Solef® PVDF for Plumbing – a prime product



Since the time of the old Romans, metals have been used for domestic water supply installations.
In recent decades, however, the metal equipment has been more and more replaced by polymer solutions as these new generation materials have doubtlessly some strong advantages over metal.

Advantages of polymer solutions over metal

- **Corrosion resistance**: Metals are sensitive to oxidizers such as sodium hypochloride which is widely used for sanitation of tap water. In the case of stainless steel, the tap water can provoke sooner or later the formation of rust in the installation. In the case of brass being an alloy of copper and zinc, this sensitivity gives rise to galvanic corrosion within the brass leading to dezincification and the formation of microporous holes in the installation. In the case of multilayer pipes with aluminum the usage of brass fittings can lead to an electric potential between the aluminum and the brass and subsequent galvanic corrosion of the aluminum.
- **No scale deposit**: Tap water - depending on its hardness level - contains a more or less high amount of calcium and magnesium carbonate which can easily precipitate. This precipitate, well known as scale, sticks strongly to metal surfaces. Scale deposit is much lower on polymer surfaces due to their high smoothness and low surface tension.
- **No biofilm adhesion**: Due to the high surface smoothness achievable with polymers, biofilm adhesion is very much suppressed. This leads to less bacteria, even in case of dead zones, and thus to cleaner water.
- **No contamination by heavy metals**: For evident reasons, there is no contamination of the tap water with heavy metals by polymeric installations which is in contrast to the situation for metal installations.
- **Easy assembly**: Assembly of metal installations often comprises hot gas welding at higher temperature. For systems based on multilayer pipes and polymeric fittings a wide variety of fixation systems is on the market for professionals as well as for do-it-yourself purposes. No welding is anymore needed.
- **Low noise**: Polymeric piping systems do transmit less the noise of water. This is important for waste water pipes. For pressure piping systems however, it plays a role in case of connections to older installations with a different diameter.

- **Good thermal insulation**: The thermal conductivity is a factor 100 to a factor 1000 lower for polymers than for metals used in plumbing. These “intrinsic” insulation properties make polymers the material of choice in particular for hot water distribution and heating systems.
- **Lower cost**: The cost of fittings made with corrosion resistant metals (in particular brass) in comparison with polymers fittings is 30 to 50% higher. This cost difference is partly due to the metal prices which have gone through ups and downs for the last years, while prices of polymeric raw material remained over all stable. The second important factor is the manufacturing cost. While metal fittings need several steps to be produced, polymeric fittings are simply injection molded and do normally not need any further machining. This brings important cost saving in the case of polymeric solutions.

Winning Solef PVDF characteristics

Solef PVDF has been successfully used in plumbing for the last decades in various fitting designs, and is used for sliding sleeves. The reasons for this success are many-fold:

- **Excellent mechanical properties**: Solef PVDF has a high stress at yield and keeps a good modulus level even at high temperature, so that it can be used for cold and hot water supply.

Property	Unit	Method	Solef PVDF standard grade
Flexural Modulus, 23°C	MPa	D790	2000 – 2400
Tensile stress at yield, 23°C	MPa	ASTM D638	53 – 57
Tensile stress at break, 23°C	MPa	ASTM D638	35 – 50
Elongation at yield, 23°C	%	ASTM D638	5 – 10
Elongation at break, 23°C	%	ASTM D638	20 – 50
Notched IZOD, 23°C	J/m	ASTM D256	110
Deflection temp, 1,82 & 0,46 MPa	°C	ASTMD648	113 & 147
Shore D Hardness (2 mm thickness)	-	ASTM D2240	78

A carbon-fiber reinforced Solef PVDF grade for extreme mechanical requirements is available upon request.

- **Excellent chemical resistance**: Solef PVDF has excellent chemical resistance to a wide range of chemicals, a property for which it has been used in the Chemical Process Industry for several decades.

Of course, Solef PVDF is resistant to NaOCl used in tap water. It is also resistant to most organic and inorganic acids, aliphatic and aromatic hydrocarbons, alcohols and halogenated solvents. Finally, it is resistant against inorganic bases and other materials in the way they are used in construction.

The following table gives an estimation of the chemical resistance of PVDF with emphasis on building and construction materials with italic entries referring to the resistance of Solef PVDF to the underlying chemical.

Chemical	Temperature	Usual Contact period	Chemical resistance
Chlorinated water 5 ppm Chlorine (NaClO)	95°C	Decades	Good
NaClO in water (pH 8) *up to 15% (= 150 g/kg)*	*50°C*	*Years*	*Acceptable*
Cement (Ca-Silicates + H2O)	25°C	Humid – Days Dry – Years	Acceptable Good
Concrete (cement + sand)	25°C	Humid – Days Dry – Years	Acceptable Good
gypsum ($CaSO_4$ + H2O)	25°C	Humid – Hours Dry – Years	Good Good
Lime mortar (CaO + H2O)	25°C	Humid – Days Dry – Years	Poor Good

Chemical	Temperature	Usual Contact period	Chemical resistance
Strong acids (40% HCl, 80% H2SO4, 50% HNO3)	*100°C*	*Years*	*Good*
Mild caustic environment (pH < 12) (dilute NaOH, KOH, Ca(OH)2)	*25°C*	*Years*	*Good*
Strong caustic environment (pH > 12) (NaOH, KOH, Ca(OH)2)	*25°C*	*Days*	*Poor*
Epoxy glue (epichlorohydrin+bisphenol-A + cat.)	25°C	Humid – Days Dry – Years	Acceptable Good
Epichlorohydrin	*25°C*	*Days*	*Acceptable*
Phenol (100%)	*50°C*	*Years*	*Good*
Acrylic paints (polymeric matrix + pigments + solvent)	25°C	Humid – Days Dry – Years	Good Good
Oil paints (pigments + linseed oil)	25°C	Humid – Days Dry – Years	Good Good
Diesel fuel (100%)	*75°C*	*Years*	*Good*
Acetone (5%)	*25°C*	*Days*	*Good*
Methanol (100%)	*25°C*	*Years*	*Good*
Pyridine (100%)	*25°C*	*Days*	*Good*
Chloroform (100%)	*25°C*	*Years*	*Good*
Linseed oil (100%)	*100°C*	*Years*	*Good*
Cleaning agent (ethanol)	50°C	Days	Good
Toilet cleaning agent (formic acid)	50°C	Days	Good
Dish liquid (anionic soaps, vinegar)	50°C	Days	Good
Formic acid (100%)	*100°C*	*Years*	*Good*
Acetic acid (50%)	*25°C*	*Years*	*Good*
Ethanol (50%)	*50°C*	*Years*	*Good*

Chemical	Temperature	Usual Contact period	Chemical resistance
Wallpaper paste (gelatin + water)	25°C	Humid – Days Dry – Years	Good Good
Bitumenbahnen (asphaltene)	25°C	Years	Good
Naphta *(100%)*	*50°C*	*Years*	*Good*
Mineral oil *(100%)*	*100°C*	*Years*	*Good*
Thread cutting liquid (mineral oil bases)	25°C	Hours	Good
Thread joins (PTFE bases)	25°C	Years	Good
Silicone resins (oligosiloxanes $Me_nSi(OH)_mO_y$ + acid)	25°C	Humid – Days Dry – Years	Good Good
Crosslinked Polyurethane foam (urea, formaldehyde, ammonia)	25°C	Humid – Days Dry – Years	Acceptable Good
Urea *(saturated solution in H_2O)*	*25°C*	*Years*	*Good*
Ammonia *(dry gas, 100%)*	*50°C*	*Years*	*Good*
Formaldehyde *(37%)*	*100°C*	*Years*	*Good*

In addition to its good chemical resistance, PVDF has very good barrier properties against migrants like O2, H2O or hydrocarbons. For heating installations, a good barrier against O2 is needed in order to avoid corrosion of boiler components.

- **Excellent UV resistance**: PVDF is resistant to UV light down to a wavelength of 232 nm. This means that it is resistant to UV-A (wavelength of 320 to 400 nm) as well as to UV-B (wavelength of 280 – 320 nm). UV light with wavelength below 280 nm (UV-C) is filtered by the atmospheric ozone layer and does normally not come to the earth.

  This excellent UV resistance of Solef PVDF is widely used for architectural coatings and protective films. It has also been proven by several tests:

  - *Artificial aging, using Weather-O-Meter equipment*: Solef PVDF 1008 films at 60 °C, irradiated with a carbon arc lamp with a maximum emission of around 390 nm, and whose spectrum is rich in wavelengths between 330 and 430 nm. After 7200 hours of exposure (which is a long enough period to affect most plastics), no measurable modification was identified with regard to the mechanical properties of the films (tensile and impact strength), the degree of polymerization or the chemical nature of Solef PVDF.

- *Accelerated tests, using Q-U-V equipment*: Solef PVDF 1008 was tested during 5000 hours of cycles composed of 4 hours of exposure to UV at 60 °C followed by 4 hours of condensation at 40 °C on 2 mm thick sheets, tensile modulus of 2600 MPa unchanged.
- *Accelerated natural aging test, according to the EMMAQUA method (ASTM D 838 standard) on 80 µm thick films made of Solef PVDF 1008*: no alteration after 1 year.
- *Natural aging in Arizona and Florida on 80 µm films made of Solef PVDF 1008*: no property alteration was found after several years, as shown by the results of tests performed on films aged for as long as 9 years.
- *Detailed test results are available upon request.*

- **High purity**: Solef PVDF is odorless and does not leach any flavor. It fulfills the requirements of NSF 61 tracing leachable organic substance. But Solef PVDF is even cleaner than that.
  For more than one decade, virgin Solef PVDF has been the material of choice for ultrapure water piping systems in the highly demanding Semiconductor Industry. Leachates of virgin Solef PVDF in ultrapure water are very poor in metallic cations as well as in anions. In the following, some typical values of leachates following the Semiconductor Industry standards (soak time 7d at 85°C in ultrapure water, detailed procedure available upon request) are presented:

Static value at 85±5°C for 7 days measured on tubes (µg/m2) – requirements of SEMI F57 standard					
Al	≤10	Li	≤2	Br	≤100
Ba	≤15	Mg	≤5	Cl	≤3000
B	≤10	Mn	≤5	F	≤60000
Ca	≤30	Ni	≤1	NO3	≤100
Cr	≤1	K	≤15	NO2	≤100
Cu	≤15	Na	≤15	PO4	≤300
Fe	≤5	Sr	≤0,5	SO4	≤300
Pb	≤1	Zn	≤10	TOC	≤60000

In order to keep a high purity piping system clean on a long term, the surface properties of the chosen polymer must fulfill quite stringent requirements. Due to its low surface tension, the biofilm adhesion on PVDF surfaces is very low and biofilm removal by chemical means, if needed, rather quick. Data can be provided upon request.

- **Easy processing**: Solef PVDF can easily be processed on a polyolefin type equipment, no pre-drying needed.

Melt temperature	200 – 240°C
Feed zone temperature	190°C
Compression zone temperature	200 – 220°C
metering zone temperature	200 – 240°C
nozzle zone temperature	200 – 240°C
Mold temperature	60 – 90°C
Screw speed	3 – 10 m/min
Back pressure	5 – 20 bar
Injection pressure	600 – 1500 bar
Hold-on pressure	600 – 1500 bar
Shrinkage (linear)	2-3%

Our experts in Computer Aided Engineering are at your disposal for any question concerning the optimum mold design and filling parameters.

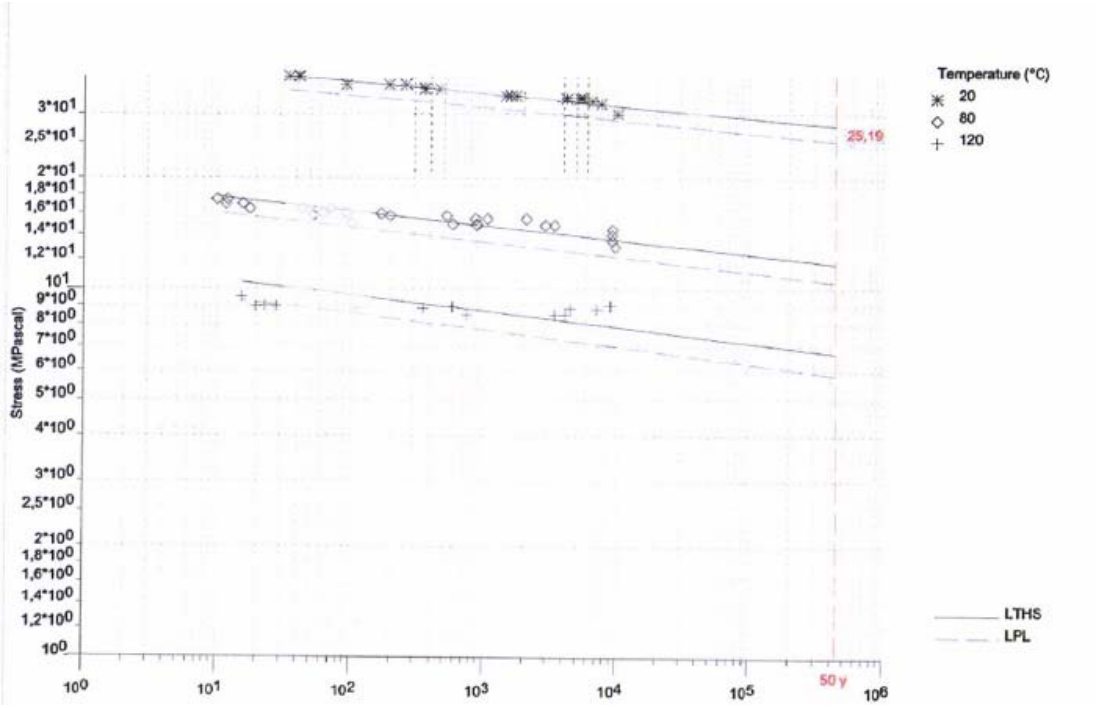
- **A multitude of national and international approvals**: Solef PVDF has undergone a multitude of tests and approvals concerning its suitability for contact with tap water and food stuffs. The most relevant ones are summarized below.

Norm/Test	Description	Measurements
Test following WRAS/BS 6920	British Water Regulations Advisory Scheme	Leaching/migration of contaminants from the material and support to microbiological growth
KTW	German “Kunststoffe und Trinkwasser“ regulation	Negative effects of the plastic on taste, odor and color of the tab water (and includes a mild test of the ability of plastics to support microbiological growth)
DVGW	German Arbeitsblatt W 270	Protocol specific for bacterial growth that does not cover the other effects studied with the KTW approach.
NSF 61	American, internationally recognized	Leaching / migration / microbiological growth.

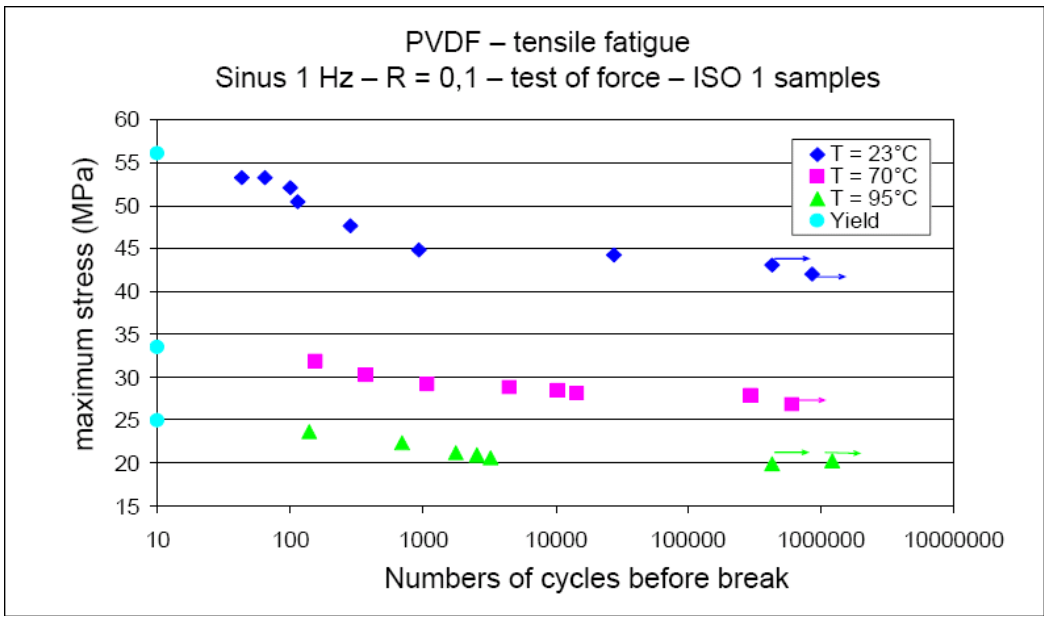
A complete overview on approvals is available upon request.

- **<u>Security through long term tests</u>**: A multitude of long term tests has been carried out for Solef PVDF during the last decades

  - *<u>Long term Pressure tests</u>*: Long term pressure tests performed on DECHEMA equipment have been gathered for Solef PVDF for up to 20 years (!) of tested lifetime. Long term pressure test performed on IPT equipment including an extrapolation to 50 years of lifetime following ISO 9080 are also available.



  - *<u>Fatigue tests</u>*: Solef PVDF has an excellent fatigue resistance.



- *Sterilization tests with industrial steam:*

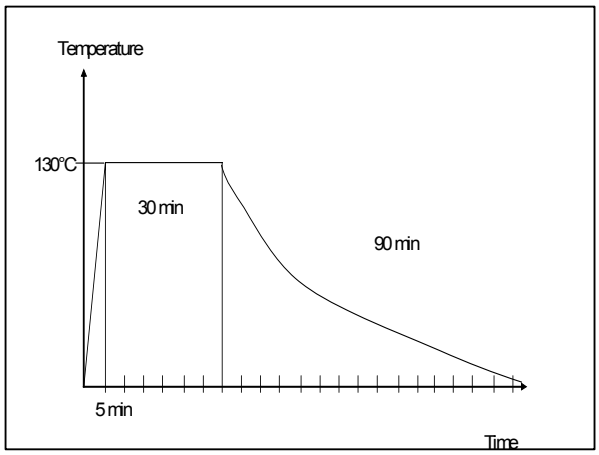
  3 bar and 127°C ± 5°C,

  100 cycles (see scheme)

  32 mm PVDF tubes and fittings

  Results:

  - no dimensional changes
  - no differences in DSC
    (observed properties: crystallinity, fusion temperature, fusion enthalpy)
  - no differences in mechanical properties
    (observed properties : yield stress, deformation at yield, stress at break, deformation at break)



How to contact Solvay Plumbing Group

- Email : brigitte.neubauer@solvay.com or your local Solvay Solexis representative
- Internet: www.solvaysolexis.com
- Phone: + 32 475 55 03 68 (B. Neubauer, Solvay Plumbing Team) or your local Solvay Solexis representative