Beta (β)-PP from Georg Fischer

A synonym for proven toughness

and chemical resistance.

Latest findings

GEORG FISCHER +GF+
Piping Systems

Beta-PP-H from **Georg Fischer**
A synonym for proven toughness and chemical resistance

Industrial plant operators, particularly those in the chemical industry, place significantly higher demands on the piping materials for their systems than they would for standard water applications. Characteristic features of this requirement profile are:

- **frequent changes in thermal load over a relatively wide range**
- **the compensation of linear thermal expansion**
- **the occurrence of dynamic stress load or hydraulic impact**
- **a much higher awareness for security and cost measures when hazardous chemicals (often media hazardous to ground water, e.g. strong acids or bases) need to be conveyed**
- **no downtime**
- **less maintenance**

The Beta-PP-H material used by Georg Fischer is ideal for these application areas.
The major advantages of Beta-PP-H compared to other PP types are explained in this technical brochure.

Considering the requirement profile above, it is obvious that the impact strength of the material plays a decisive role in piping system construction. High impact resistance warrants maximum safety against unforeseeable impact in transport, in installation and last but not least in operation of the system.

This is why Georg Fischer recommends the material Beta-PP-H.

- **Systematic tests spanning several years and including various materials confirm the extraordinarily high impact strength of this material even at low temperatures. Note that also the welding zone shows the continuation of the beta-properties.**
- **In particular, it has been shown that an adaptation of the reduction factors (A4) of Beta-PP-H to those of PP-R is entirely justifiable.**
- **The excellent chemical resistance and the high stiffness of Beta-PP-H round off the profile of this material ideal for the chemical industry.**

The different PP types

PP belongs to the class of semi-crystalline polymers, whose ordered (crystalline) phase can occur in various modifications. The type and content of the crystalline phase determines the mechanical properties, such as stiffness and toughness of the material to a large extent. It is a well-known fact that the impact strength of PP can be significantly increased (compared to Alpha-PP), without any noteworthy loss in the rigidity of the material, by the formation of the beta phase as crystallite modification. Basically, this beta phase is realized by adding traces of special nucleating agents. It is the processing that has a decisive impact on the extent to which the beta phase and the related positive material properties are realized in the end product. Combined with the nucleating agents, it is exactly these factors which determine the formation of a homogenous and fine structure with minimal internal stress.

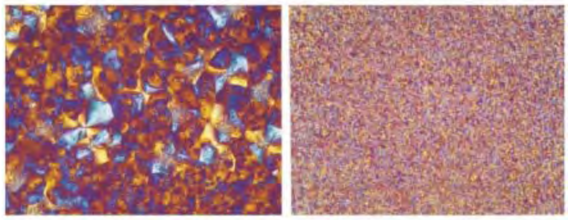


Fig.1: Structure of non-nucleated PP-H (left) and nucleated Beta-PP-H (magnification = 80x; transmitted light, polar; 15 µm microtomic section)

There are three different types of polypropylene generally used in piping systems construction today:

- PP homopolymer (PP-H; Type 1); Standard (Alpha-) PP-H and **Beta PP-H** belong to this category
- PP block copolymer (PP-B; Type 2)
- PP random copolymer (PP-R, Type 3).

PP as a polyolefin belongs to the class of non-polar materials, whose surface hardly swells or is difficult to dissolve; so-called functional groups are not present in the material without pre-treatment. Solvent cementing is therefore not possible without special surface treatment and also not possible under field conditions. However, PP can be fused very easily. For pressure piping, heating element socket fusion, heating element butt fusion and the non-contact infrared (IR-Plus®) fusion technology developed by Georg Fischer are used.
The excellent cost-performance ratio renders PP in combination with its extensive chemical resistance and its attractive range of properties (even under higher temperatures) a very interesting piping system material.

Beta-PP-H from Borealis

Georg Fischer has used Beta-PP-H since more than ten years successfully.
An innovative extrusion process makes sure that the inherent potential of this raw material is optimally transformed into a high-quality product with minimal internal stress. Thanks to the special processing technique, an **extremely smooth** pipe inner surface is achieved, the topography of which is by no means inferior to that of injection moulded parts.
Extensive tests give evidence to the special barrier effect of a homogenous and **microcrystalline structure** over the entire wall thickness of fitting and pipe in view of the interaction with diverse media. The considerably improved inner surface increases the chemical resistance of the pipes, fittings and valves made of Beta-PP-H even more. The flow behaviour thus optimised **lowers the risks of leach-out and deposits.**
Due to the low internal stress in the pipes and fittings, Beta-PP-H has a **very good stress cracking resistance**.
When considering the range of properties of Beta-PP-H, it becomes obvious that the material demonstrates an ideal **balance between stiffness and toughness**.
Even at lower temperatures, Beta-PP-H has excellent impact resistance, but is still rigid enough to be used as a valve material. Arguments in favour of this are the high dimensional stability and the high tensile modulus of elasticity (see Fig. 2) in comparison to PP-R.

Stiffness

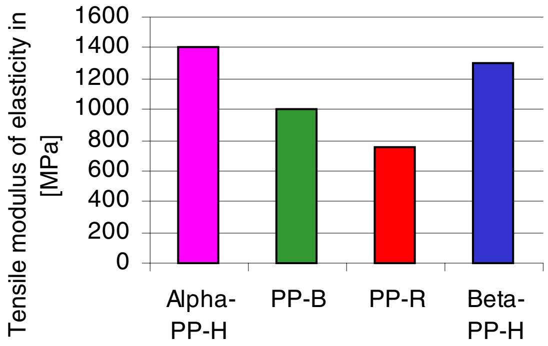


Fig. 2: Tensile modulus of elasticity of different PP types

The excellent properties of Beta-PP-H are further reflected in its long-term pressure test.

Fatigue strength

PP-H has the highest creep strength of the three PP types at 20°C and is classified as MRS 10 (minimum required strength) (see Fig. 3).

Minimum Required Strength

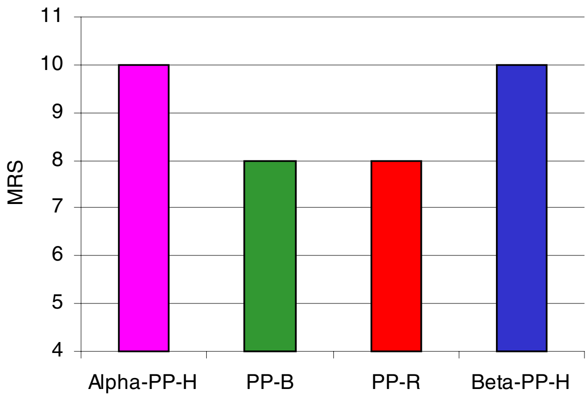


Fig. 3: MRS of different PP types

Beta-PP-H clearly exceeds the corresponding standards of the DVS 2205 concerning the long-term pressure performance; the thermo-oxidative ageing (steep section of the curves, divided by the knee) is shifted to longer times. This means more safety when used at elevated service-temperatures.

Beside the long-term pressure properties of a pipe material, the impact resistance is also of great importance, which is why this is considered in determining the allowable stress in the form of reduction factors.

Material properties of different PP types

Property	Alpha-PP-H	PP-B	PP-R	Beta-PP-H	Unit	Test standard
Density	0.90-0.91				g/cm³	ISO 1183
Yield stress at 23°C	37	28	25	31	MPa	EN ISO 527-1
Tensile modulus of elasticity at 23 °C	≥1400	≥1000	≥750	≥1300	MPa	EN ISO 527-1
Notch impact resistance at 23 °C *	7	51	31	85	kJ/ mm²	DIN EN ISO 179/1eA
Notch impact resistance at 0 °C *	2	5	3	5	kJ/ mm²	DIN EN ISO 179/1eA
Ball indentation hardness (132N)	72	48	49	58	MPa	DIN EN ISO 2039-1
Dimensional stability HDT B (0.45 MPa)	98	78	75	95	°C	ISO 75-B
Coefficient of thermal expansion	$15 \bullet 10^{-5}$				m/m K	DIN 53752
Thermal conductivity at 23 °C	0.23				W/m K	DIN 52612

*Table 1. Material properties of different PP types; *Guide values determined using moulded samples*

Notch sensitivity

To analyse the impact strength, the Charpy impact test according to DIN EN ISO 179-1 has become an established method in Europe.
In Fig. 4 the notched impact tests of various PP types are depicted in relation to temperature. These are minimum values which are achieved in competent processing in the injection moulding, extrusion as well as compression moulding.

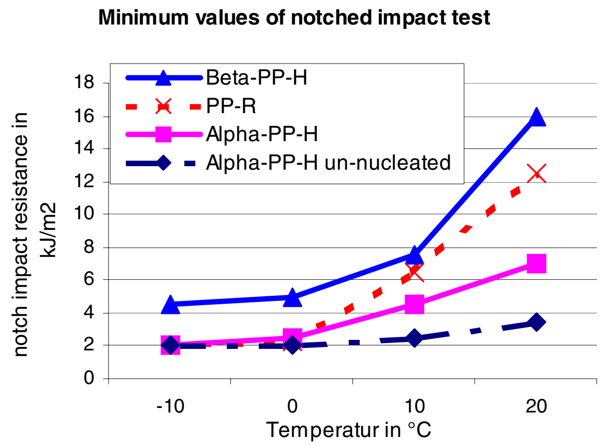


Fig. 4: Minimum values of notch impact strength of different PP types according to DIN EN ISO 179/1eA

These results were determined in a wide-ranging study. Beta-PP-H exceeds the DIN EN 1778 (DVS 2205-1) and the DIN EN ISO 15494 norm requirements over the entire temperature range.

Comprehensive tests on injection moulded test specimens illustrate the high notch impact resistance of Beta-PP-H.

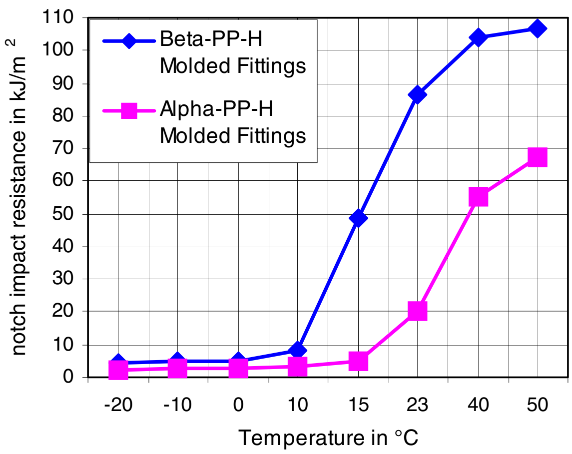


Fig. 5: Notch impact resistance according to DIN EN ISO 179/1eA of different PP-H types on moulded fittings

In comparison to Alpha-PP-H or PP-R, Beta-PP-H has the highest notched impact resistance. This results in a very high level of safety against external impact stress, especially at low temperatures, which could occur during transport, installation or even during operation (e.g. water hammer, vibration) of a piping system.

Welding quality of Beta-PP-H piping systems

The Georg Fischer concept of system solutions, which also applies to the Beta-PP-H line, presupposes that all the individual components are compatible with one another. This is particularly true in the case of welding (butt fusion with heating element or non-contact infrared (IR-Plus)). The material used for pipes and fittings is subjected to one and the same specification that has been adapted to the individual requirements of Georg Fischer.
The Beta-PP-H material used by Georg Fischer shows a melt flow behaviour, which complies with all the requirements of the relevant standard (DVS-2207-11) regarding PP weldability. Georg Fischer Beta-PP-H pipes and fittings can therefore be welded without any problems with other PP pipes in accordance with the DVS, or are compatible as long as the latter also meet the material specifications of the DVS 2207-11.
It has to be the objective of every jointing method of system components to avoid discontinuities in properties or weak spots in the joint. Concerning Beta-PP-H this means that the welding itself should reveal the same characteristics as the pipes and fittings. To examine this aspect in more detail, pipes were joined with fittings (T-piece 110x10 mm) by butt fusion according to DVS guidelines using a heating element as well as with the IR-Plus® technology; the material structure was analysed in the fusion zone and compared to the data measured on the semi-finished product. Fig. 6 shows the results of the structure analysis (WAXS) on the welded Beta-PP-H pipe system.

Structure analysis on welded Beta-PP-H pipe system

Specimen sampling location

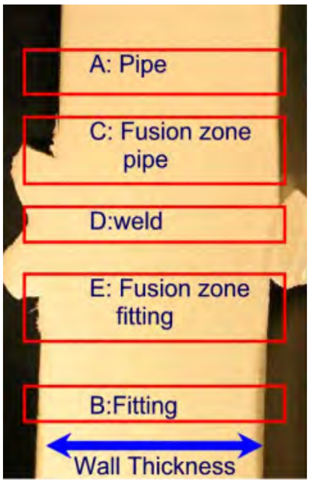
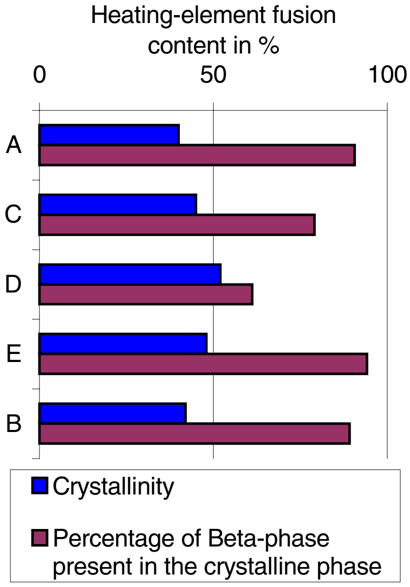
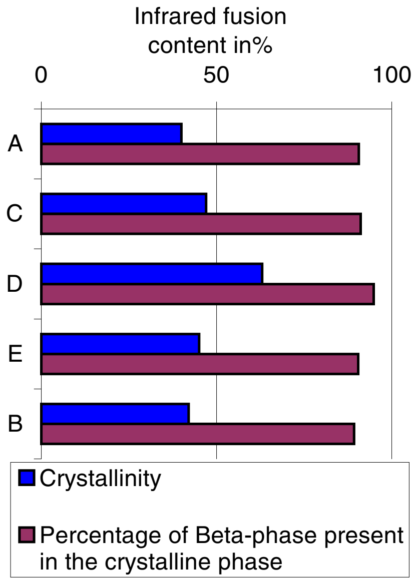


Fig. 6 a.) Illustration of the sampling section (specimen sice 10x10x1mm) for an IR weld: 110x10mm



*b.) Structure analysis (WAXS) on welded Beta-PP-H pipe system – **Heating element** fusion of T-piece with pipe (110 x 10 mm)*



*c.) Structure analysis (WAXS) on welded Beta-PP-H pipe system - **IR Plus**-fusion of T-piece with pipe (110 x 10 mm)*

The correct test method

The wide-angle X-ray scattering (WAXS) is a spectroscopic method to determine the structure e.g. of semi-crystalline polymers. In the case of determination of the crystalline structure of Beta-PP-H, this is the only method possible for reliable results. The conventional and frequently applied method of thermal analysis (DSC) is not applicable due to a phase transition of the beta phase while doing the DSC measurement.

The following statements can be concluded:

- The pipe and fitting show identical structure properties; the extremely high beta crystal content underscores the high quality of the products.
- The full potential of the Beta-PP-H system components has been tapped through optimal processing, i.e. the typical Beta-PP-H properties are completely developed.
- The welding fits harmoniously in the structure of the semi-finished products. There is no change in properties in the welding zone. This holds particularly for the IR Plus® method.
- The many years of excellent experience in practice with the Georg Fischer Beta-PP-H piping systems receive sustainable confirmation from these results.

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Reduction factors (A4 factors)

The impact strength of thermoplastic materials is taken into consideration in determining the degree of stress allowed in the construction of piping systems, containers and equipment using the A4 reduction factor in accordance with the DVS guideline 2205-1 and DIN EN 1778.
The Deutsche Institut für Bautechnik (DIBt) follows this standard or guideline in granting approvals for building regulations in the area of media hazardous to water.

The allowable stress is determined according to the DVS guideline 2205-1 and DIN EN 1778 as follows:

$$\sigma_{zul} = \frac{K(A1,A3) \cdot f_s}{A2 \cdot A4 \cdot S} \quad \text{Eq.1}$$

σ_{zul} allowable stress
K(A1,A3) creep strength at given temperature
f_S welding factor
A1 dependence of strength on stress duration
A2 effect of medium conveyed
A3 dependence of strength on temperature during stress duration
A4 effect of specific impact resistance
S safety factor

The reduction factor A4 takes into consideration the effect of the specific impact strength of the material. According to the DVS, a material is defined as tough when the notch impact resistance exceeds 16 kJ/m^2 at room temperature. The reduction factor is then assigned the value 1. For a material behaviour, which is characterised as brittle – for example glass –, the reduction factor has been established at the value 2. Per definition this corresponds to a notch impact strength of 1 kJ/m^2 at room temperature. The calculation of the reduction factors ($1 \leq A4 \leq 2$) follows an (empirical) exponential function.
With a view to the impact strength of the different materials, the respective reduction factors are illustrated in Table 3.

Despite the clear differences substantiated in experiments of the notch impact strength within the class of different PP compounds (especially the comparison between “conventional Alpha-PP-H and Beta-PP-H”), the values indicated in Table 3 have not been taken up in the standard yet.

Georg Fischer, however, recommends the use of the A4 factors as calculated in table 3 for all its Beta-PP-H products.

A comprehensive and up-to-date report on the subject matter referred to here can be found in Reinhardt, G., *3R International 5/***2003**, 42.

Overview of reduction factors

material	**A4- Reduction factors**					
Temperature [°C]	**-10**	**0**	**10**	**15**	**23**	**40**
PP-H per DVS 2205-1	1.8	—	—	—	1.3	1.0
PP-R per DVS 2205-1	1.5	—	—	—	1.1	1.0
PP-H per DIN EN 1778	1.8	—	—	—	1.3	1.0
PP-R per DIN EN 1778	1.2	—	—	—	1.0	1.0

Table 2: Material-related reduction factors according to DVS 2205-1 and DIN EN 1778

material	**A4- Reduction factors**					
Temperature [°C]	**-10**	**0**	**10**	**15**	**23**	**40**
Alpha PP-H (un-nucleated)	1.8	1.8	1.75	1.65	1.3	1.0
Alpha PP-H	1.8	1.7	1.5	1.4	1.3	1.0
Beta-PP-H	1.55	1.5	1.35	1.0	1.0	1.0
PP-R moulding compound	1.8	1.7	1.4	1.1	1.0	1.0

Table 3: Material-related reduction factors based on notched impact tests

More safety thanks to exceptional toughness

The allowable operational stress on a piping system is calculated according to Eq. 1. If the same A4 reduction factors are used here for Beta-PP-H as for Alpha-PP-H, then significantly better safety against impact stress can be achieved based on the notch impact resistance values (see Fig. 4 and 5) and the corresponding long-term pressure behaviour of the respective PP types for Beta-PP-H in the range of minus 10°C to plus 40°C, since the toughness potential of Beta-PP-H is not entirely utilised.

Fig. 7 shows the high safety reserves of Beta-PP-H. Especially at low temperatures, in case of water hammer, vibrations and improper handling during transport and installation, Beta-PP-H offers extra safety due to its excellent notch impact resistance. Based on this high safety, a Beta-PP-H piping system can be dimensioned at the same level as a PP-R piping system.

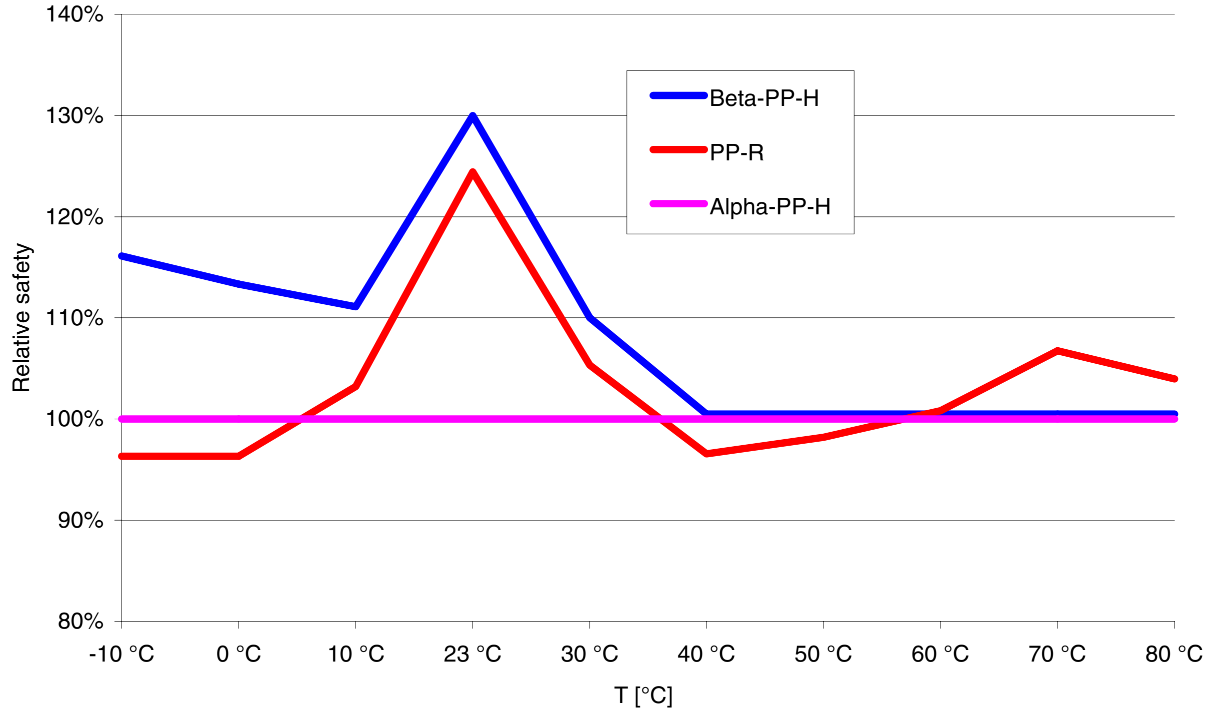

Fig. 7: Safety reserves of Beta-PP-H ("Matterhorn effect")

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Chemical resistance

For industrial piping systems, in addition to the creep strength and the impact resistance, the chemical resistance of the piping material is of major importance.

The preferred point of chemical attack or diffusion / swelling of PP pipes which come into contact with media is the amorphous, i.e. randomly arranged area between the crystallites of a semi crystalline material. Because of the special nucleation of Beta-PP-H and a processing technique which is adapted optimally to the material, the best possible crystallinity, in other words a reduction of the amorphous section, as well as a very fine crystalline structure is achieved (see Fig. 1). In this way and in combination with the very good quality of the inner surfaces, the penetration of chemicals or an attack on the surface can be dramatically reduced. An exceptionally efficient heat stabiliser system also creates a long-lasting buffer against thermo-oxidative degradation. For the colour, a high-quality titanium dioxide (TiO_2) is used as a chemically inert pigment. Extensive long-term practical tests, long-term pressure tests under chemical exposure or simple immersion tests have confirmed the superior chemical resistance of Beta-PP-H pipes from Georg Fischer which come into contact with the many relevant media classes in practice. Beta-PP-H meets with a large safety margin the requirements of the current draft of the DIBt mould compound listing for PP also in relation to the FNCT test.

Georg Fischer offers the chemical industry a solution ideally suited to their specific requirements in terms of chemical resistance of PP in the form of Beta-PP-H.

For detailed information, please check the comprehensive list of chemical resistances from Georg Fischer or contact your Georg Fischer subsidiary.

The good chemical resistance of Beta-PP-H is especially evident in contact with oxidative media; Fig. 8 shows a section of a PP pipe used to convey a 30% hydrogen peroxide solution (T=20-30°C; p <1bar) after a working duration of 6 years. DEKAPROP Beta-PP-H was used for the pipe, a PP-copolymer for the fitting.

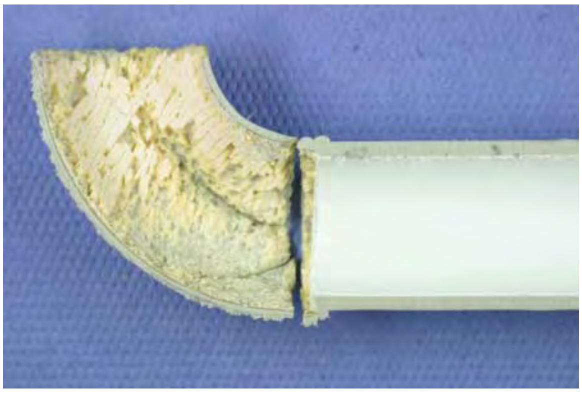


Fig. 8: PP-copolymer fitting and Beta-PP-H pipe in contact with oxidative hydrogen peroxide solution.

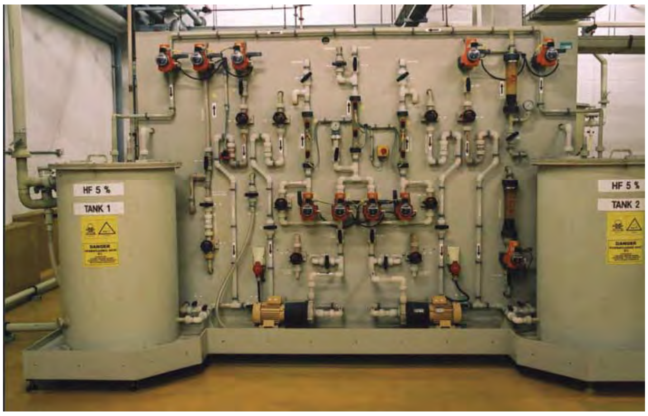
Beta-PP-H in use

Due to its excellent chemical resistance and its ideal balance of mechanical properties, Beta-PP-H has made a name for itself in industry during the more than twenty years of its use as a piping system material. The following examples give an idea of the wide range of possible applications for Beta-PP-H from Georg Fischer:

Surface treatment plant at Krupp Presta in Liechtenstein

Phosphate baths, which must be both rinsed and heated, are used at the surface treatment plant. The heating pipes made of Beta-PP-H are therefore exposed to a temperature of up to 92°C and an internal pressure of 3 bar.
Alkalis heated to 70° flow through the rinsing pipes.
The very good alkali resistance of Beta-PP-H is also given at high temperatures.

Acids batching unit for display manufacturing at Philips



To clean and prepare TV screens as well as to etch the inner side of the television tubes, highly corrosive and toxic media, such as hydrofluoric acid (HF) need to be conveyed.
Beta-PP-H has very good chemical resistance against numerous acids, even at higher temperatures. That is why the Philips company decided to use this material.

Piping systems for printed circuit board production

In manufacturing printed circuit boards (PCBs), highly corrosive media such as hydrochloric acid, sulphuric acid, caustic soda solution, caustic potash solution and other alkaline etching agents are conveyed through piping systems at temperatures of up to 70°C and pressures of ca. 2-3 bar.
Beta-PP-H stands up to these extreme conditions and thus contributes to safety in production.

Proven in practice: Beta-PP-H is ideal for applications with contact to highly aggressive chemicals, whether acids or alkalis. Beta-PP-H is also very resistant to many solvents.

The advantages of Beta-PP-H in summary

Having used a standard material of the polypropylene homopolymer for many years, Georg Fischer decided more than ten years ago to change to the beta-nucleated PP-H from the Borealis company. Over this time, Beta-PP-H has proven to be an excellent piping material, especially for the chemical industry.

Here, at a glance, its most outstanding features:

⇒ Complete line of products in one material: pipes,
manual and actuated valves, socket and butt fusion fittings

⇒ Several jointing technologies to choose from:
Flange connections, unions, socket, butt or IR fusion

⇒ Highest pressure resistance of all PP types in piping system construction (MRS10)

⇒ Highest product quality is documented by DIBT approval
– far superior to the DIN 8077/78 standard

⇒ Excellent, long-term, proven chemical resistance due to special formulation and in-house processing technology (surface quality, special structure)

⇒ Excellent balance between stiffness and ductility

⇒ Constant material property profile in the entire system
– even in the welding zone

⇒ Superior impact resistance compared to any Alpha-PP-H or PP-R
Much tougher than required by the respective standards
and thus higher safety reserve for:

- Stress below room temperature
- Multi-axial states of stress
- Water hammer and vibrations
- Improper handling during transport and installation

⇒ Due to this high safety, a Georg Fischer Beta-PP-H piping system can be dimensioned at the same level as a PP-R piping system.

Based on 35 years of know-how in PP pipe, fitting and valve manufacturing, testing, and jointing, you can rely on Georg Fischer!

C. Rytka, May 2003

Global Support

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for Quality and Management Systems

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SQS Certificate
ISO 9001:1994 / ISO 14001:1996

ISO 9001 quality management systems are the foundation for the continuous improvement of our services.

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