

# Ketoprix™ Polyketone - A Unique Value Proposition for demanding applications

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Crystalline thermoplastic resins (i.e. PA, PPS, POM, PP) generally provide better chemical resistance than do amorphous (i.e. PC, ABS, PS, PMMA) resins and Ketoprix™ polyketone is no exception to this rule. However, crystalline resins rarely exhibit resistance to attack by a broad range of chemicals, have excellent practical toughness AND good strength properties. Typically crystalline resins *either* exhibit good strength values *or* good toughness but rarely both. For example, PBT, POM, PA, PPS, and PPA exhibit good strength and stiffness but generally do not exhibit good practical toughness (impact resistance) - particularly at low temperatures. On the other hand some PE co and ter polymers do offer good practical toughness but exhibit relatively low strength and stiffness. In this way Ketoprix™ polyketone resins offers a unique value proposition with the combination of excellent ductility (toughness) at room and sub-ambient temperatures, and high strength values as well as excellent resistance to attack by a wide range of chemicals.

When a thermoplastic part is subjected to an impact load it will dissipate the energy in one of two ways: it will deform without breaking or it will deform and crack or shatter. The primary material property that determines which of these outcomes occurs is whether or not the imposed strain (deformation) related to the impact event exceeds the elongation at break value for the material used to produce the part. Said another way – the higher the elongation at break value a material exhibits the more impact resistant the material. As can be seen in table 1 below the tensile elongation at break for unreinforced grades of Ketoprix™ polyketone resins are very high for a crystalline resin with high strength values which translates into the ability of the material to dissipate high levels of impact energy without cracking or shattering. In other words, it's tough!

Table 1. Tensile Elongation @ break, 23C for several crystalline resins

| Resin                             | POM | PA66, dry | GF PPS | PVDF | Ketoprix™ |
|-----------------------------------|-----|-----------|--------|------|-----------|
| Tensile Elongation @ break, 23C,% | 45  | 25        | 1.2    | 35   | >350      |

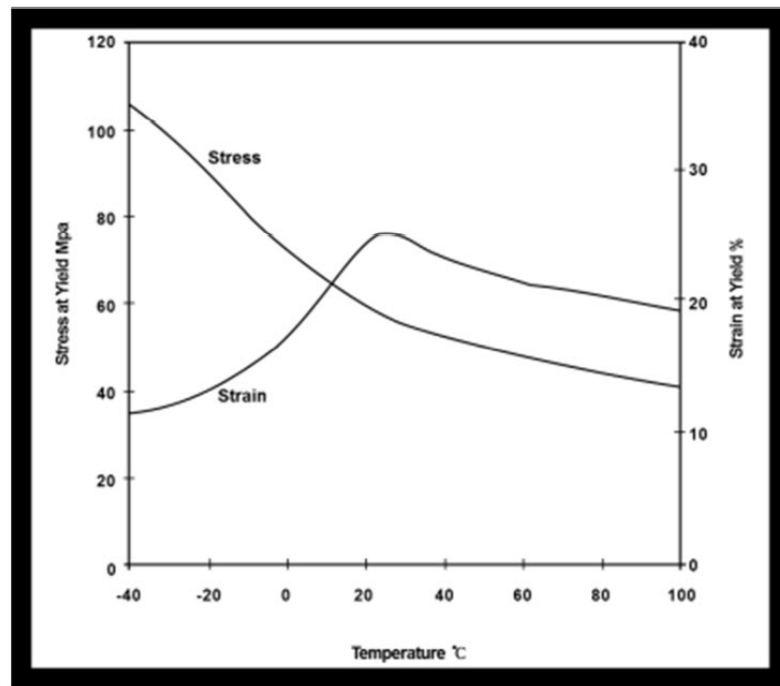
Similarly, the ability of a resin to sustain numerous impact events without cracking, or repeated loading to high strain rates such as occurs with multiple snap fit assembly-disassembly cycles without failure is reflected in the tensile elongation at yield value exhibited by the resin. Simply put the greater this value, the greater the deformation the part made from the material can survive without permanent damage. As is shown in Table 2 below, Ketoprix™ polyketone resins excel in this regard as well.

Table 2. Tensile Elongation @ yield, 23C for several crystalline resins

| Resin                             | POM | PA66, dry | GF PPS | PVDF | Ketoprix™ |
|-----------------------------------|-----|-----------|--------|------|-----------|
| Tensile Elongation @ yield, 23C,% | 10  | 4.5       | 1.2    | 7    | ~25       |

Ketoprix™ polyketone resins also retain their ductility over a wide range of temperatures as is reflected in the graph below which provides tensile stress and strain values for an unfilled grade of Ketoprix™

polyketone resin at temperatures ranging from -40 C to 100 C. As is shown there the tensile elongation at yield for this resin is greater than 10% even at -40C! For frame of reference the tensile elongation at yield for a general purpose unreinforced polycarbonate resin –which is one of the most ductile of thermoplastic resins - is in the range of 5-7% at 23C.



Perhaps the most commonly overlooked fundamental indications of a materials toughness is the tensile stress-strain test. When this test is performed an axial load is applied to a standard specimen and the resultant deflection measured. When these values are plotted the area underneath this curve is proportional to the energy absorbed by the material during the test. Accordingly, the higher the load (strength) and elongation at yield values a resin exhibits the greater the area underneath this curve will be and therefore so is the amount of energy absorbed by the material during the test. Therefore, when a material has both higher strength and elongation at yield, as does Ketoprix™ polyketone, this is an indication that the material should be able to survive high levels of impact energy without failure. It is important to remember when reviewing tensile-stress strain data that due to the inherent viscoelastic nature of all thermoplastics the mechanical response of the material to loading is both temperature and rate dependent so whenever possible data which is collected at the temperature your applications may be exposed to will provide the most relevant insight into how the material will behave in the conditions your part will experience.

There are also a number of standardized impact tests utilized in the thermoplastics industry as a means to quantify a resins' toughness/impact resistance. Some of the more common are:

- \*Izod Impact (Notched & Un-Notched)
- \*Charpy Impact (Notched & Un-Notched)
- \*Instrumented Impact

### \*Tensile Impact

Perhaps the most commonly referenced test method among these is Notched Izod Impact resistance. In this test a standardized rectangular bar with a specific notch cut in the center of the sample is clamped on one end in a vise and impacted on the side of the bar opposite this notch with a weighted pendulum. The amount of energy required to fracture the bar is reflected in the distance the pendulum travels beyond the clamp where the sample is mounted. As can be seen in table 3 below Ketoprix™ polyketone excels in this regard not only at room temperature but in sub ambient temperatures as well when compared to some other crystalline resins.

Table 3. Notched Izod Impact at 23C & -40C for several crystalline resins

| Resin                          | POM | PA66, dry | GF PPS | PVDF | Ketoprix™ EK63 |
|--------------------------------|-----|-----------|--------|------|----------------|
| Notched Izod Impact, J/m, 23C  | 64  | 53        | 91     | 160  | 240            |
| Notched Izod Impact, j/m, -40C | 43  | 27        | N/A    | N/A  | 50             |

While it is common to find crystalline resins which offer good strength these resins are typically not very tough (ductile or impact resistant) and those crystalline resins which do offer good impact resistance typically do not offer good strength values. As noted previously it is this combination of properties which makes Ketoprix™ polyketone resins a unique value proposition since it does afford high strength and good impact resistance as shown in Table 4 below.

Table 4. Tensile strength, elongation and Notched Izod Impact values for two grades of Ketoprix™

| Property                          | Ketoprix™ EK33 | Ketoprix™ EK63 |
|-----------------------------------|----------------|----------------|
| Melt Flow Rate, g/10min           | 60             | 6              |
| Tensile Strength, yield, 23C, psi | 8700           | 9400           |
| Tensile Elongation, yield, 23C, % | 20             | 25             |
| Tensile Elongation, break, 23C, % | >250           | >350           |
| Notched Izod Impact, 23C, j/m     | 107            | 240            |

Ketoprix™ polyketones exhibit another unique and valuable trait as well. As is the case with many crystalline resins they readily accept reinforcement; however, unlike what usually happens when glass fiber is added to a resin glass reinforced Ketoprix™ polyketone resins retain their good practical toughness. As a result glass reinforced grades of Ketoprix™ polyketone resins exhibit not only very high strength properties but excellent impact resistance as well. For example EKT33G3P Ketoprix™ polyketone exhibits a tensile strength of approximately 22,500 psi with a Notched Izod Impact value of approximately 2.4 ft-lb/in (128 j/m) at 23C in the dry as molded state.

Owing largely to their di-polar and semi-crystalline morphology Ketoprix™ polyketone resins exhibit excellent resistance to attack by a broad range of chemicals including:

- Aromatic & aliphatic hydrocarbons
- Ketones, esters & ethers
- Inorganic Salt Solutions

- Weak Acids & bases

There are in fact few known solvents for Ketoprix™ polyketone resins. The structure of the resin also confers excellent permeation resistance to aliphatic and aromatic hydrocarbons. As a result the material is widely used in hydrocarbon barrier applications resins.

In addition to resistance to attack by a broad range of chemicals the carbon-carbon backbone of the resin ensures that it exhibits good hydrolytic stability with only limited affinity for moisture. This inherent hydrolytic stability and chemical resistance is reflected in the data in table 5 below. The table provide tensile strength at yield values for Ketoprix™ EK63 polyketone resin after 25 days exposure to various aqueous environments for 25 days as compared to type 6,6 polyamide (nylon).

Table 5. Hydrolytic stability data for Polyketone & Polyamide 6,6

| Chemical                | POLYKETONE<br>M630A<br>MPa | Polyamide 66<br>MPa |
|-------------------------|----------------------------|---------------------|
| Control (50% Rh)        | 60.0                       | 57.2                |
| Water                   | 59.2                       | 33.1                |
| Seawater                | 60.0                       | 33.1                |
| 5% w/w Acetic Acid      | 54.9                       | 33.8                |
| 5% w/w Calcium Chloride | 60.0                       | 33.8                |
| 50/50 Antifreeze        | 59.2                       | 35.8                |

Tensile testing to ASTM D638 was conducted at 23°C

Some examples of applications where Ketoprix™ polyketone resins present an excellent value proposition as a result of this unique combination of properties are under the hood automotive connectors, fuse boxes, gears for appliances and printers, pumps & valves in the chemical processing and agricultural industries, plumbing and conveying applications as well as fuel lines, radiator end tank caps and oil/gas pipelines.



To summarize, if your application requires good strength and practical toughness while being resistant to attack by a broad range of chemicals along with hydrolytic stability, Ketoprix™ polyketone resins offer an excellent value proposition.



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### Three Reasons you Should Consider Ketoprix Polyketone for your Medical Devices

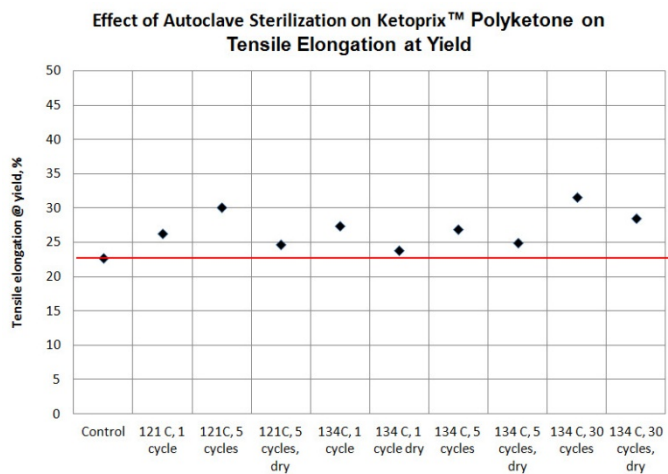
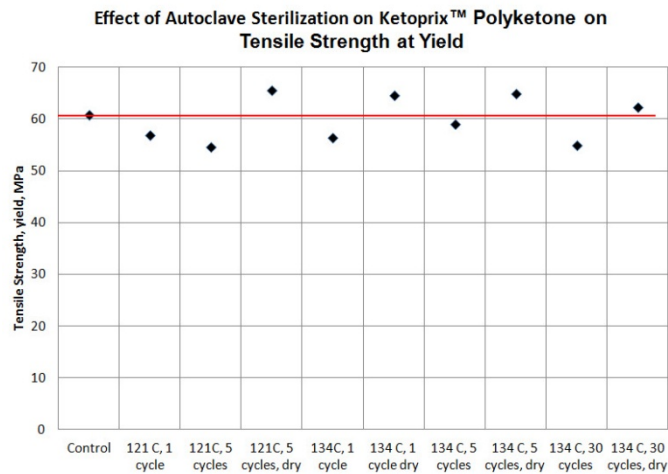
Thermoplastics are increasingly being used to replace glass and metals in medical devices due to their design flexibility, economics and overall ease of use. However, medical device applications do present some significant and unique challenges which can be problematic for some polymers. For example these devices typically require sterilization, can be exposed to aggressive cleaning agents and often incorporate fine detail or very thin walls in their designs. The designer must take care to address these considerations when selecting a resin as not all materials are equally suited for use in these demanding applications. Ketoprix™ aliphatic polyketone is uniquely suited for use in these types of applications as its' properties are virtually unaffected by all common sterilization techniques, offers excellent chemical resistance and exhibits very low melt viscosity with rapid crystallization rates.

#### **Effects of common sterilization methods**

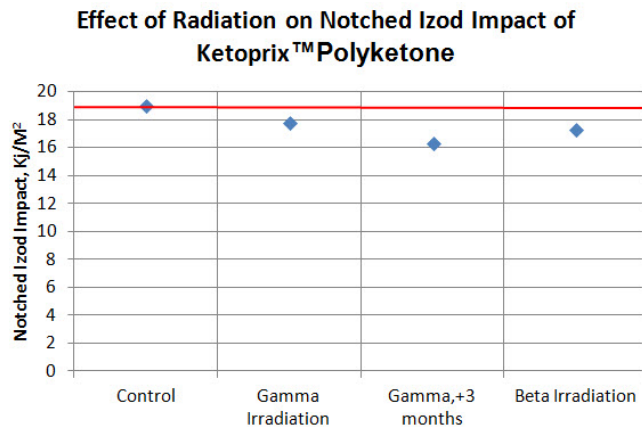
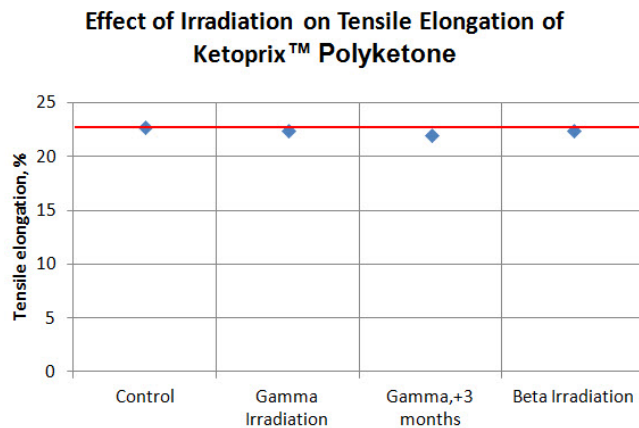
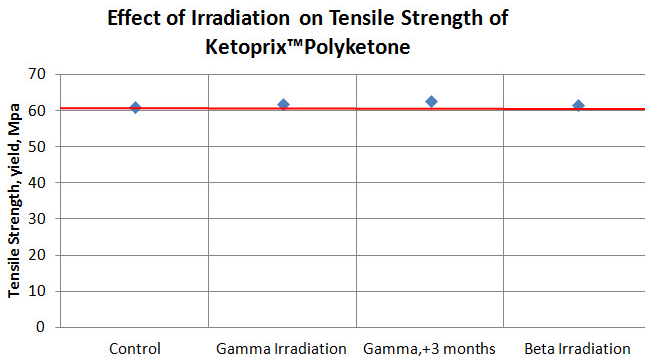
All medical devices require sterilization prior to use. In the case of reusable devices the part will see multiple sterilization cycles during its' life cycle which greatly increases the importance of addressing this consideration when selecting a resin. There are four general types of sterilization processes in use today. These are: dry heat, autoclave, irradiation and gaseous chemicals.

Although effective and inexpensive dry heat is rarely utilized with devices which utilize thermoplastic resins due to the oxidation effects this technique has with many polymers. However, autoclaving is a commonly used process as it is effective, capital equipment costs are comparatively low and there are minimal industrial hygiene considerations as compared to radiation and gaseous treatment methods. However, this method of sterilization is generally not well suited for use with parts molded from condensation polymers such as acetal, nylon, polyesters and polycarbonate – particularly in items are subject to repeated sterilization. This is due to the cumulative effects of hydrolytic degradation with these types of resins which typically leads to embrittlement.

As is shown in the charts below even with as many as 30 autoclave cycles at 134 C there is no significant loss of strength or toughness in the polymer is as common with many polymers when subjected to repeat autoclave sterilization cycles.



Irradiation is another commonly utilized sterilization technique and with the radiation usually generated by either cobalt 60(  $C_{60}$ ) or electron beam (E-b). Both methods are effective however the effects of radiation on thermoplastics are cumulative and particularly for reusable items which will require multiple sterilization cycles some damage to the polymer is inevitable with these sterilization techniques. This extent of this damage varies from one polymer to another and is dependent upon the total radiation dosage as well as the environment in which the sterilization is performed. In particular when performed in the presence of oxygen the process can produce peroxides which give rise to the formation of free radicals in the polymer matrix. These free radicals are then available to propagate the chain scission process thereby leading to a loss of properties over time. While the actual dosage required to sterilize an item will vary depending on the actual bio-load involved generally speaking a dosage of 2.5 Mrad in air is sufficient to sterilize clean items. However, in anaerobic conditions the required dosage may be as much as twice as high. Unfortunately many polymers, including PTFE, PA and POM are only resistant to significant damage from irradiation up to about 2.5 Mrad. However, as is shown in the charts below Ketoprix™ polyketone resins show no significant loss of strength or ductility after exposure to 3.5 Mrad gamma or 2.5 Mrad beta irradiation even up to 3 months after exposure.



Sterilization using gaseous chemicals can be accomplished with a number of different chemicals the most common of which is ethylene oxide (EtO). The majority of thermoplastics, including Ketoprix™ polyketone, are unaffected by EtO ; however, EtO is regarded by the EPA as toxic as well as possibly carcinogenic . Therefore since some resins absorb EtO during the sterilization process the rate at which residual EtO can be removed from the item being sterilized becomes important. The maximum permissible EtO content after sterilization is 20 ppm for medical devices not in direct contact with the human body. Following a ‘severe’ sterilization cycle at 50 C with an EtO concentration of 800 mg/l for four hours Ketoprix™ polyketone samples aerated with dry air at 40C for 5 days 4 mm thick specimens exhibited an EtO content of 17 ppm. Note that the rate at which sterilization occurs and at which residual EtO is liberated from a thermoplastic part is dependent upon several variables including part thickness. The thicker the part, the more time will be required to remove residual EtO content.





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## Disinfection

There are many durable medical devices which do not require sterilization but do require disinfecting periodically. The most common disinfectants used for this purpose are various compositions of quarternary ammonium compounds. These compounds attack many thermoplastics. However, as discussed in a previous article ([insert link to LI article on chemical resistance here](#)) Ketoprix polyketone resins are resistant to attack by a broad range of chemicals including quarternary ammonium compounds as is shown in the table below which provides test results for Ketoprix™ polyketone when exposed to a 10% aqueous solution of ammonium hydroxide for 100 days at room temperature. It should be noted that 10% is a much higher concentration than is typically recommended or used with disinfectants and the exposure is much more severe than would be experienced when used for cleaning. For example, one particular such disinfectant often used in medical facilities recommends a dilution rate of 1:256.

## Resistance to attack by ammonium hydroxide

Sample    Tensile Strength,psi    Tensile Elongation, %

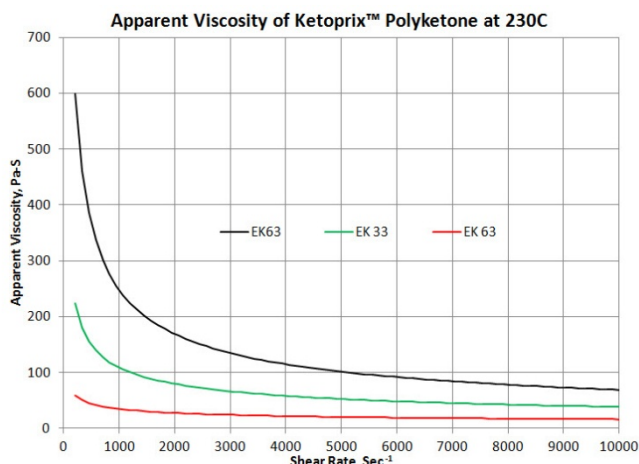
|         |       |    |
|---------|-------|----|
| Control | 8,294 | 25 |
| Exposed | 8,294 | 23 |

## Molding considerations

As is true with many types of applications technology advances are resulting in ever smaller devices in the medical field with greater detail density and thinner wall sections. This presents a significant molding challenge with many resins as the flow length to wall thickness ratio increases along with increasingly complex filling patterns during the molding process. Ketoprix™ polyketone offers a distinct advantage in this regard due to its' inherently low viscosity, rapid crystallization rate and relatively low processing temperature requirements.

Ketoprix™ polyketone resins are available in a wide range of viscosities with melt flow index values ranging from 3 to 350 g/10 min. However, as this test is conducted at very low shear rates these values do not reflect the high degree of shear thinning exhibited by these resins during the molding process. In the image below are apparent viscosity curves for three grades of Ketoprix™ resins at a temperature

of 230 C which span the range of 6 to 350 g/10 min MFI values. As can be seen there at the high shear rates which approach those common to injection molding there is no practical difference (<20 Pa-S) in the apparent viscosity of these resins even at the low end of the suitable temperature range for molding these materials.



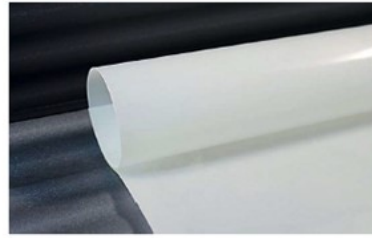
This significant shear thinning effect and resultant low apparent viscosity results in a material which that can be molded in thinner wall sections in parts with more tortuous filling patterns at lower clamp tonnage. This permits part designs with greater complexity and functionality.

The rapid crystallization rate of Ketoprix™ polyketone resins translates to faster cooling time when injection molding. This of course translates into reduced overall cycle time which equates to improved productivity and lower product costs. Typical cycle time reductions of 10-15% can be achieved vs. other resins such as type 6,6 nylon, acetal and polyesters. Cycle time reductions will be significantly greater than this vs. amorphous materials such as polycarbonate and ABS.

To summarize Ketoprix™ polyketone resins offer the designer a material which is resistant to the effects of all common sterilization techniques, exhibits excellent resistance to attack by common disinfectants and is easily molded in thin walled intricate designs with reduced cycle times. Combine all of these important attributes with very attractive economics and it's easy to see why Ketoprix™ polyketone resins are very well suited for use in medical applications and should be considered for your new designs.

## Project Information

- Current material : Multi-layer of PE-EVOH
- Product : **M620F, M630F of Polyketone**
- Customer : Film Extruders in US
- Film thickness : 20mil to 0.5mil  
(500micon to 12micron)



## Customer Requirements

- Gas Barrier property
  - N<sub>2</sub>, H<sub>2</sub>SO<sub>4</sub>, CH<sub>4</sub>, CO<sub>2</sub>, O<sub>2</sub>, Water
- Chemical Resistance
  - Crude oil, Fuel, Acid, Alkali
- Low moisture absorption
- Dimensional stability
- Low scratch, Low abrasion loss

## Value In Use

- Physical property retention than PE, EVOH
- Good performance of Gas Barrier
  - Similar EVOH, **but** competitive price
- Good performance of Fuel resistance
  - Better than PA11/12 **and** competitive price
- Multi-pile layer of EVOH only **but** to make mono-layer of PK with same property

## Why Polyketone?

### 2. Gas Permeability (1)

CH<sub>4</sub>

| Temperature,<br>°C | Relative Humidity<br>% | Permeability, 10 <sup>9</sup> × cm <sup>3</sup> / cm <sup>2</sup> × s × bar |                           |      |
|--------------------|------------------------|---|---------------------------|------|
|                    |                        | PK  | PA11 (Rilsan BESNO P40TL) | HDPE |
| 20                 | 0                      | -   | 0.60                      | -    |
| 40                 | 0                      | -   | 2.00                      | -    |
| 60                 | 0                      | -   | 5.50                      | -    |
| 80                 | 0                      | 4.70  | 15.0                      | -    |
| 100                | 0                      | 11.1  | 35.0                      | -    |
| 120                | 0                      | 27.6  | -                         | -    |

PK data measured at IFP (French Institute of Petroleum)  
PA data cited from Rilsan BESNO P40TL data sheet.

CO<sub>2</sub>

| Temperature,<br>°C | Relative Humidity<br>% | Permeability, 10 <sup>9</sup> × cm <sup>3</sup> / cm <sup>2</sup> × s × bar |                           |      |
|--------------------|------------------------|---|---------------------------|------|
|                    |                        | PK  | PA11 (Rilsan BESNO P40TL) | HDPE |
| 20                 | 0                      | 2.4   | 7.1 (6.0)*                | 27.4 |
| 50                 | 0                      | -   | (21)                      | -    |
| 60                 | 0                      | 5.4   | 52.4                      | 104  |
|                    | 50                     | 6.9   | 58.9                      | 106  |
| 75                 | 0                      | -   | (54)                      | -    |
| 100                | 0                      | -   | (110)                     | -    |

Data measured on commercial sheet (0.5mm thick) at Mocon  
\*( ) : PA data cited from Rilsan BESNO P40TL data sheet

## 2. Gas Permeability (2)

### 3.2. Comments on the simulation program

Table 2 shows the present known permeability's of Rilsan (Polyamide), Solef and Coflon (both PVDF's), HDPE and Carilon (note that not all values are known). The polymers with (Depl) are deplasticised polymer grades. Absence of plastisation components in the polymer has a tremendous reducing effect on the permeability. From these figures, one can already estimate the permeation rates. However, the extra information obtained with the simulation program, is the time scale of the pressure build up. Furthermore, the program allows gas consumption via corrosion of steel.

**Table 2. Permeation constants for gases through polymers present in program.**

|                         | Rilsan   | Solef    | Solef (Depl.) | Coflon   | Coflon (Depl.) | HDPE     | Carilon  |
|-------------------------|----------|----------|---------------|----------|----------------|----------|----------|
| CH <sub>4</sub> Pe°     | 1.30E-01 | 7.12E-02 | 1.60          | 3.87E-04 | 1.51E+00       | 3.76E-02 | 1.93E-03 |
| E <sub>a</sub> (kJ/mol) | 47.7     | 40.6     | 56.5          | 27.3     | 57.1           | 40.6     | 38.5     |
| CO <sub>2</sub> Pe°     | 7.91E-04 | 1.94E-03 | -             | 6.88E-04 | 8.43E-01       | 5.06E-04 | 3.39E-03 |
| E <sub>a</sub> (kJ/mol) | 28.5     | 23.5     | -             | 23.8     | 49.3           | 30.1     | 32.9     |
| H <sub>2</sub> S Pe°    | 2.40E-02 | 1.18E-03 | 3.00E-02      | -        | 3.37E+00       | 7.00E-03 | -        |
| E <sub>a</sub> (kJ/mol) | 32.9     | 20.6     | 51.3          | -        | 49.3           | 39.7     | -        |
| N <sub>2</sub> Pe°      | -        | -        | -             | -        | -              | 9.91E-03 | -        |
| E <sub>a</sub> (kJ/mol) | -        | -        | -             | -        | -              | 39.7     | -        |
| O <sub>2</sub> Pe°      | -        | -        | -             | -        | -              | 4.23E-03 | -        |
| E <sub>a</sub> (kJ/mol) | -        | -        | -             | -        | -              | 35.1     | -        |
| H <sub>2</sub> O Pe°    | 3.26E-04 | 3.23E-07 | -             | -        | -              | 2.87E-07 | -        |
| E <sub>a</sub> (kJ/mol) | 30.2     | 14.5     | -             | -        | -              | 18.5     | -        |

"-" means no permeability happen

# Why Polyketone?


## 2. Gas Permeability (3)

| Polymer | Oxygen | Hydrogen |
|---------|--------|----------|
| EVOH-F  | 0.01   | 3.8      |
| EVOH-S  | 0.06   | 11       |
| Barex   | 0.80   | 4.5      |
| MXD-6   | 0.32   | -        |
| PVDC    | 0.15   | 0.1      |
| PA6     | 3.6    | 22       |
| PET     | 3.5    | 1.2      |
| PP      | 160    | 0.7      |
| HDPE    | 150    | 0.4      |
| PS      | 260    | 9.0      |
| PK      | 0.06   | 11       |

Source: Shell

Polyketone is its high barrier effect compared with many low-molecular media such as oxygen or fuel. Compared with other barrier materials such as EVOH, PVDC, and MXD-6, PK(Polyketone) exhibits similarly favourable values. Depending on specific requirements, it is even possible to replace complex multiple layer systems (multiple layer pipes made of PA 12 and PVDF) with a mono-system using PK



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[FCN No. 1562](#)

### FCN No. 1562

#### Hyosung Corporation

According to Section 409(h)(1)(C) of the Federal Food, Drug, and Cosmetic Act, food contact substance notifications (FCNs) are effective only for the listed manufacturer and its customers. Other manufacturers must submit their own FCN for the same food contact substance and intended use.

|   |  |
|---|--|
| <b>Food Contact Substance:</b>  | Carbon monoxide-ethylene-propylene terpolymer (CAS Reg. No. 88995-51-1).   |
| <b>Notifier:</b>  | Hyosung Corporation  |
| <b>Manufacturer:</b>  | Hyosung Corporation  |
| <b>Intended Use:</b>  | For use in articles intended for repeated-use in food processing establishments, for multilayer flexible packaging for refrigerated food products, and for reheatable or microwavable rigid retort packaging for food, except for use in contact with infant formula and breast milk (see Limitations/Specifications).   |
| <b>Limitations/Specifications<sup>**</sup>:</b>                           | For use in contact with all foods, except beverages containing more than 8 volume percent alcohol, under Conditions of Use A through H, as described in Table 2. The maximum thickness of the FCS is 10 mil. The FCS is not for use in contact with infant formula and breast milk. Such uses were not included as part of the intended use of the substance in the FCN. |
| <b>Effective Date:</b>  | Jan 9, 2016  |
| <b>National Environmental Policy Act (NEPA)<sup>***</sup> Submission:</b> | Environmental Assessment (in PDF)  |
| <b>FDA Decision:</b>  | Finding of No Significant Impact (FONSI)   |

<sup>\*\*</sup>See Food Types and Conditions of Use for Food Contact Substances.

<sup>\*\*\*</sup>More about Environmental Decisions and Definitions of Environmental Terms.

See also Inventory of Environmental Impact Decisions for Food Contact Substance Notifications.

# 1. Comparison of Chemical Resistance



: Observed Change after 10 days and 20 days Immersion

| Solvent/Source         | Temp. | 10day               | 20day               |                      |
|------------------------|-------|---------------------|---------------------|----------------------|
|                        |       | POK                 | POK                 | BAREX                |
| Ethyl Alcohol          | 23°C  | None                | None                | None                 |
|                        | 38°C  | None                | None                | None                 |
| Ethylene Glycol        | 23°C  | None                | None                | None                 |
|                        | 38°C  | None                | None                | None                 |
| Isopropyl Alcohol      | 23°C  | None                | None                | None                 |
|                        | 38°C  | None                | None                | None                 |
| Benzene                | 23°C  | None                | None                | None                 |
|                        | 38°C  | None                | None                | None                 |
| Toluene                | 23°C  | None                | None                | None                 |
|                        | 38°C  | None                | None                | None                 |
| Xylene                 | 23°C  | None                | None                | None                 |
|                        | 38°C  | None                | None                | None                 |
| D-Limonene             | 23°C  | None                | None                | None                 |
|                        | 38°C  | None                | None                | None                 |
| Acetone                | 23°C  | None                | None                | Frosted, Softened    |
|                        | 38°C  | None                | None                | Frosted, Softened    |
| Methyl Ethyl Ketone    | 23°C  | None                | None                | Frosted, Softened    |
|                        | 38°C  | None                | None                | Frosted, Softened    |
| Methyl Isobutyl Ketone | 23°C  | None                | None                | None                 |
|                        | 38°C  | None                | None                | None                 |
| Soy sauce              | 23°C  | Discolored          | Discolored          | Discolored           |
|                        | 60°C  | Discolored          | Discolored          | Discolored, Shrunken |
| Tabasco sauce          | 23°C  | Little Discolored   | Little Discolored   | Little Discolored    |
|                        | 60°C  | Little Discolored   | Little Discolored   | Discolored, Swell    |
| Mustard sauce          | 23°C  | Discolored          | Discolored          | Discolored           |
|                        | 60°C  | Discolored          | Discolored          | Discolored, Shrunken |
| Iodine solution        | 23°C  | Discolored          | Discolored          | Discolored           |
|                        | 60°C  | Discolored, Brittle | Discolored, Brittle | Discolored, Shrunken |

