Pf Technologies

# GLASS LININGS

PURITY STABILITY DURABILITY


Pfaudler

Defining the standard

# Pfaudler Glass Linings

## Maximum durability for the highest standards

**Pfaudler Glass Linings – Chemical and Physical Perfection**

Since establishing itself as a pioneer in the field of technical glass linings, Pfaudler has never relinquished its position in the forefront of technological development, continually setting new standards for glass lined apparatus. Also, our manufacturing plants are designed to allow us to meet specific customer requirements with specific solutions – for special demands call for creative answers. For example, **Pfaudler Pharma Glass PPG** plays a trailblazing role in the production of pharmaceutical products, whereas **Pfaudler Anti Static Glass ASG** solves the problems associated with electrostatic charging. Our standard product **Pfaudler World Wide Glass WWG** is characterised by the wide range of areas in which it can be used.

**Pfaudler Glass Linings – Reliability and Innovation**

We aim to achieve this by always staying one step ahead. What nature has produced in its wild, untamed and apparently arbitrary fashion serves as our starting point – to be investigated, refined and brought to a state of manufacturing perfection. Today, Pfaudler is the number one address when it comes to glass lined processing plants, apparatus, equipment and accessories. Where resistance to corrosion and abrasion is important, the name Pfaudler is a guarantee for reliability. Being able to depend on the product represents hard and fast economic security for our customers. We achieve these standards with a mixture of creative innovation, engineering skills and a profound knowledge of steel, glass and how to work them. This in turn is based on our understanding of the laws of physics and chemistry, which form the basic ingredients of our focused research and development efforts.

**Pfaudler Glass Linings – Highest Quality**

Pfaudler glass linings represent purity and durability. Focused research means optimisation and adaptation. In many production processes the main demand is for absolute durability, for instance where very aggressive substances are involved. To meet this demand Pfaudler has developed **Pharma Glass PPG** especially for use in pharmaceutical process engineering. The composite material steel/glass is characterised by an extremely high degree of purity. The lining quality is checked layer for layer so that even the smallest defects can be excluded. This is Pfaudler's guarantee for absolute purity and highest standards of quality. Diamonds have also been a byword for purity and durability. Nature's way of creating diamonds can be compared with the manufacturing process for making glass: millions of years ago volcanic activity brought masses of molten lava to the earth's surface. The combination of pressure and temperatures of around 4,000 °C cause carbon to crystallise into diamonds. The smelting process in the production of enamel takes place at 1,390 °C and produces a substance similar to molten lava.


GLASSTEEL
ANTI CORROSION STICK STATIC
Lorem ipsum dolor sit amet, consectetur adipiscing elit. Vivamus eu fermentum justo. Maecenas porta ultrices nisl non vehicula. Morbi ultrices nisl vel nunc aliquam eu posuere urna placerat.
ION SENSITIVE
pH VALUE 2.0
<1
1
2
3
4
5
6
7
8
9
10
11+
H3C
CH3
CH3
CH3
COOH
CH3
REACTION
ENGINEERING

# Pfaudler Glass Linings

## There is much to be said for using Glass Lining Technology

There are many reasons for choosing glass lined steel. The most important ones are: protection, safety and not least increased productivity.

**Pfaudler Glass Linings – to protect your equipment**

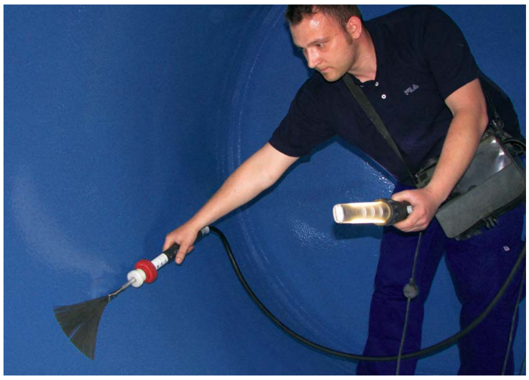
Industrial glass linings serve mainly to provide protection against corrosion. Our glass linings can be used to protect against all kinds of corrosive media, even under extremes of temperature. The only exceptions to this are to be found in the high temperature range in respect of hydrofluoric acid and strong caustic solutions. The linings are resistant to strong oxidising or reducing agents. This high degree of stability makes them ideal for implementation in hydrolytic, chlorination, sulphonation, nitration and bromation processes.

Other uses can be found in the manufacture of pesticides and herbicides, acidic ore leaching processes, flue gas desulphurisation and the recycling of chromic and sulphuric acids.
In contrast to metallic materials, glass linings are electrical insulators and therefore immune to all types of galvanic corrosion. Therefore they can be used in nuclear technology, for instance, where organic insulators cannot meet the exacting demands. Glass lining, on the other hand, can still provide the necessary protection where metals are liable to various types of corrosion such as intercrystalline, crevice, pitting and contact corrosion. With appropriately designed tanks the material can even withstand temperatures as low as -75 °C.

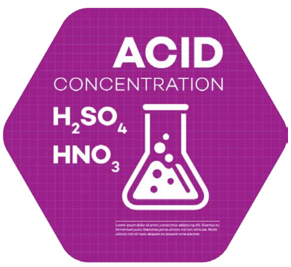
**Pfaudler Glass Linings – to protect your products**

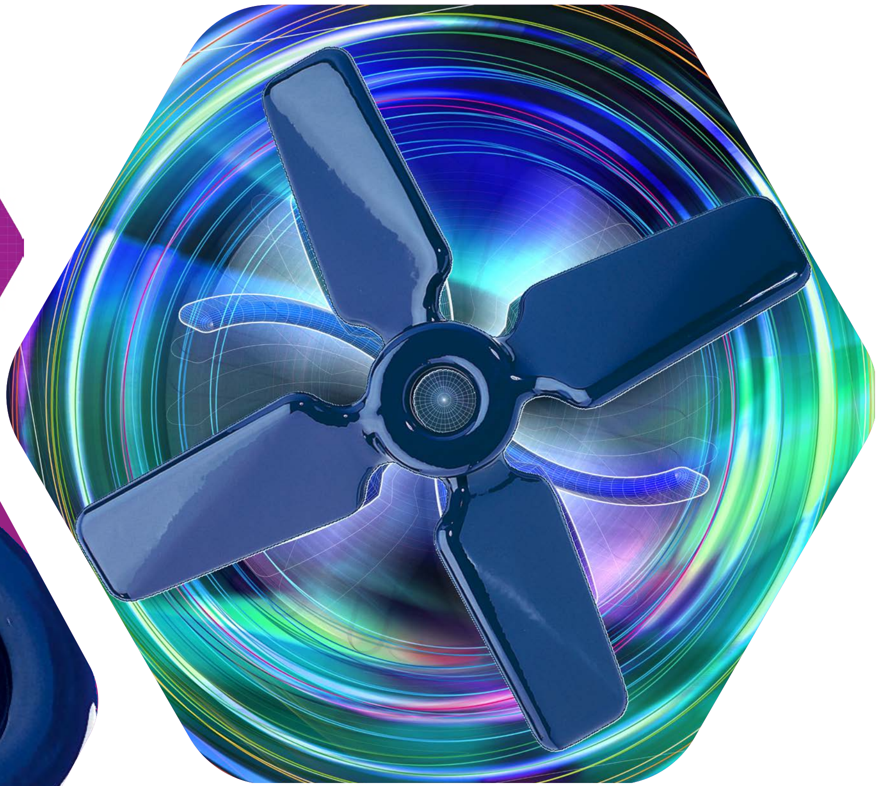
Glass lined steel protects delicate products from any kind of unwanted influence, especially contact with metal. This is particularly important in the manufacture of very pure organic and inorganic substances and where it is also necessary to ensure uniform consistency, such as in the synthesis of vitamins. Similar standards must be met in the pharmaceutical, plastics, semiconductor and paints industries.

Glass linings are useful allies in preventing pathological infections, because



they can easily be kept germ free.
This is a major advantage in respect of the processing and storage of sensitive products such as medicines, foodstuffs, fruit juices and concentrates. This has been confirmed through comparative studies involving different materials. Glass linings achieved the best results for germ inhibition in respect of both natural and artificially induced germ infestation. Furthermore, glass lined equipment and components are excellently suited for use in biotechnological applications. In the semiconductor industry glass lined receptacles are attracting more and more interest as only they are able to deliver the required extremely high standards for contamination levels, with impurities remaining below the prescribed parts-per-billion level.



**Pfaudler Glass Linings – for process reliability**

Glass lined production equipment simplifies processing and contributes to improved operating security. Recent research under realistic conditions has shown that process reliability and security depend both on the chemical and biological inertness of the apparatus material as well as on its surface characteristics.

The interface surface produced by the fusion flow is not only glassy smooth, but structurally coherent and therefore extremely anti-adhesive. This helps to prevent product film and coagulation as well as promoting the reaction process in allowing unhindered thermal transmission.

Our fully coated measuring sensors for process control and continuous monitoring have been contributing to operative security and productivity for many years. These sensor systems make the Pfaudler reactor literally transparent.

**Pfaudler Glass Linings – improve productivity**

Technological improvements of glass have increased its durability over large temperature gradients so that rapid heating or cooling is no longer a problem. Glass linings can very easily be cleaned, so production down-times can be reduced and therefore operating costs as well.

High quality also means a long service life with minimal repairs, two more factors which make a large difference to the profitability of production plants. Another great advantage of glass lining technology makes itself felt when a production technique is altered or a plant is recommissioned for another purpose. For if, after many years of good service, it proves necessary to reglass plant equipment, the result is virtually equivalent to brand new – and thus delivers unbeatable cost effectiveness.

Therefore Pfaudler glass linings represent the ideal answer when it comes to finding a universal material for plant, equipment and apparatus.

# Our Product Range

From classical to avant-garde

## Standard grade – tried and tested in many years of practical application

### Pfaudler World Wide Glass WWG

Our standard glass lining displays high levels of corrosion resistance, mechanical stability and thermal shock resistance. The surface is anti-adhesive and is equitensile. The physical characteristics have been enhanced through knowledge gained in the development of high technology ceramics, and resistance to water, acidic and caustic chemicals have improved significantly.

Normally, **Pfaudler WWG** has the colour cobalt blue. Alternatively, the colour white is available. In addition to the characteristics already mentioned, the high reflectivity of the glass lining makes reaction vessels very bright, so that colour changes in reactive processes can be recognised more easily. **Pfaudler WWG** white is the ideal material for photo reactions.



## Special grade – for special purposes

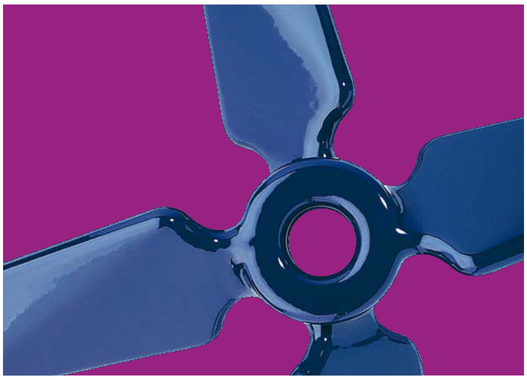
### Pfaudler Pharma Glass PPG

For a long time there were few differences between the way plants for the chemical and pharmaceutical industries were equipped – especially in respect of glass lined reactors. Today, however, the requirements of each industrial sector have diverged considerably. For pharmaceutical purposes the main concern is about extremely high degrees of purity as demanded by the US Food and Drugs Authority. An example of such a special requirement relates to processes involving changing acidic and alkaline milieus.
Responding to calls for increasingly specialised materials for specific processes and uses, such as the manufacture of vitamins and fine chemicals, Pfaudler developed the ground-breaking product **Pfaudler Pharma Glass PPG**.

### Pfaudler Anti Static Glass ASG

The process of stirring solids in **nonaqueous solvents such as toluene or acetone causes the mixture to develop a strong static charge**. Electrostatic discharge can damage reactors and other equipment, causing down-times and increased costs. Our carefully targeted research produced a solution to the problem:
**Pfaudler Anti Static Glass ASG**.
Pfaudler has been gaining experience in glass linings with anti-static glass since 1972. **Pfaudler Anti Static Glass ASG** displays the following characteristics:

- The resistance to chemicals is in no way influenced by the electrical conductivity of the material. In this respect it has the same properties as our proven product WWG.
- The glass lining remains fully inert without any catalytic tendencies (as can be the case with platinum fibres).
- All components can be coated with an anti-static glass layer.
- Electrical discharges are in no way harmful to the surface layer.



Special Glass Linings are also available for use in other areas than the chemical and pharmaceutical industries. Exceptional requirements and problems call for exceptional solutions.

# Product Overview

## The characteristics of our range

The following passage contains a brief overview of the advantages of the most common Pfaudler glass linings.

**WWG** Pfaudler World Wide Glass
**PPG** Pfaudler Pharma Glass
**ASG** Pfaudler Anti Static Glass
**ARG** Pfaudler Abrasing Resistant Glass

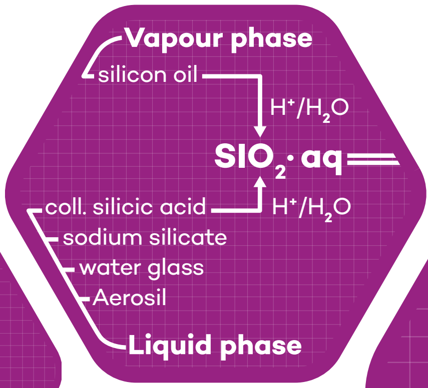
**WWG blue**
- High corrosion resistance
- High resistance to mechanical impacts
- Good resistance to thermal shock
- Anti-adhesive surface
- Equitensile lining

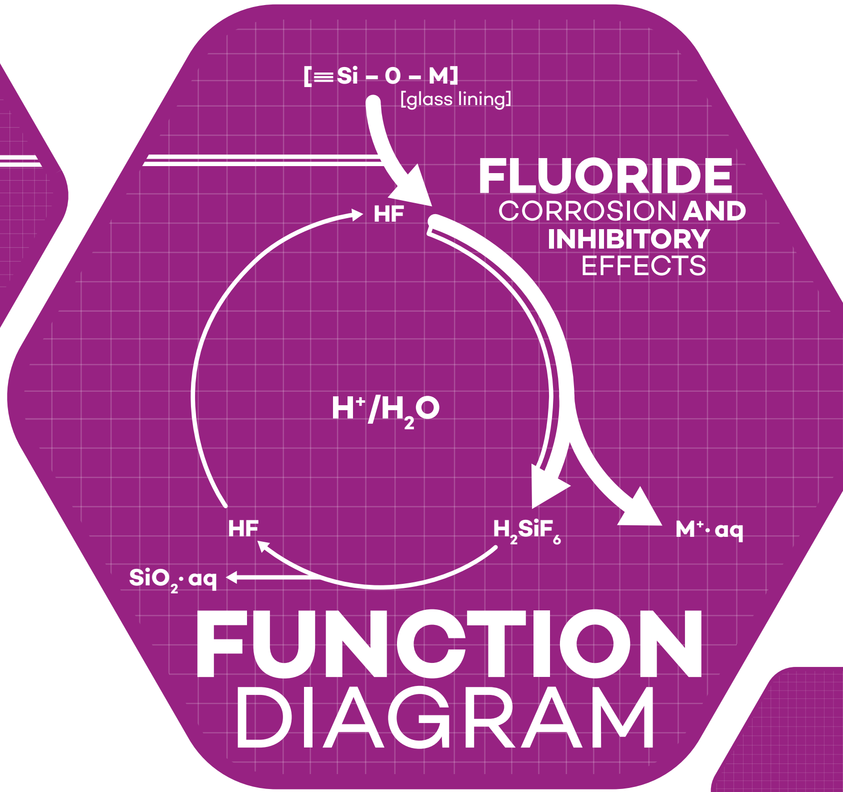
**WWG white**
- High corrosion resistance
- High resistance to mechanical impacts
- Product residues can easily be detected
- High optical contrast to product
- Highly reflective

**PPG**
- Extremely smooth surface
- Free of heavy metals
- Improved resistance to alkalis
- Better chromatic transparency
- Product residues can easily be detected when vessel is cleaned
- Long service life even with alternating usage (acid/alkali)
- Highly reflective

**ASG**
- Avoids or reduces static charging
- Avoids damage such as flaking
- Chemical durability as with WWG

**ARG**
- Increased resistance abrasion
- No loss in resistance to corrosion
- Long service in harsh processes


# Progress in research

## The chemical behavior of Glass Linings

**Innovation and a pioneering spirit have always been characteristic of Pfaudler's approach**

Over many decades Pfaudler has maintained its position as an industry leader in innovation. An impressive testimonial to this can be found in the fact that all the relevant testing norms DIN/ISO/EN are based on Pfaudler's efforts and initiatives. Many years of research effort in laboratories and plants have provided a worldwide basis for examination methods relating to comparison of material properties.

Pfaudler has conducted practical experiments to study the relationship between product volumes and lining surfaces as well as the significance of favourable inhibitory effects on the corrosion resistance characteristics of glass linings. The results of these studies have been incorporated into the corrosion resistance specifications.

**Organic Media**

Organic solids, solutions, liquids and gases present special challenges in respect of resistance to aggressive chemicals.

**Inorganic Media**

Pfaudler glass linings display a very high degree of resistance to all inorganic media from concentrated acids to strongly alkaline substances. Depending on the medium, chemical influences only begin to make themselves felt in the temperature range between 120 °C and 160 °C. Pfaudler glass linings are almost entirely resistant to attack from anhydrous acids.

**Water**

Water generally does not affect glass linings. Only in the case of extremely pure water at temperatures above 160 °C an influence can be detected.

### Halogens

Despite their reputation in general as problem substances, the halogens chlorine, bromine and iodine have no influence on the chemical stability of our glass linings, which remain fully inert.

### Acids

In practice acids are always encountered in association with other liquids, dissolved substances or gases. Depending on the exact nature of the mixture, the influence which it has on glass linings may be favourable or not.

### Caustic Solutions

The aggressiveness of caustic solutions increases with their concentrations and the degree of glass corrosion also increases more quickly with rising temperatures than is the case with other substances. Therefore with concentrated caustic solutions it is necessary to pay careful attention to temperature limits. The aggressiveness of strong caustic solutions is not just dependent on the pH value alone. With aqueous solutions of alkali hydroxides with pH values of 14 the actual concentration in percentage by weight must be taken into account. This may mean that the operating temperature must be adjusted.

Additionally, the specific reaction or solvent characteristics of a caustic solution are relevant factors which can influence the stability of glass linings.

In practical applications it is important to bear in mind that even slight impurities such as tap water in sodium hydroxide can have a significant influence on the rate of corrosion. In case of doubt product solutions must be subjected to direct tests in order to find out exactly what they contain.

During our tests, we conducted experiments using polypropylene bottles to eliminate the effects of  the testing apparatus on the corrosion rates. For tests above boiling point we used stainless steel autoclaves with tantalum linings or PTFE inserts. On further investigation we were able to show that the testing apparatus did not exercise an inhibiting influence.

### Organic Bases and Metal-Organic Compounds

As anhydrous or practically water-free compounds these substances are not regarded as caustic in respect of glass corrosion.

### Inorganic Bases

Inorganic bases are known for their propensity to dissolve glass in their anhydrous state. However, Pfaudler glass linings are fully resistant to anhydrous gaseous ammonia.

### Fluorine

Hydrofluoric acid and fluoridated acid solutions are exceptional substances, for even in extremely low concentrations and at low temperatures they react with silicate based materials. A concentration as low as 0.001% can render a glass lining matt and rough after long exposure. Such concentrations can arise simply through sulphuric acid being piped through PTFE tubing at 160 °C, for instance. One way in which the fluorine problem can be tackled is to introduce finely granulated or dissolved silicic acid into the process. The effects of the fluoride concentrations on the linings can be reduced considerably by using this technique. Our own investigations into these effects have shown that hydrofluoric acid corrosion is subject to many different factors. Apart from the obvious factor of the concentration level of the acid, these include the pH value and the temperature of the solution and not least the quality of the glass lining. Processing in acid media is permissible with stable fluorine compounds. However, it is wise to find out by means of a simple corrosion test on an enamelled dish, for instance, whether hydrofluoric acid is present or likely to be produced.

In this respect silica plays a particular role. Even tiny traces of $SiO_2$ have a very favourable effect on the durability of glass linings.

# Fluoride Corrosion

## Using Silica to reduce Fluoride Corrosion

**Durability**

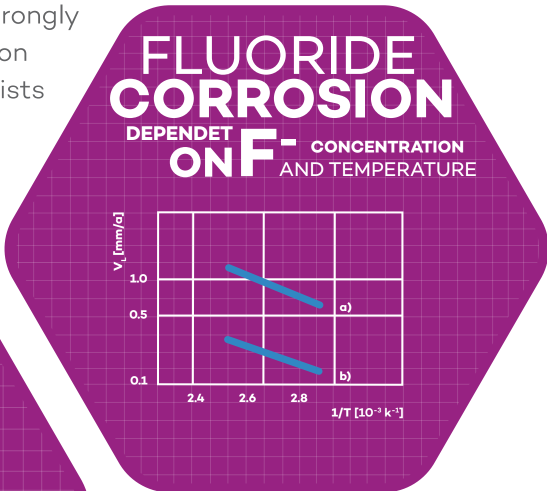
Pfaudler Glass Linings have been tested by the German Federal Institute for Materials Research and Testing as part of the process for certifying them for the storage of substances detrimental to waters.

The table shows the results for a number of different media and gives a rapid general overview of the chemical properties of our materials. The data come from practical experience and laboratory tests on Pfaudler glass linings. They are only to be taken as a guide and are of necessity not exhaustive. Thus the concentrations and temperatures given do not represent either usage or guarantee levels.

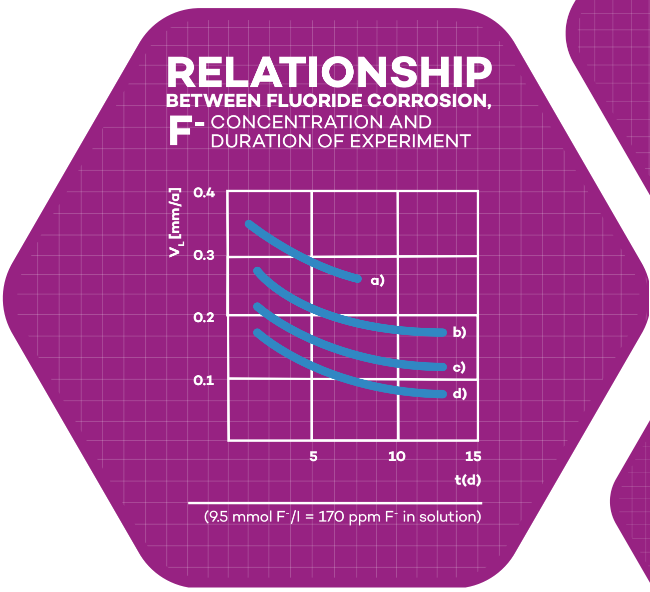
For applications not listed in the table and in particular where combinations of substances are involved we strongly recommend the implementation of corrosion tests. Our specialists will be glad to supply expert advice.

Key to figures and abbreviations used in the table:

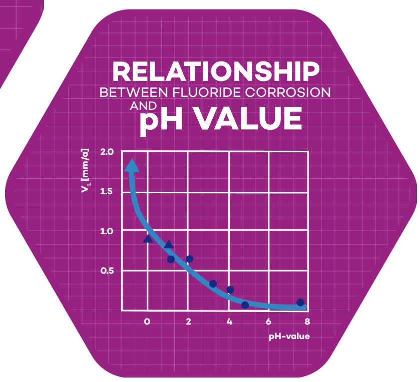
| level | durability/resistance |
|---|---|
| 1 | highly resistant |
| 2 | limited resistance |
| 3 | not resistant |
| aqu.sol. | aqueous solution |
| B | boiling point |




a) 19 mmol/l fluoride
(19 mmol $F^-$/l = 360 ppm $F^-$ in solution)
b) 9.5 mmol/l fluoride
(9.5 mmol $F^-$/l = 180 ppm $F^-$ in solution)
$V_L$ = corrosion progress in mm/a




a) no additive
b) 100 mg/l $SiO_2$
c) 200 mg/l $SiO_2$
d) 400 mg/l $SiO_2$
pH = 1 | 80 °C




Corrosion progress VL in relation to pH value; in a solution with 19 mmol/l Fluoride at 80 °C.
● = corrosion in buffer solutions
▲ = corrosion in aqueous hydrochloric acid

| Substance | °C | durab. |
|---|---|---|
| Acetic acid | 180 | 1 |
| Acrylic acid | 150 | 1 |
| Aluminium chlorate conc. aqu.sol. | 110 | 1 |
| Aluminium chloride 10 % aqu.sol. | B | 1 |
| Aluminium chloride | 250 | 1 |
| Aluminum acetate fusion | 200 | 1 |
| Aminoethanol | 170 | 1 |
| Aminophenol | 150 | 1 |
| Ammoniac | 80 | 1 |
| Ammonium carbonate aqu.sol. | B | 1 |
| Ammonium chloride 10 % aqu.sol. | 150 | 1 |
| Ammonium nitrate aqu.sol. | B | 1 |
| Ammonium phosphate aqu.sol. | B | 1 |
| Ammonium sulphate | 320 | 3 |
| Ammonium sulphate aqu.sol. | B | 1 |
| Ammonium sulphide aqu.sol. | 140 | 3 |
| Ammonium sulphide aqu.sol. | 80 | 1 |
| Aniline | 184 | 1 |
| Antimony(III) chloride | 220 | 1 |
| Antimony(V) chloride | 120 | 1 |
| Aqua regia | 140 | 1 |
| Barium hydroxide aqu.sol | B | 2 |
| Benzaldehyde | 150 | 1 |
| Benzoic acid | 150 | 1 |
| Benzole | 250 | 1 |
| Benzyl chloride | 130 | 1 |
| Boric acid aqu.sol. | 150 | 1 |
| Boron trifluoride in org. sol. | 40 | 1 |
| Bromine | 100 | 1 |
| Butanol | 140 | 1 |
| Calcium chloride (CaO free) aqu.sol | 150 | 1 |
| Carbon dioxide 200 mg/l aqu.sol. | 140 | 1 |
| Carbon disulfide | 200 | 1 |
| Carbon tetrachloride | 200 | 1 |
| Chlorinated bleaching agent aqu.sol. | 150 | 1 |
| Chlorinated paraffin | 180 | 1 |
| Chlorinated water | 150 | 1 |
| Chlorine | 200 | 1 |
| Chloropropanoic acid | 175 | 1 |
| Chlorosulphuric acid | 150 | 1 |
| Chromic acid aqu.sol. | 150 | 1 |
| Citric acid 10 % aqu.sol. | B | 1 |
| Copper chloride 5 % aqu.sol. | 150 | 1 |
| Copper nitrate 50 % aqu.sol. | 100 | 1 |
| Copper sulphate aqu.sol. | 150 | 1 |
| Cyanoacetic acid | 100 | 1 |
| Dichlorbenzol | 220 | 1 |
| Dichloressigsäure | 150 | 1 |
| Dichlorpropionsäure | 175 | 1 |
| Diethylamin | 100 | 1 |
| Dimethylaminopropanol | 150 | 1 |
| Dimethylsulfat | 150 | 1 |
| Eisen(III)chlorid wL | 150 | 1 |
| Eisensulfat wL | 150 | 1 |
| Essigsäure | 180 | 1 |
| Essigsäureethylester | 200 | 1 |
| Ethylalkohol | 200 | 1 |
| Ethylendiamin 98 % wL | 80 | 1 |
| Ethylendiamin 50 % wL | 80 | 1 |
| Ethylesther | 100 | 1 |
| Fatty acids | 150 | 1 |
| Ferric(III) chloride aqu.sol. | 150 | 1 |
| Fluorides in acidic aqu.sol. | 20 | 3 |
| Formaldehyde | 150 | 1 |
| Formic acid 98 % aqu.sol. | 180 | 1 |
| Glycerine | 100 | 1 |
| Glycol | 150 | 1 |
| Glycolic acid 57 % aqu.sol. | 150 | 1 |
| Hydrazine hydrat 40 % aqu.sol. | 90 | 2 |
| Hydrazine hydrate 80 % aqu.sol. | 90 | 1 |
| Hydrazine sulphate 10 % aqu.sol. | 150 | 1 |
| Hydrochloric acid 20 % | 130 | 1 |
| Hydrogen peroxide 30 % aqu.sol. | 70 | 1 |
| Hydrogen sulphide water | 150 | 1 |
| Hydroidic acid 20 % aqu.sol. | 160 | 2 |
| Hydroidic acid 60 % aqu.sol. | 130 | 1 |
| Iodine | 200 | 1 |
| Iron sulphate aqu.sol. | 150 | 1 |

| Substance | °C | durab. |
|---|---|---|
| Isoamyl alcohol | 150 | 1 |
| Isopropyl alcohol | 150 | 1 |
| Lactic acid 95 % aqu.sol. | B | 1 |
| Lead acetate | 300 | 1 |
| Lithium chloride 30 % aqu.sol. | B | 1 |
| Lithium chloride 4 % aqu.sol. | 80 | 1 |
| Lithiumhydroxid conc. aqu.sol. | 60 | 1 |
| Magnesium carbonate aqu.sol. | 100 | 1 |
| Magnesium chloride 30 % aqu.sol. | 110 | 1 |
| Magnesium sulphate aqu.sol. | 150 | 1 |
| Maleic acid | 150 | 1 |
| Methyl 4-hydroxybenzoate | 150 | 1 |
| Methyl alcohol | 200 | 1 |
| Monochloroacetic acid | B | 1 |
| Naphthalene | 215 | 1 |
| Naphthalenesulphonic acid | 180 | 1 |
| Nitric acid 30 % | 135 | 1 |
| Nitrobenzene | 150 | 1 |
| Nitrogen oxides | 200 | 1 |
| Octanol | 140 | 1 |
| Oleum (10 % SO3) | 170 | 1 |
| Oxalic acid 50 % aqu.sol. | 150 | 1 |
| Palmitic acid | 110 | 1 |
| Perchloric acid 70 % aqu.sol. | B | 1 |
| Phenol | 200 | 1 |
| Phosphoric acid conc.aqu.sol. | 100 | 1 |
| Phosphoric acid triethyl ester | 90 | 1 |
| Phosphorous acid (F- free) | 100 | 2 |
| Phosphorous acid (F- free) | 80 | 1 |
| Phosphorus trichloride (F- free) | 100 | 1 |
| Phosphoryl chloride (F- free) | 100 | 1 |
| Phthalic anhydride | 260 | 1 |
| Picric acid | 150 | 1 |
| Potassium bromide aqu.sol. | B | 1 |
| Potassium chloride aqu.sol. | B | 1 |
| Potassium hydrogen sulphate | 200 | 1 |
| Potassium hydroxide conc. aqu.sol. |  | 1 |
| Potassium hypochloride aqu.sol. | 70 | 1 |
| Pyridine | B | 1 |
| Pyridine hydrochloride | 150 | 1 |
| Pyrogallic acid 5 % aqu.sol. | B | 1 |
| Pyrrolidine | 90 | 1 |
| Soda ash conc. aqu.sol. | 60 | 1 |
| Sodium bicarbonate conc. aqu.sol. | 60 | 1 |
| Sodium bisulphate | 300 | 1 |
| Sodium bisulphite 2 % aqu.sol. | 150 | 1 |
| Sodium chlorate aqu.sol. | 80 | 1 |
| Sodium chloride aqu.sol. | B | 1 |
| Sodium ethylate | B | 1 |
| Sodium glutamate | 150 | 1 |
| Sodium hydroxide conc. aqu.sol. | 50 | 1 |
| Sodium hypochlorite aqu.sol. | 70 | 1 |
| Sodium methylate | 320 | 1 |
| Sodium nitrate | 320 | 1 |
| Sodium sulphide 4 % aqu.sol. | 50 | 2 |
| Sulphochromic acid | 200 | 1 |
| Sulphur | 150 | 1 |
| Sulphur dioxide | 200 | 1 |
| Sulphuric acid 40 % | 130 | 1 |
| Tannic acid | 150 | 1 |
| Tetrachlorethylene | 150 | 1 |
| Tin chloride | 250 | 1 |
| Toluole | 150 | 1 |
| Trichloracetic acid | 150 | 1 |
| Triethylamine | 130 | 1 |
| Triethylamine 25 % aqu.sol. | 130 | 3 |
| Triethylamine 50 % aqu.sol. | 130 | 3 |
| Triethylamine 50 % aqu.sol. | 80 | 1 |
| Triethylamine | 80 | 1 |
| Trimethylamine 30 % aqu.sol. | 80 | 1 |
| Trisodium phosphate 5 % aqu.sol. | B | 2 |
| Trisodium phosphate 50 % aqu.sol. | 80 | 1 |
| Urea | 150 | 1 |
| Vinylphosphoric acid (waterfree) | 120 | 3 |
| Water | 130 | 1 |
| Zinc bromide aqu.sol. | B | 1 |
| Zinc chloride | 330 | 1 |
| Zinc chloride aqu.sol. | 140 | 1 |

# Testing Procedures

## Standard procedures and more

**Standard Procedures**

In order to conduct useful comparative tests on glass materials of different origins standard tests are essential. Differences in quality, for instance regarding the chemical durability, can only be established reliably by subjecting samples to the same testing conditions. Experience has shown us, however, that grey areas always exist between the results of tests on specimen plates or sample materials and the actual behaviour of large containers and components under operating conditions. For example, a mixing vat represents a complex combination of differently shaped components which mean that there are simply too many different operating parameters which can play a role. Therefore Pfaudler has developed a practical corrosion test which has been incorporated into the DIN EN 14 483-5 standard. The test is designed for acidic and neutral media in closed systems.

**Acids**

Method according to DIN EN 14 483-2
Samples (plates) acc. to DIN ISO 2723
Equipment acc. to DIN EN 14 483-2
The test can be used for all acids to their boiling points. It produces quantitative results for the liquid and vapour phases respectively. Suspended specimens for processes under laboratory conditions or on a technical scale produce qualitative results.

**Molten Salts and highly viscous Liquids**

Cover testing dish with glass plate. Heat in an oil or sand bath in a drying cabinet. The results are quantitative.

**Caustic Solutions**

Method according to DIN EN 14 483-5
Samples (plates) acc. to DIN ISO 2723
Equipment acc. to DIN EN 14 483-5
The test can be used for all caustic solutions up to 80 °C. The results are quantitative.

**Water**

Method according to DIN EN 14 483-2
Samples (plates) acc. to DIN ISO 2723
Equipment acc. to DIN EN 14 483-2
The test can be used up to boiling point. It produces quantitative results for the liquid and vapour phases respectively. Corrosion tests under normal conditions above boiling point require specially constructed pressure autoclaves.

**Corrosion Test according to DIN EN 14 483-5 – our research for your safety**

For safety reasons it is important to know the maximum degree of damage which an acid can cause to a glass lining. For this reason the test must be designed to exclude inhibitory influences. Thus the isocorrosion curves established using pro analysi acids show corrosion rates which are sometimes far greater than those displayed under operating conditions.

**Testing Conditions**

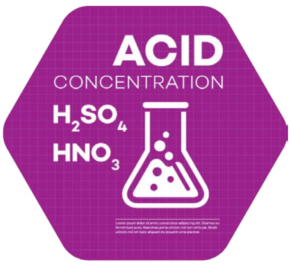
Very small test objects, which are fully enamelled to allow for a very precise measurement of weight loss, are each subjected to the effects of pro analysi acids for 24 hours. The samples have a surface area of only 11 cm². They are exposed to large quantities of acid (500 ml) in autoclaves which are lined with tantalum to prevent $SiO_2$ inhibition.

**Absolutely pure Production…**

Only first class production plants can produce first class quality products. In the USA, only medicines which were manufactured in plants inspected and certified by the Food and Drugs Administration Agency (FDA) can be approved for use. The FDA sets extremely high standards for production plants and equipment, standards which are satisfied by **Pfaudler Pharma Glass PPG.** Reactors lined with this material represent an important contribution towards achieving the necessary degree of purity, for **Pfaudler Pharma Glass PPG** is practically free of heavy metals: The proportion of dissolved heavy metal lies below the detection limits.

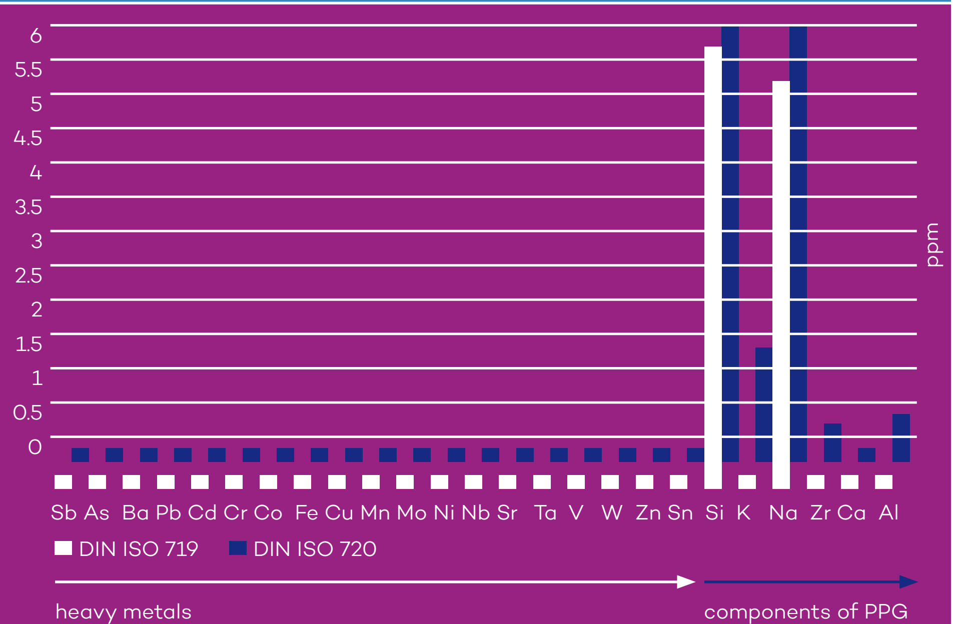
**… with optimal Apparatus**

The better the apparatus, the easier it is to apply optical checks. **Pfaudler Pharma Glass PPG** has a light blue colour which gives a good contrast to white as well as other colours. In addition it helps to illuminate the reactor very well. This is an aid to supervising production processes and also to postproduction cleaning.



## **HEAVY METAL CONTENTS** of Pfaudler PharmaGlass PPG

| | acc. DIN ISO 719* | acc. DIN ISO 720* |
|---|---|---|
| Sb | < 0.01 | < 0.01 |
| As | < 0.02 | < 0.02 |
| Ba | < 0.001 | < 0.001 |
| Pb | < 0.01 | < 0.01 |
| Cd | < 0.002 | < 0.002 |
| Cr | < 0.01 | < 0.01 |
| Co | < 0.001 | < 0.001 |
| Fe | 0.02 | 0.02 |
| Cu | < 0.01 | < 0.07 |
| Mn | < 0.005 | < 0.005 |
| Mo | < 0.01 | < 0.01 |
| Ni | < 0.005 | < 0.005 |
| Nb | < 0.1 | < 0.1 |
| Sr | < 0.001 | < 0.003 |
| Ta | < 0.1 | < 0.1 |
| V | < 0.005 | < 0.005 |
| W | < 0.1 | < 0.1 |
| Zn | < 0.01 | < 0.01 |
| Sn | < 0.05 | < 0.05 |




**What is the leaching effect on boiling water on PPG glass?**
The tests were conducted on ground glass
between 0.3 < 0.425 mm acc. DIN 719 – 98 °C
and 0.3 < 0.500 mm acc. DIN 720 – 121 °C

* Heavy metal determination according to DIN EN ISO 11885: units ppm

**Thermal Limits of Workability**
The upper operating limit for our materials in respect of thermal load is +230 °C. This limit is independent of the chemical behaviour of the material, which in many cases would permit higher temperatures. However, the type of gasket used for the connecting sections and the mechanical seal place limit the maximum temperatures. The shock diagram and operating diagram are intended as general indicators only. Resistance to temperature change was determined according to DIN ISO 13807.

**Glass and Steel – an ideal Pair**
**thermal conductivity**
Using a steel body it is possible to keep the glass layer – compared with apparatus made of glass alone – relatively thin. The higher thermal conductivity of steel compensates for the lower conductivity of glass. As the materials are chemically bonded there is also no internal thermal transfer resistance to be overcome. Therefore the thermal transfer figures for glass lined steel are much higher than those for plastic or rubber coated steel, for instance.

# The physical limits

## thermal limits and conductivity

Cleaning glass linings using high pressure hose. The data assumes a fully intact lining surface.

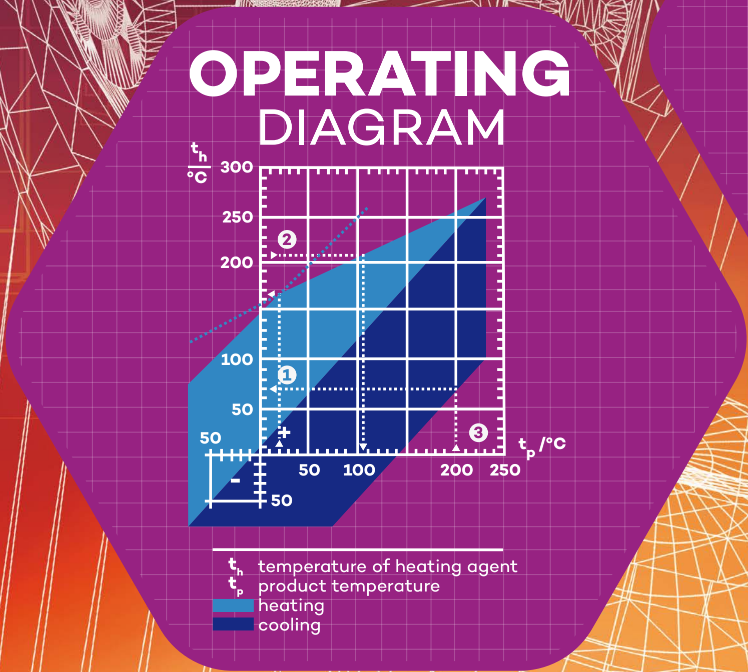
| PARAMETER | small vessels to 6 m² | large vessels | cleaning by hand |
|---|---|---|---|
| Pressure | 350 bar | 400 bar | 150 bar |
| Distance to wall | min. 250 mm | min. 500 mm | > 200 mm |
| Angle to wall | max. 45° | can be 90° | max. 45° |
| Temperature | room temperature | room temperature | room temperature |
| Cleaning agent (filtered) | pure water | pure water | pure water |
| Jet type | continually in motion | continually in motion | continually in motion |
| Water throughout | max. 200 l/min | max. 150–220 l/min | ca. 150 l/min |
| Cleaning time (approx.) | 15–20 min | 20–30 min | – |

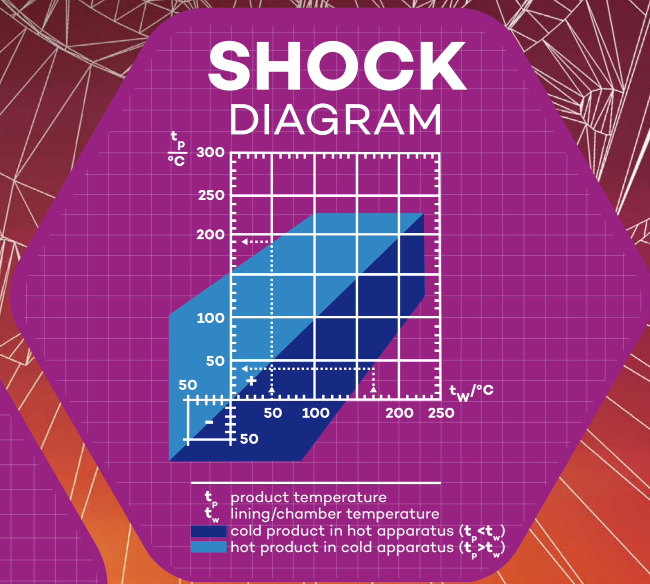
**Avoiding Cavitation damage**
The introduction of hot vapours into low temperature liquids can lead to changes in the glass lining close to the point of entry. This is caused by individual vapour bubbles which are distributed in the liquid. Owing to the temperature difference the vapour condenses suddenly and dissolves in the liquid. The bubble then consists of a vacuum which immediately implodes, causing the surrounding liquid to exercise a mechanical impulse on the lining and other components. This impulse has the same effect as a blow from a solid object. Cavitation can also occur when solutions are mixed where the individual liquids involved have boiling points more than 50 °K apart. In regions of strong turbulence local pressure differences can cause one of the components to boil spontaneously. The effect can be controlled e. g. with pressurised nitrogen or by changing the rate of mixing. Please consult our experts for further information on combating this condition.

**Electrostatic Charging**
For processes which are likely to cause electrostatic charging **Pfaudler Anti Static Glass ASG** should be implemented. Many years of practical experience in collaboration with leading chemical manufacturers as well as recent technological developments have produced solutions for all problems related to electrostatic charging with glass lined apparatus.

**Abrasion**
Abrasion damage can occur when strongly abrasive solids are mixed in a tank. This can be avoided by adopting different operating techniques. Please consult us in respect of this kind of problem.

**Cleaning of glass lined equipment**
It is not possible to provide general specifications for cleaning glass linings using high pressure hoses. The parameters provided here are based on experience gained by plant manufacturers and operators and allow for safe cleaning of glass linings. The information given is based on the assumption that the glass lining in question is completely intact. It is very important to ensure that PTFE surfaces will not deform or begin to flow, and the figures given are chosen to ensure that this is the case.

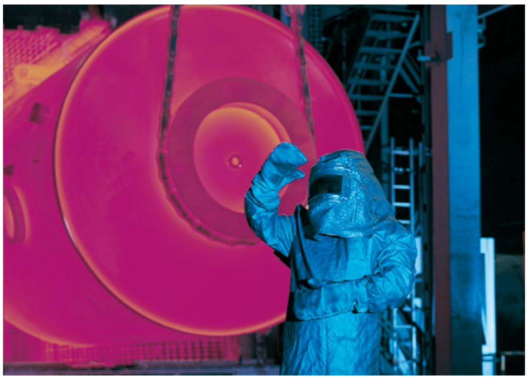

OPERATING
DIAGRAM
$t_h$ °C
300
250
200
100
50
50
50
100
200
250
$t_p$/°C
50
$t_h$ temperature of heating agent
$t_p$ product temperature
heating
cooling


SHOCK
DIAGRAM
$t_p$ °C
300
250
200
100
50
50
50
100
200
250
$t_w$/°C
50
$t_p$ product temperature
$t_w$ lining/chamber temperature
cold product in hot apparatus ($t_p<t_w$)
hot product in cold apparatus ($t_p>t_w$)

# Data

## relating to Glass Linings

| MATERIAL DATA | | industrial glass lining | low alloy steel | Pfaudler steel bonded glass lining |
|---|---|---|---|---|
| adhesiveness | $N/mm^2$ | – | – | > 100 |
| tensile strength | $N/mm^2$ | 70 | 400...600 | 70 |
| pressure resistance | $N/mm^2$ | 800 | 220...350 | 800...1000 |
| modulus of elasticity | $N/mm^2$ | 70 000 | 210 000 | ca. 80 000 |
| stretch at breaking point | % | 0.1 | 15...30 | 0.1 |
| Vickers hardness test | HV | 600 | 110 | 450 |
| coefficient of thermal conductivity | W/mK | 1.2 | 52 | 1.2 |
| specific heat | J/kgK | 835 | 460 | 835 |
| specific electrical resistivity<br>at room temperature<br>at 200 °C | <br>Ω/cm<br>Ω/cm | <br>$10^{13}$<br>$2 \cdot 10^9$ | <br>0.002<br>– | <br>$10^{13}$<br>– |
| resistance to disruptive discharge | kV/mm | 20...30 | – | 20...30 |
| density | $g/cm^3$ | 2.5 | 7.8 | – |
| softening temperature | °C | 570 | approx. 1000 | 570 |
| coefficient of linear expansion between 20 °C and 400 °C | $\alpha_{20\text{-}400} 10^{-7} K^{-1}$ | 88 | approx. 135 | 88...115 |
| thickness of lining | mm | – | - | 0.8...2.4 |



Technologies

# Expertise
you can trust

Solutions

Innovation

Services

**Established in 1884, we are a world-leading process solutions company, providing technologies, solutions, services and innovations to meet the specific requirements of our customers in the chemical, pharmaceutical and other process industries. With engineering and manufacturing facilities located around the globe, we define the standard.**

## Technologies
For over 130 years, we have developed new technologies to meet the highly specific chemical processing needs of our clients. Over 90% of the ICIS top chemical companies trust our technologies for the unit operations throughout their plants including fluid mechanics, reaction kinetics, agitation/mixing, heat transfer, mass transfer, separations, filtration, drying and materials engineering.

## Innovation
Driven by a pioneering spirit, we are continuously developing innovative new technologies. We have developed many corrosion resistant innovations with glass-lined steel, fluoropolymers and reactive metal technologies and our wide-ranging reaction, filtration and evaporation innovations improve the process yield, quality and efficiency.

## Solutions
We create the complete packaged solution for your processing needs. With over 130 years' chemical processing experience and expertise, you can trust us to deliver a completely integrated solution including the process, equipment, piping, insulation, instruments, controls and all peripherals.

## Services
Our engineering, technical services and aftermarket parts services are there to keep your chemical process systems operating smoothly. We will work closely with you to trouble shoot processes and design and install process upgrades to help achieve improved efficiency, reduced maintenance, improved reliability, reduced operating costs and system uptime. Our technicians will provide all your equipment maintenance needs from installation to repairs and preventative maintenance. They will also work with you upfront and during your projects, carrying out engineering studies, pilot testing, feasibility studies and general consulting.

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