

SP Z.O.O - PAM Business Unit

Ul. Cybernetyki 21
PL-02-677 WARSZAWA - Poland
Phone: + 48 22 751 41 72

PORTUGAL

SAINT-GOBAIN PAM PORTUGAL

Est. Nac. 10 - Lugar de D. Pedro - Apartado 1708
P-2690-901 - SANTA IRIA DE AZOIA - Portugal
Phone: + 351 218 925 000

ROMANIA

SAINT-GOBAIN CONSTRUCTION PRODUCTS

ROMANIA S.R.L. - PAM Business Unit

Str. Tipografilor nr. 11-15
S-Park/Corp - B3 B4 - Sector 1 - Cod 013714
BUCHAREST - Romania
Phone: + 40 21 207 57 37

SLOVAKIA

SAINT-GOBAIN CONSTRUCTION PRODUCTS

PAM Business Unit

Stara Vajnorska 139
83102 - BRATISLAVA - Slovakia
Phone: + 421 265 45 69 61

SOUTH AFRICA

SAINT-GOBAIN CONSTRUCTION PRODUCTS

PAM Business Unit

N1 Business Park
Corner Olievenhoutbosch Road & Old Johannesburg Road
Samrand - PO BOX 700
GERMISTON - South Africa 1400
Phone: +27 12 657 2800

SPAIN

SAINT-GOBAIN PAM ESPANA SA

Paseo de la Castellana n°77 - Edificio Ederra - Planta 10
E-28046 - MADRID - Spain
Phone: + 34 91 397 20 00

UNITED ARAB EMIRATES

SAINT-GOBAIN PAM

PO BOX 47102 - Building N° 1092 - Villa N° 7
Muroor Road - ABU DHABI - United Arab Emirates
Phone: + 971 2 448 20 10

UNITED KINGDOM

SAINT-GOBAIN PAM UK

Lows Lane - Stanton-by-Dale
ILLKESTON - DERBYSHIRE - DE7 4QU
United Kingdom
Phone: + 44 115 930 5000

VIETNAM

SAINT-GOBAIN PAM

201-203 Cach Mang Thang 8, Ward 4 - District 3
HO CHI MINH CITY - Vietnam
Phone: +84 8 39 30 72 74

www.pamline.com

SAINT-GOBAIN PAM

Head office

91, avenue de la Libération
54076 NANCY CEDEX
FRANCE

Marketing Department – Water & Sewage

21, avenue Camille Cavallier
54705 PONT-A-MOUSSON CEDEX
FRANCE
Phone: +33 (0)3 83 80 73 50