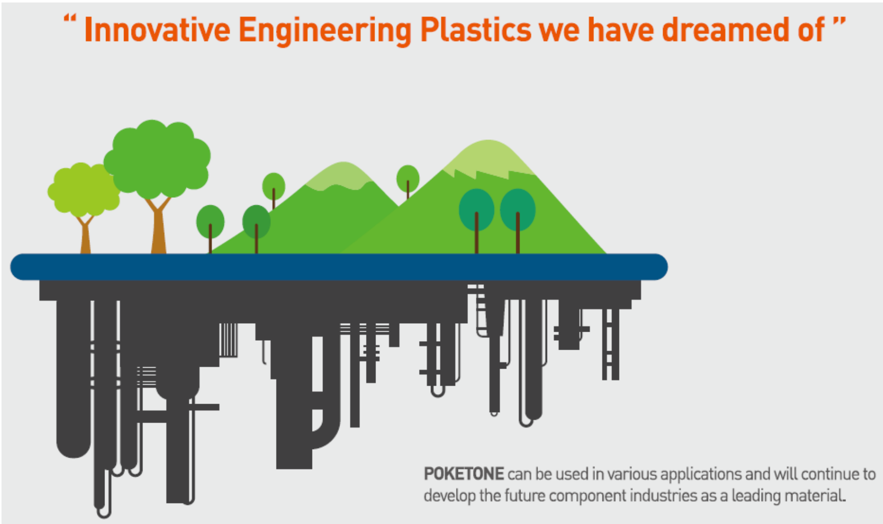
POKETONE
HYOSUNG POLYKETONE

POKETONE

High Performance Thermoplastic Polymer



HYOSUNG CORPORATION

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INTRODUCTION

New horizons in polymer performance

What are POKETONE Polymers?

POKETONE Polymers are a new class of revolutionary engineering thermoplastics which is changing people's perceptions about the future for such materials.
These tough, semi-crystalline polymers were originally made possible as the result of an important catalyst discovery at the Shell Research Laboratories in Amsterdam, whose commercialization could not be continued after 1999.
In 2004, HYOSUNG started the research of new technology to produce this unique polymer at commercial level and succeeded in 2013.

POKETONE Polymers have the perfectly alternating structure made of carbon monoxides and alpha olefins such as ethylene. POKETONE offers a unique balance of processing and performance properties which, in combination, can satisfy a very broad range of applications. This potential stimulates innovative thinking in product designers, expanding their horizons in an unprecedented way.

By challenging conventional thinking about the use of engineering thermoplastics, POKETONE Polymers are capable of turning the unexpected into reality. As you will discover by using this design data brochure, their applications could be as diverse as your imagination will allow.

A global market perspective

The commercialization of aliphatic polyketones, as POKETONE Polymers, has been widely acknowledged in the polymer industry as one of the most significant developments since the introduction of polyamides and polycarbonate.

Previously, the global market for engineering thermoplastics consisted of the so-called "Big Five": polyamides, polyesters, polyacetals, polycarbonates and modified polyphenylene oxide. The introduction of POKETONE Polymers means that the "Big Five" is set to become the "Big Six". Because of their enormous potential for new applications, POKETONE Polymers are expanding the global market for engineering thermoplastics into new areas.

Now, the pilot production facility is operating at capacity of 1,000MT/Year in Yong-yeon, Ulsan, South Korea. The first factory at commercial level of production 50,000MT/Year is currently operating at the same site in Korea, from June of 2015.

A broad range of performance properties

POKETONE Polymers are characterized by a carbon-carbon backbone consisting of carbon monoxide and alpha-olefins. Their perfectly alternating structure gives rise to a unique combination of performance properties:

- Short molding cycles and good mold definition
- Low warpage and no need for conditioning
- Superior resilience and toughness
- Very good impact performance over a broad temperature range
- High chemical resistance and barrier performance
- Very good hydrolytic stability
- Good friction and wear characteristics.

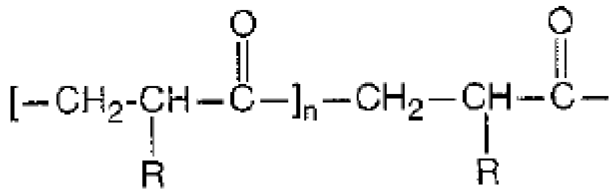
These polymers are suitable for injection molding, extrusion, rotational molding and blow molding as well as the production of coatings, films and fibers.

New horizons in polymer performance

In most cases, POKETONE Polymers can be processed using standard equipment.

Tough, semi-crystalline structure

Structure



Where R may represent for example either H or CH_3
POKETONE Polymer chains are flexible and possess the molecular symmetry and cohesive energy, derived from the perfectly alternating polyketone groups, necessary to produce a tough, high-melting-point, semi-crystalline thermoplastic suitable for a broad range of applications.
In the polymerization process, a second olefin monomer such as propylene may be randomly substituted with ethylene to produce PK ter-polymer. The controlled addition of monomers facilitates the related properties.

Chemical resistance and barrier performance

The broad chemical resistance exhibited by POKETONE Polymers is strongly influenced by their di-polar and semi-crystalline morphology. (See section 4.3) POKETONE Polymers are widely used in hydrocarbon barrier applications. This is a consequence of their di-polar nature which confers resistance to attack and permeation by aliphatic and aromatic hydrocarbons. In addition, the symmetry and chain flexibility of POKETONE Polymers promote crystallization, which, in turn, promotes resistance to swelling and dissolution in all but the strongest polar environments.
In aqueous environments, POKETONE Polymers absorb a limited amount of water which results in mild plasticization, yet their carbon-carbon backbone ensures that they also exhibit good hydrolytic stability. (See section 4.2)

Consider the potential of a polymer that:

- Combines resistance to many fuels and aggressive chemicals with good barrier properties
- Is stiff, strong and wear resistant, but at the same time demonstrates resilience and snap-ability
- Easily fills complex molds, yet shows little warpage or distortion
- Retains its properties not only in sub-zero temperatures but also in "hot under the hood" type applications
- In flame-retarded form, combines low smoke density and can be flame retarded without toxicity while retaining its mechanical properties.

Only one class of thermoplastic offers such a unique combination of performance and processing properties: POKETONE Polymers.
This compilation of performance data is dedicated to helping you widen your horizons and discover what POKETONE Polymers can do.

Environmental friendly

POKETONE polymerization process has lower carbon dioxide release than other polymers process. CO2 emission factor is 2.9kg per 1kg POKETONE

- LCA(Life Cycle Assessment)
  An international standardization tool for assessing environmental impact by quantifying input and output such as energy and environmental contaminants up to raw materials and production processes, logistics and disposal of products (an analysis in accordance with the ISO 14004 Guide)

Expand your horizons

In Toys applications

POKETONE has not only excellent balanced mechanical properties, especially high impact strength, but also eco-friendly characteristic, it can be applicable in a variety of plastic toy industries.

Nowadays, the importance of child safety has been being rapidly increased, because once toys are unexpectedly broken, it may injure child. That's the reasons why the industries have been focusing on safety, and POKETONE is the best choice. In addition, it also has low VOCs properties. POKETONE consists of olefins and ketone; it means that POKETONE doesn't contain formaldehydes, tetrahydrofuran and kinds of nitriles. POKETONE has the following certifications for plastic toy industries.

- EN 71- part 3 (EN 71-3 : 2019 – Migration of certain elements, Category III : Scrapped-off toy material)
- EN 71- part 9 (EN 71-9 : 2005+A1:2007 : Safety of Toys, Organic Chemical Compounds)
- US CPSC (Consumer Product Safety Commission) ASTM F963-17 Phthalates

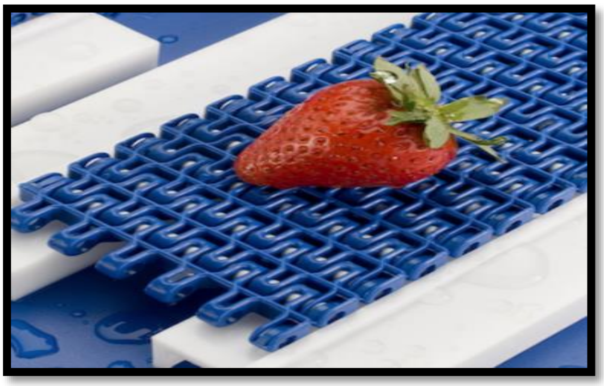
Polycyclic Aromatic Hydrocarbons (PAHs)

In Food Contact applications

POKETONE has high mechanical property retention rate, low water absorption rate, chemical resistance and hydrolytic stability. It make them well suited for use in the food or water contact applications. And especially POKETONE has eco-friendly characteristic (No formaldehydes, No VOCs)

POKETONE has the following certifications for drinking water and food regulations.

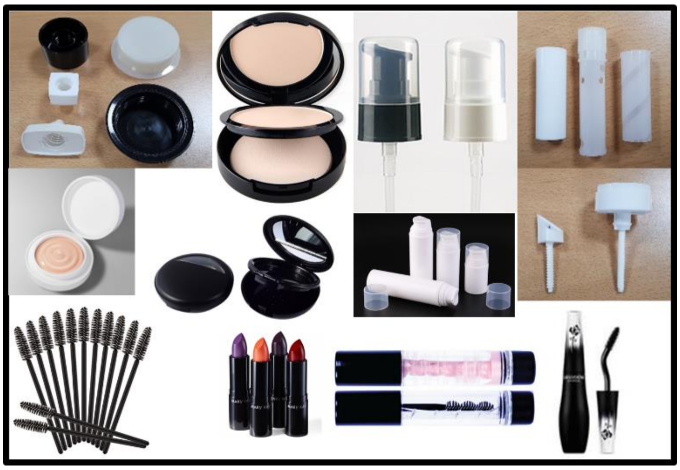
* NSF 51/61, KTW, W270, ACS, WRAS
* EU Directive 10/2011, REACH, FDA (FCN 1847)



Expand your horizons

In Packaging applications

POKETONE Polymers have lowest extractable, and satisfy regulations for Cosmetic Packaging Market. This Formaldehyde-Free polymers support customers to avoid any risk of safety. Thanks to its chemical resistance, POKETONE Polymers can be a reliable choice for cosmetic contact parts.



In Pipe applications

POKETONE Polymers' advanced extrusion grades have been designed to maintain dimensional stability under demanding conditions, including elevated temperatures and harsh chemical environments. These qualities make POKETONE Polymers well-suited for many industrial corrosion control applications.

Industrial applications demand strength and uncompromising performance. POKETONE polymers exhibit a unique balance of mechanical properties relative to other engineering plastics with very good impact strength and flexural modulus.

Resistance to hydrolysis, swelling and permeation give POKETONE polymers good dimensional stability when exposed to aggressive hydrocarbon environments. In addition, POKETONE polymers exhibit very good barrier properties, outperforming competing materials in gas permeation test.

Expand your horizons

In automotive applications

The mechanical performance of POKETONE Polymers over a broad temperature range is combined with permeation resistance to many automotive fuels to create new opportunities. Permeation levels surpass the requirements of current and anticipated legislation with regard to hydrocarbon emissions from automotive fuel systems.

POKETONE Polymers are also resistant to coolants, transmission fluid, oils, greases and the automotive environment in general.

See section 4.4 to find out more.

In Medical applications

POKETONE is highly resistant to diverse chemicals. The good hydrolysis resistance as well as the dimensional stability ensure that components made of POKETONE are suitable for sterilization procedures like heated steam, radiation. Products made of POKETONE especially stand out for their glossy and hard surface. Moreover, POKETONE can withstand mechanical stress very well and shows excellent friction and wear behavior. Due to the combination of outstanding resilience, toughness and sliding behavior POKETONE is highly suitable for the production of functional components such as valves, plugin connectors, gearwheels and spring elements. All F grades of POKETONE are satisfied with FDA, NSF 51,61, and USP Class VI.

Expand your horizons

In E&E applications

The mechanical properties, chemical resistance and hydrolytic stability offered by POKETONE Polymers make them well suited for use in the appliance sector where there is a constant drive to reduce assembly costs, minimize waste and improve the cost performance ratio.

A unique combination of stiffness, toughness and high elongation at yield means that POKETONE Polymers can be subjected to a high level of repetitive deformations without failure. In manufacturing, push and snap fit assemblies may be utilized without the need for preconditioning or tempering.

For further information about chemical resistance and hydrolytic stability, see section 4.

In industrial applications

The combination of mechanical performance, chemical and hydrolytic stability, toughness and long-term durability enable POKETONE Polymers to out-perform other thermoplastics in a broad range of industrial applications.

POKETONE Polymers perform well in gears and bearings, due to their superior wear resistance and good tribological properties. Particular benefits can be achieved in power transmission applications. (See section 3.)

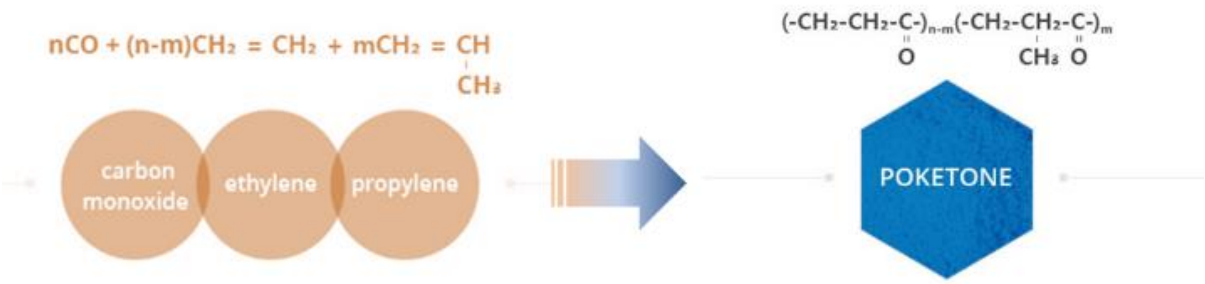
The chemical and hydrolytic stability of POKETONE Polymers enables them to continue to perform their function in many hostile environments. This opens up opportunities for use in a wide range of chemical and industrial processing equipment.

POKETONE Polymer is used for various industrial application due to well-balanced properties with chemical and hydrolysis resistance.

(e. g. caster, pump part, water meter, fastener)

PRODUCTION RANGE

POKETONE is a perfectly alternating copolymer of Carbon monoxide and Olefin.



(iv) Introduction to product range

(v) Current product range and typical compounds

Introduction to product range

POKETONE Polymers are available in a few base resin products and a number of forms of compounds, which may be broadly divided into the following categories:

- Unreinforced grades for injection molding taking full advantage of the short cycle times and ease of molding.
- Glass-fiber-reinforced compounds featuring enhanced mechanical strength, modulus and heat distortion temperatures.
- Non-halogen flame-retardant compounds exhibiting good tracking resistance while maintaining a UL94 V-0 rating and the broad range of mechanical properties associated with POKETONE Polymers. These compounds can be made with or without glass fiber reinforcement as free from added halogens or red phosphorous.
- Tribological compounds with added lubricants further enhancing the tribological performance associated with POKETONE Polymers.
- Unreinforced grades for extrusion offering flow behavior optimized for extrusion processes, in addition to the normal range of properties.

POKETONE™
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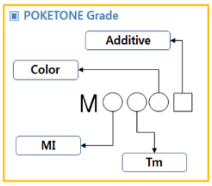
Current product range and typical compounds

Base resin naming rule of POKETONE polymers



Grade	MI(g/10min.)
M9_0	200~300
M3_0	50~70
M6_0	4~8
M7_0	2~4

Grade	Tm(℃)
M_10	195~200
M_30	220~225
M_40	232~238

Measurement condition
M_10 : 220℃, 2.16kg
M_30 : 240℃, 2.16kg
M_40 : 245℃, 2.16kg

	Additive code	Use
Pellet	A	Interior
	F	Food & Drug contact
	R	Thermal resistance
	V	UV resistance, Exterior

Unreinforced injection molding grades

- M630A, M630F, M630V
  General-purpose injection molding grade
- M330A, M330F, M330V
  High-flow injection-molding grade
- M930A, M930F, M930V
  Advanced high-flow injection molding grade

Pipe grades

- E710
  Food & Drug extrusion grade
- M730R
  Thermal resistant extrusion grade

Film grades

- E400
  Monofilament grade
- E700
  Film grade for EvOH blend

Reinforced injection molding compounds

- M33A(F)G3A
  15 percent glass-reinforced general-purpose injection molding compound
- M33A(F)G6A / M63AG6A
  30 percent glass-reinforced High-flow/ general-purpose injection molding compound
- M93AG8H
  40 percent glass-reinforced advanced high-flow injection molding compound
- M93AG9A
  50 percent glass-reinforced advanced high-flow injection molding compound

UV resistance grades

- M63VX0A-WH1, M63VX0A-BK0
  3 percent TiO2, 2 percent carbon black compound
- M33A(F)G6A / M63AG6A
  30 percent glass-reinforced High-flow/ general-purpose injection molding compound

Flame-retardant injection molding compounds

- M33AF2Y
  Flame-retardant (V-0, 0.8mm), High-flow injection-molding compound
- M93AG6P
  Flame-retardant (V-0, 0.8mm), 30 percent glass-reinforced, Advanced high-flow injection-molding compound
- M33AG2Y
  Flame-retardant (V-0, 0.8mm), 10 percent glass-reinforced compound

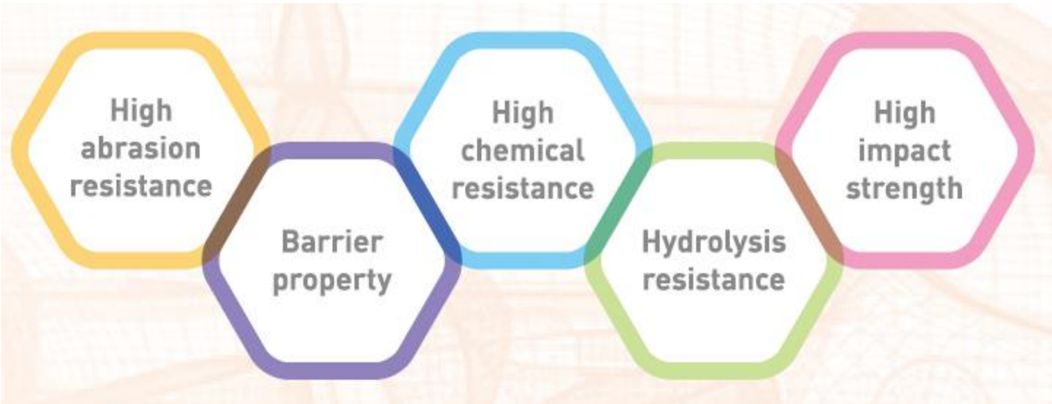
Tribological injection molding compounds

- M33AS1A
  Lubricated high-flow injection-molding compound
- M63AS1A
  Lubricated injection-molding compound

Current product range and typical compounds

- M33AR3B
  TPU Lubricated high-flow injection-molding compound

PROPERTIES OF POKETONE POLYMER



(vi) Summary of properties

Summary of properties

A. Strong and ductile

- Tensile yield stress, approximately 60 MPa at 23°C
- Tensile yield strain, approximately 22 % at 23°C
- Tensile and flexural moduli, approximately 1.4 GPa at 23°C
- Deflection temperature under load, 102°C at 1.8 MPa

B. Injection molders benefit from:

Easy mold ability

- Short cycle times
- Low clamp-force requirements
- Not sensitive in humidity (easy drying)
- Superior flow ability (M330A/M930A)

C. Superior resilience

- Elongation at yield is very high: 22 %
- POLYKETONE Polymers can be subjected to larger, cyclic, deformations than other ETPs before irreversible deformation occurs

D. High impact resistance and toughness

- POLYKETONE Polymers exhibit a high level of ductility over a broad temperature range
- Elongation at break is approximately 300 percent at 23°C
- Notched Charpy impact strength is 17 kJ/m^2 at 23℃

E. Superior chemical resistance and barrier properties

POKETONE Polymers are resistant to swelling and attack in a broad range of:

- Aliphatic and aromatic hydrocarbons
- Ketones, esters and ethers
- Inorganic salt solutions
- Weak acids and bases
- They can also provide a good barrier to automotive fuels and other solvents.

There are only a few known solvents for POLYKETONE Polymers, such as Hexafluoro-isopropanol and phenolic solvents.

F. Very good hydrolytic stability

POKETONE Polymers exhibit very good hydrolytic stability and consequently they are:

- Not susceptible to hydrolysis upon processing
- Resistant to hydrolysis in a broad range of aqueous environments
- Slightly plasticized by the absorption of small amounts of water (0.5 percent at 50 percent RH)

G. Tribological properties

POKETONE Polymers' tribological behavior may be characterized by:

- A low wear factor against steel, 7.3 × 10^{-2} mm^3/Nm
- A low coefficient of friction against self of 0.36, at low surface velocity
- A low coefficient of friction against steel of 0.60, at low surface velocity

H. Electrical properties

POKETONE Polymers can be effectively flame retardant with relatively low loadings of non-halogen flame retardants to give grades tailored towards:

- UL94 rating V-0 while maintaining a good balance of electrical and mechanical properties.

1. Physical properties

1.1 Molecular weight

1.1.1 Average molecular weight

The molecular weights of POKETONE Polymers are summarized in table 1.1.1. These values are obtained by gel permeation chromatography, GPC. Hexafluoro-Isopropyl alcohol (HFIP) is used as the solvent and molecular weights are determined relative to polymethylmethacrylate (PMMA) standards.

Table 1.1.1 Average molecular weight

Grade	Mn	Mw	PDI
Resins			
M630	100,000	320,000	3.2
M330	72,000	180,000	2.5
M930	60,000	132,000	2.2
M730	120,000	400,000	3.5

Mn Number average molecular weight

Mw Weight average molecular weight

PDI Polydispersity Index

Test condition:

- Instrument: Waters 1515 pump
- Column: Shodex HFIP-806M (8 mm * 300 mm) * 2 at 35℃
- Eluent: HFIP 1 ml/min(10 mM TFA) with degassing and 0.2 µm suction Filtering
- Detection: Waters 2414 RI detector (35℃)
- Material: 0.1 % (0.001 g/1ml)
- Narrow STD: PMMA (903K, 608K, 366K, 287K, 182K, 93.3K, 58.7K, 31.6K, 10.9K, 2.58K)Injection: 100µL

1.1.2 Intrinsic viscosity

The intrinsic viscosity (IV) or limiting viscosity number (LVN), of POKETONE Polymers is summarized in table 1.1.2. These values are obtained measured in a capillary viscometer using Hexafluoro-Isopropyl alcohol at 25℃ as the solvent.

Table 1.1.2 intrinsic viscosity

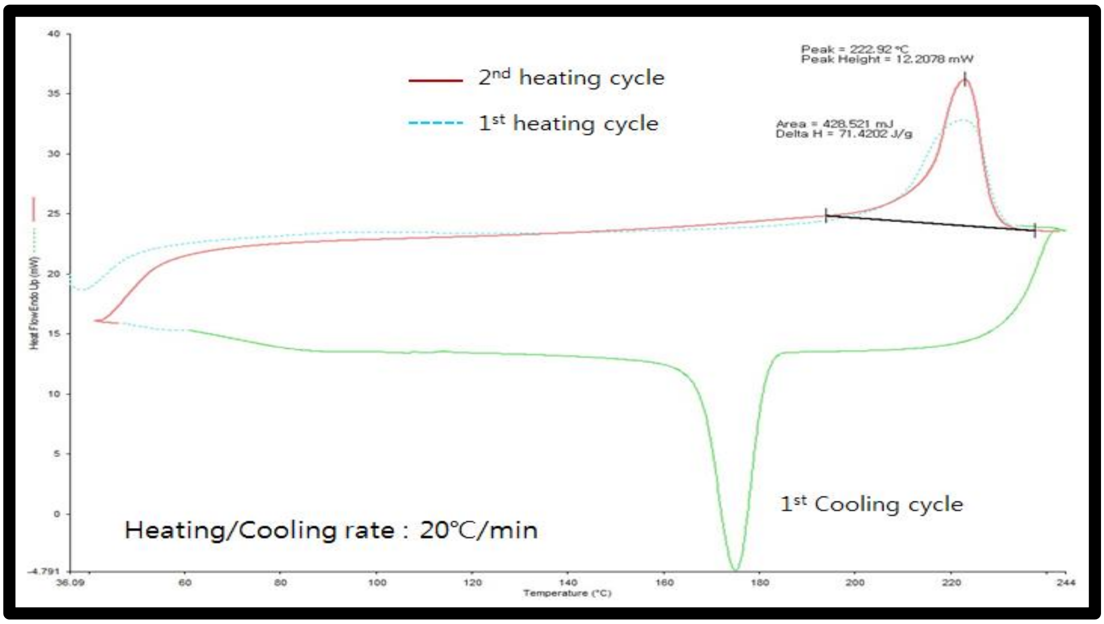
Grade	I.V dL/g
Resins	
M630	2.16
M330	1.46
M930	1.10
M730	2.34

1.2 Thermal characteristics

1.2.1 Typical DSC curve

Figure 1.2.1 shows typical heat flow curves as a function of the temperature for the grade M630A. These curves were obtained on a DSC during the course of a first heating up to 240℃, a cooling down to 40℃ followed by a second heating.

Figure 1.2.1 Heat flow curves for POKETONE Polymer M630A



1.2 Thermal characteristics

1.2.2 Thermophysical data

The thermophysical data for POKETONE Polymers are derived from DSC analysis, and DTMA analysis. The glass transition temperature, Tg, was determined for dry material at a frequency of 1 rad/sec with strain amplitude of 0.2 percent in the torsional testing mode.
DSC analysis consisted of heating 240℃ followed by cooling to 40℃ and then reheating to 240℃ all at a rate of 20℃/min. The melting temperature, Tm, is determined as the peak of the second heating cycle and the crystallization temperature, Tc, is determined as the peak of the first cooling cycle.
These values are summarized in table 1.2.2

Table 1.2.2 Thermophysical data

	M630	M330
Tg, °C	12	12
Tm, °C	222	222
Tc, °C	176	180
$\triangle H_f$, J/g	70	73
$\triangle H_{f100}$, J/g	227	-??

Tg Glass transition temperature
Tm Crystalline melting point
Tc Crystallization temperature
$\triangle H_f$ Typical heat of fusion for molded material
$\triangle H_{f100}$ Heat of fusion for 100% crystalline material

1.2 Thermal characteristics

1.2.3 Heat distortion temperature under load ISO 75/A and ASTM D648

The heat distortion temperature is an index of the short-term thermal behavior of a material under load. The heat distortion temperatures for various POKETONE Polymers are determined in accordance with ISO 75/A and ASTM D648, HDT values for POKETONE Polymers are summarized in table 1.2.3.

Table 1.2.3 Heat distortion temperatures

Grade	HDT ASTM D648, 0.455MPa °C	HDT ASTM D648, 1.82MPa °C	HDT ISO 75/A, 0.455 MPa °C	HDT ISO 75/A, 1.82 MPa °C
Resins				
M630	195	102	185	90
M330	200	105	190	92
M930	200	105	190	92
M710	155	75	140	65
M730	190	90	185	80
Compounds				
M33A(F)G3A	215	210	215	205
M33A(F)G6A	215	210	215	210
M63AG6A	215	210	215	210
M93AG8H	215	210	215	210
M93AG9A	215	210	215	210
M33AF2Y	190	110	185	90
M33AG2Y	212	163	207	150
M93AG6P	215	210	215	210
M33AS1A	190	100	185	82
M63AS1A	190	100	185	82
M33AR3B	180	85	175	70

1.2 Thermal characteristics

1.2.4 VICAT softening point ISO 306/B50, ASTM D1525

The VICAT softening point for materials also provides an indication of short-term thermo-mechanical behavior. Unlike the HDT method, the VICAT method applies a point load and determines the temperature at which a certain degree of penetration occurs. The VICAT softening points for various POKETONE Polymers were determined in accordance with ISO 306/B50 and ASTM D1525 and these values are summarized in table 1.2.4.

Table 1.2.4 VICAT softening points

Grade	VICAT ASTM D1525 5 kg, °C	VICAT ISO 306/850 50 N, °C
Resins		
M630	192	190
M330	195	190
M930	195	190
M710	155	152
M730	190	190
Compounds		
M33A(F)G3A	205	205
M33A(F)G6A	210	210
M63AG6A	210	210
M93AG8H	210	210
M93AG9A	210	210
M33AF2Y	185	185
M33AG2Y	195	195
M93AG6P	210	210
M33AS1A	187	187
M63AS1A	190	190
M33AR3B	174	174

1.2 Thermal characteristics

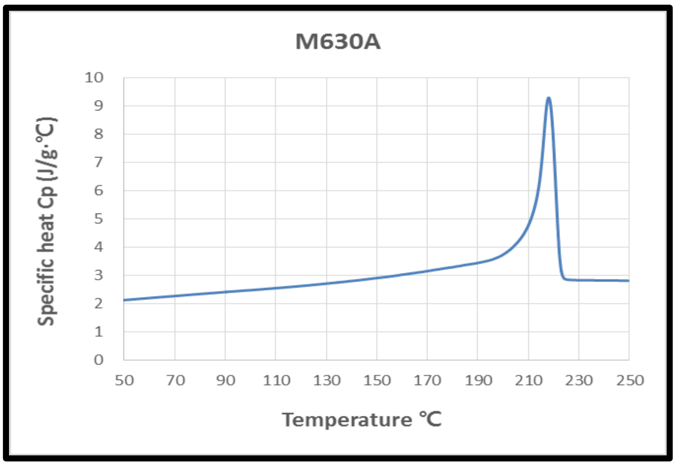
1.2.5 Specific heat capacity

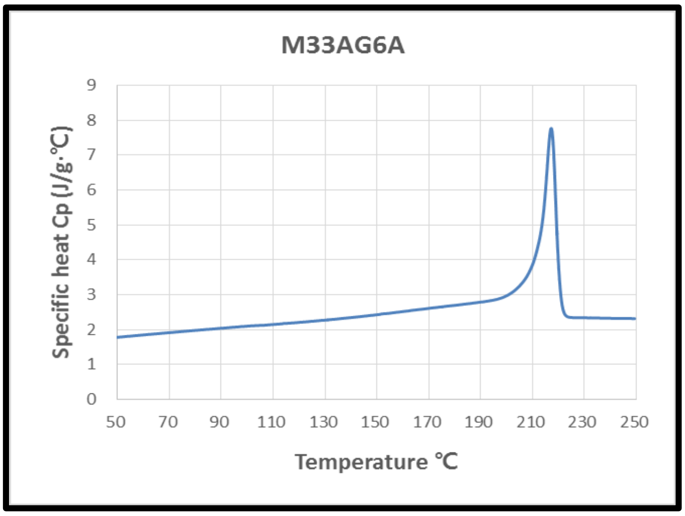
The thermal dependence of the specific heat capacity at constant pressure, C_p (J/g·℃), is shown in figure 1.2.5 for POKETONE Polymers. The specific heat capacity is measured by adiabatic calorimeter on a DSC under a constant heating rate of 20℃/min. These values are summarized in table 1.2.5.
The C_p increases gradually up to 180℃. Above this temperature the C_p reaches a peak, corresponding with the melting point of the polymer. Beyond this peak the variation of C_p as a function of temperature is re-established.

Table 1.2.5 Specific heat capacity

Grade	C_p(J/g·℃)		
	at 50 °C	at 170 °C	at 250 °C
Resins M630 M330	 2.13 1.73	 3.15 2.73	 2.81 2.34
Compound M33AG6A	 1.78	 2.61	 2.31

Figure 1.2.5 Specific heat capacity (M630A & M33AG6A)





1.2 Thermal characteristics

1.2.6 Thermal conductivity

The thermal conductivities λ (W/m·℃) of POKETONE Polymers are measured in the temperature range 26℃ - 250℃ using an adaptation of a piston type PVT measurement technique.

λ is plotted as a function of temperature in figures 1.2.6.1 and 1.2.6.2. λ values, at 26°C, for the various grades and compound of POKETONE Polymers are summarized in table 1.2.6.

Figure 1.2.6.1 Thermal conductivity of POKETONE Polymer M630A

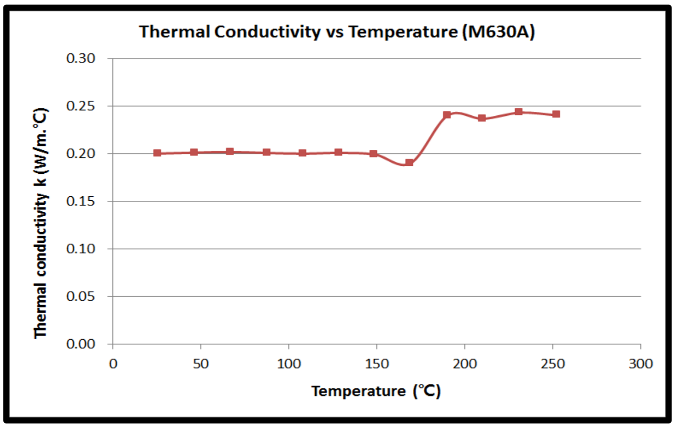


Figure 1.2.6.2 Thermal conductivity of POKETONE Polymer GF 30% Filled (M63AG6A)

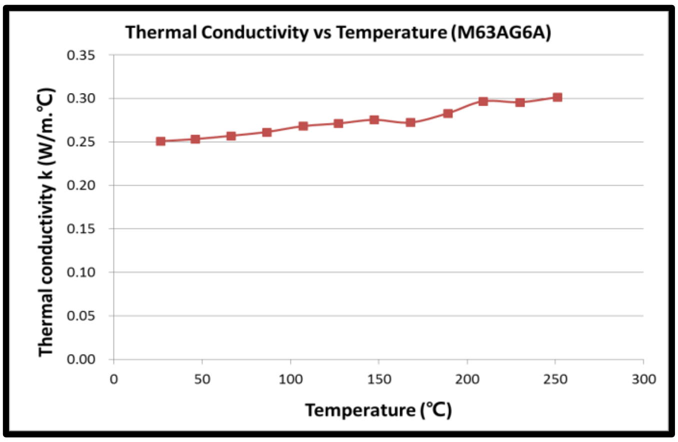


Table 1.2.6 Thermal conductivity at 26℃

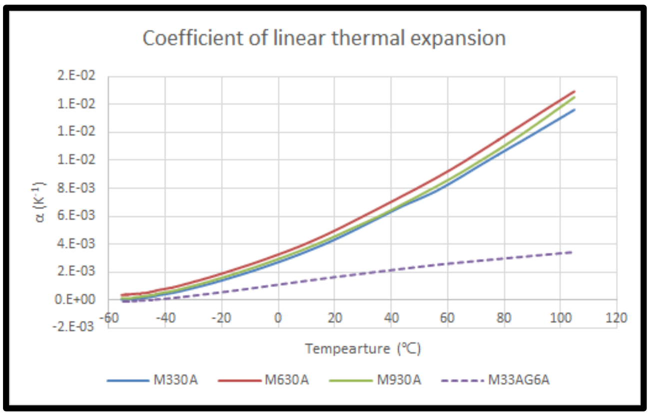
Grade	λ (W/m·℃)
Resins	
M630	0.200
M330	0.266
Compounds	
M33AG6A	0.287
M63AG6A	0.251

1.2 Thermal characteristics

1.2.7 Coefficient of linear thermal expansion

The coefficient of linear thermal expansion α (K^{-1}) of POKETONE Polymers is measured by TMA, thermal mechanical analysis, according to the requirements of ASTM E831.
Measurements are carried out on injection-molded samples with a measured both parallel and perpendicular to the direction of flow to account for anisotropy in the system.
The coefficient of linear thermal expansion is expressed as a mean value taken over the temperature range 25℃ to 55℃ for each direction. These values are summarized in table 1.2.7.

Figure 1.2.7 Coefficient of linear thermal expansion curves for POKETONE polymers



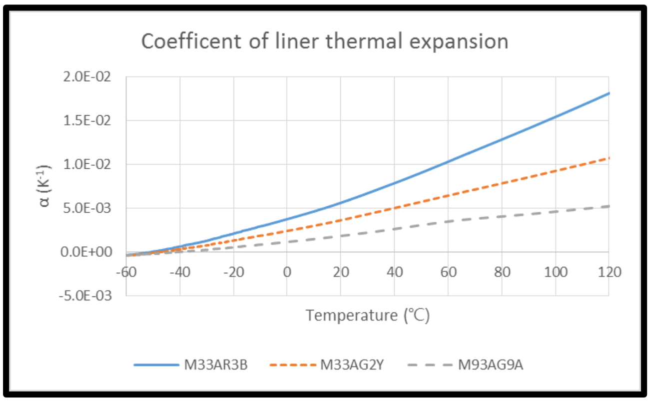


Table 1.2.7 Coefficient of linear thermal expansion

Grade	α (K^{-1}) x 10^{-5}
Resins	
M630	10
M330	9.7
M930	10
M710	10
M730	10
Compounds	
M33A(F)G3A	4.6
M33A(F)G6A	2.8
M63AG6A	3.8
M93AG8H	2.8
M93AG9A	4.2
M33AG2Y	7.1
M93AG6P	2.9
M33AS1A	10
M63AS1A	10
M33AR3B	11.6

1.3 PVT relationships

1.3.1 PVT data

PVT data are of particular interest for injection molding, where they may be used in the optimization of the injection and packing phases of the molding cycle.
Specific volume (cm³/g), the inverse of the density p, was measured at pressures of 0, 50, 100, 150 and 200 MPa as a function of temperature. The resulting curves for M630A, M330A and GF 30% Filled Compound are presented in figures 1.3.1.1 to 1.3.1.3. These PVT diagrams were obtained by measuring the volume changes of a mass of material placed in a cylindrical barrel, molten and subsequently cooled at a rate of 5℃/min.

Figure 1.3.1.1 PVT curves for POKETONE polymer M630A

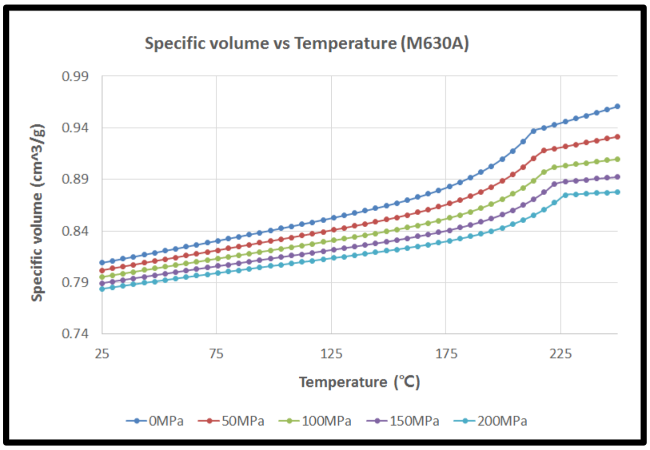


Figure 1.3.1.2 PVT curves for POKETONE Polymer M330A

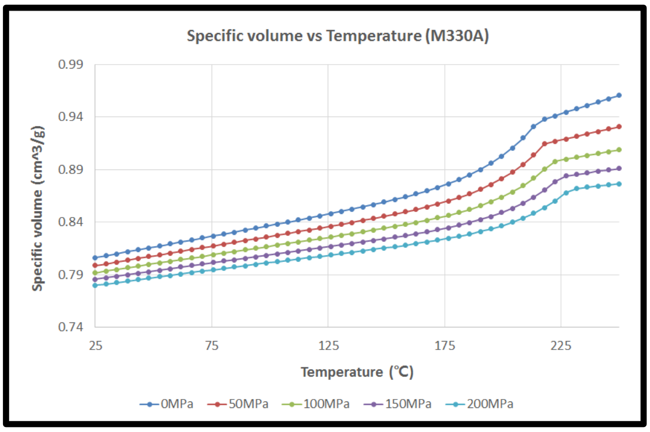
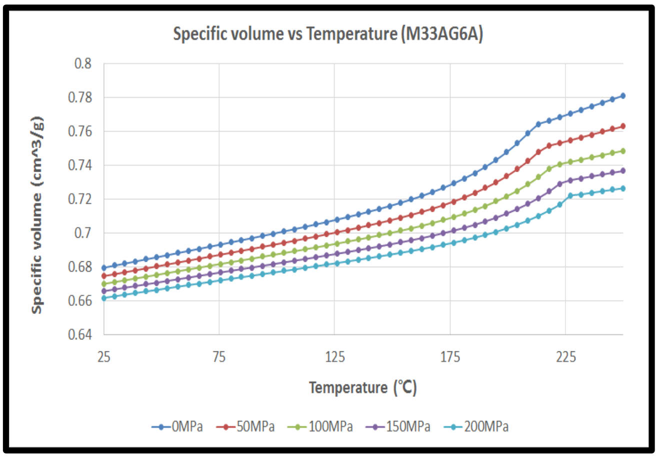


Figure 1.3.1.3 PVT curves for POKETONE Polymer M330A GF 30% Filled Compound (M33AG6A)



1.4 Densities

1.4.1 Density, ASTM D792

The densities ρ (g/cm³) at 23°C for POKETONE Polymers were measured in accordance with ASTM D792. These values are summarized in table 1.4.1.

Table 1.4.1 Densities

Grade	Density g/cm³
Resins	
M930	1.24
M630	1.24
M330	1.24
M710	1.22
M730	1.24
Compounds	
M33A(F)G3A	1.35
M33A(F)G6A	1.47
M63AG6A	1.47
M93AG8H	1.57
M93AG9A	1.67
M93AG6P	1.47
M33AF2Y	1.26
M33AG2Y	1.29
M33ASIA	1.24
M63ASIA	1.24
M33AR3B	1.23

1.4.2 Bulk density, ASTM D1895

The bulk densities for POKETONE Polymer granules were measured in accordance with ASTM D1895. These values are summarized in table 1.4.2.

Table 1.4.2 Bulk densities

Grade	Density kg/m³
Resins	
M630	750
M330	750
M930	750
M710	750
M730	750
Compounds	
M33A(F)G3A	690
M33AG6A	740
M63AG6A	750
M93AG8H	710
M93AG9A	810
M93AG6P	680
M33AF2Y	750
M33AG2Y	710
M33ASIA	780
M63ASIA	750
M33AR3B	800

1.4 Densities

1.4.3 Amorphous and crystalline densities

The crystalline densities of POKETONE Polymers were determined at 23℃ using wide angle X-ray diffraction analysis. The amorphous densities are then derived from the measured crystalline density and the measured degree of crystallinity.
The values measured and calculated are summarized in table 1.4.3.

Table 1.4.3 Amorphous and crystalline densities of POKETONE Polymer M630A

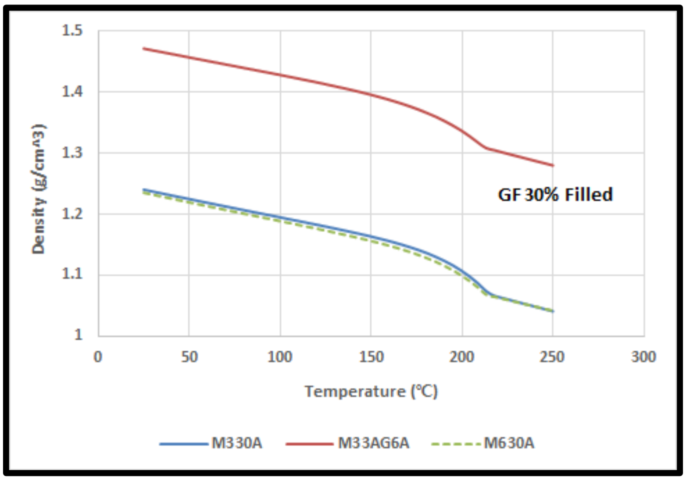
Phase	Density (g/cm^3)
Amorphous	1.206
α-Crystalline	1.382
β-Crystalline	1.297

1.4 Densities

1.4.4 Density temperature relationship

The influence of temperature on density is illustrated in figure 1.4.4. These data were derived from PVT data; see section 1.3, at a pressure of 1 bar, 0.1 MPa.

Figure 1.4.4 Density as a function of temperature



1.5 Rheological characteristics

1.5.1 Melt flow rate, ISO 1133, ASTM D1238

Typical melt flow rates for POKETONE Polymers are summarized in table 1.5.1, measured at 240℃ with a load of 2.16 kg, in accordance with the above standards.

Table 1.5.1 Melt flow rates

Grade	ASTM D1238 g/10 mins	ISO 1133 ml/10 mins
Resins		
M630	6	5.6
M330	60	56
M930	200	187
M710 [1]	3	2.8
M730	3	2.8
Compounds		
M33A(F)G3A	24	22
M33A(F)G6A	14	13
M63AG6A	1.3	1.2
M93AG8H	19	18
M93AG9A	24	22
M93AG6P	25	23
M33AF2Y	34	32
M33AG2Y	25	23
M33ASIA	49	46
M63ASIA	5.7	5.3
M33AR3B	68	64

[1] M_10 Grade measured at 220℃ with a load of 2.16 kg

1.5 Rheological characteristics

1.5.2 Apparent melt viscosity

The following figure 1.5.2 illustrates the apparent melt viscosities, η (Pa·s), for various POKETONE Polymers. The data is presented as a function of shear strain rate, γ (s^{-1}), over a range of temperatures. The flow curves were generated using a constant shear strain rate capillary rheometer and all data were corrected using the Bagley and Rabinowitz methods. Data were not corrected for shear heating or pressure effects.

Figure 1.5.2.1 Apparent melt viscosities (M630A)

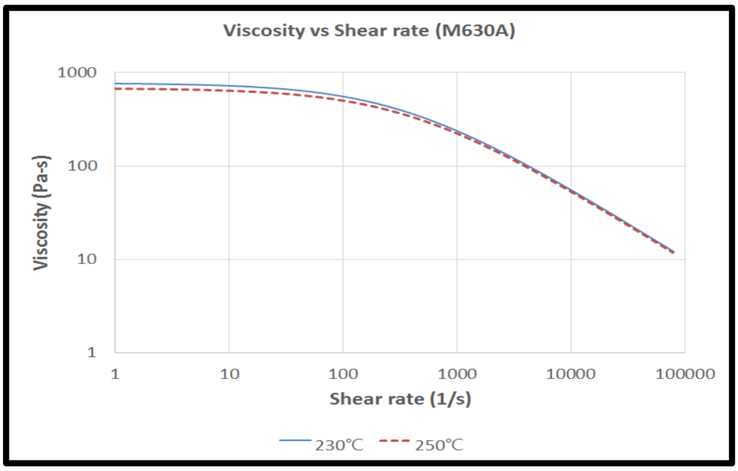
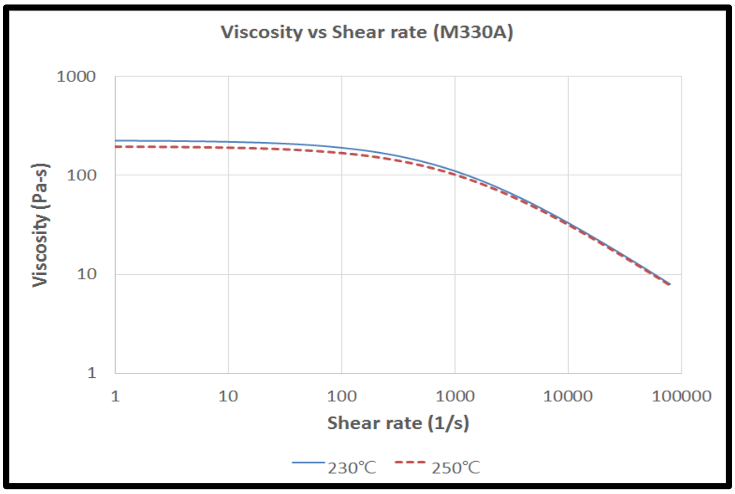


Figure 1.5.2.2 Apparent melt viscosities (M330A)

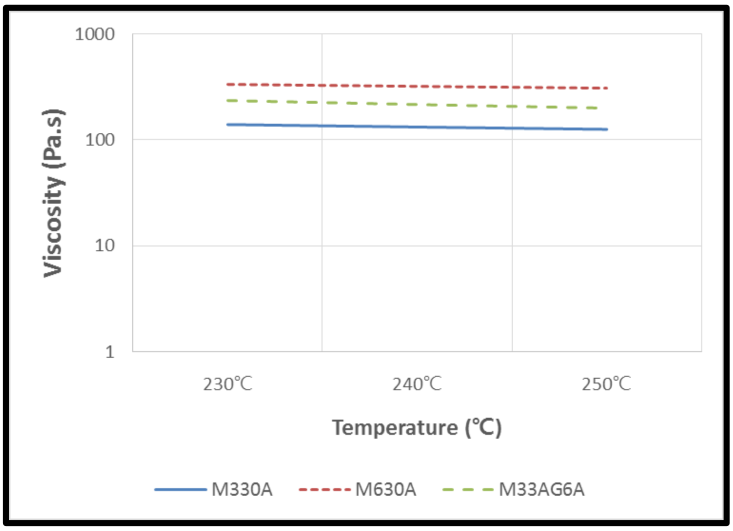


1.5 Rheological characteristics

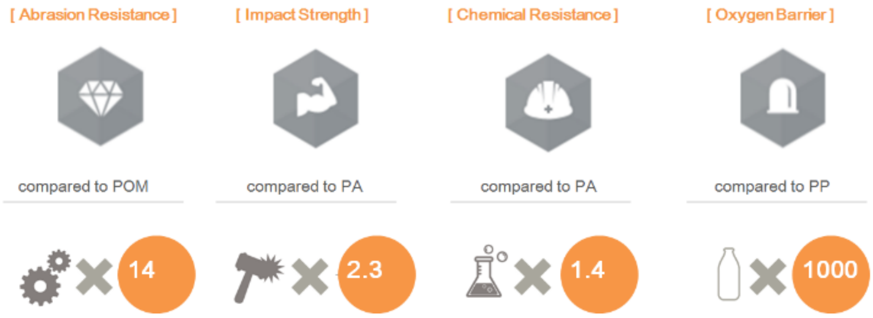
1.5.3 Effect of temperature on apparent melt viscosity

Figure 1.5.3 demonstrates the relative insensitivity of apparent viscosity to melt temperature for POKETONE Polymers.

Figure 1.5.3 Effect of temperature on Melt viscosity measured at a shear strain rate of 500 s^{-1}



2. Mechanical properties



2.1 Tension

2.1.1 Tensile properties ISO 527-1 / ASTM D638

The tensile properties of POKETONE Polymers are determined in accordance with the relevant sections of the above standards. Briefly this involves the elongation of a standardized injection molded test specimen at a constant displacement rate while recording the resulting force.
Figure 2.1.1 illustrates a generic tensile test curve for POKETONE Polymers. All of the properties in the section were measured at 23℃ and 50 percent RH.
The following material parameters have been derived from this type of test and may be found within this section.
As the specimen dimensions, method of manufacture and test conditions vary between standards, often the results obtained are also significantly different between standards.

2.1.1.1

- The stress (strength) and strain (elongation) at yield.

2.1.1.2

- The strain (elongation) at break.

2.1.1.3

- The elastic modulus in tension, Young's modulus.

2.1.1.4

- Poisson's ratio

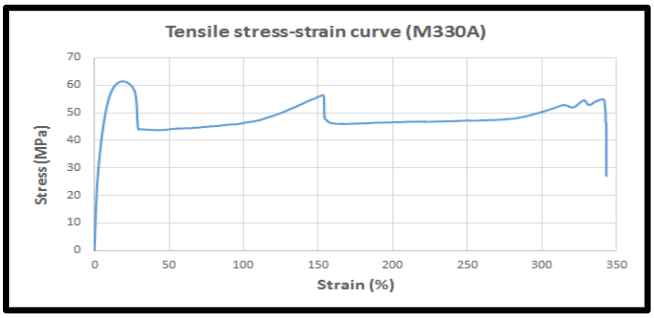


Figure 2.1.1 A generic tensile stress-strain curve for POKETONE Polymer M330A

Table 2.1.1.1 Tensile yield properties

Grade	ASTM D638		ISO 527-1	
	Stress at yield MPa	Strain at yield %	Stress at yield MPa	Strain at yield %
Resins				
M630	58	22	58	22
M330	60	21	60	21
M930	62	20	62	20
M710	43	19	43	19
M730	56	24	56	24
Compounds				
M33A(F)G3A	100	-	100	-
M33A(F)G6A	140	-	140	-
M63AG6A	135	-	135	-
M93AG8H	165	-	165	-
M93AG9A	180	-	180	-
M33AF2Y	50	21	50	21
M33AG2Y	53	12	53	12
M93AG6P	140	-	140	-
M33AS1A	60	21	60	21
M63AS1A	58	22	58	22
M33AR3B	48	25	48	25

2.1 Tension

Table 2.1.1.2 Tensile failure properties

Grade	ASTM D638 Strain at break %	ISO 527-1 Strain at beak %
Resins		
M630	300	300
M330	300	300
M930	150	150
M710	300	300
M730	250	250
Compounds		
M33A(F)G3A	6.0	6.0
M33A(F)G6A	3.8	3.8
M63AG6A	4.8	4.8
M93AG8H	2.9	2.9
M93AG9A	2.2	2.2
M33AF2Y	40	40
M93AG6P	4.0	4.0
M33AG2Y	18	18
M33AS1A	200	200
M63AS1A	200	200
M33AR3B	300	300

Table 2.1.1.3 Tensile modulus

Grade	ASTM D638 Modulus MPa	ISO 527-1 Modulus MPa
Resins		
M630	1,450	1,350
M330	1,600	1,500
M930	1,650	1,550
M710	950	900
M730	1,400	1,300
Compounds		
M33A(F)G3A	4,100	4,050
M33A(F)G6A	7,700	7,500
M63AG6A	7,500	7,150
M93AG8H	10,500	10,200
M93AG9A	12,800	11,100
M33AF2Y	1,850	1,700
M93AG6P	8,500	8,000
M33AG2Y	2,650	2,550
M33AS1A	1,550	1,450
M63AS1A	1,400	1,300
M33AR3B	1,400	1,300

Table 2.1.1.4 Poisson's ratios

Grade	Poisson's Ratio
Resins	
M630	v12 0.44 / v23 0.47
M330	v12 0.44 / v23 0.47
Compounds	
M63AG6A	v12 0.44 / v23 0.60
M33A(F)G6A	v12 0.45 / v23 0.57

2.2 Flexion

2.2.1 Flexural properties ISO 178 / ASTM D790

The flexural strengths and moduli of POKETONE Polymers are measured in accordance with ISO 178 and ASTM D790.

Table 2.2.1.1 Flexural strength

Grade	ASTM D790 Stress MPa	ISO 178 Stress MPa
Resins		
M630	53	53
M330	57	57
M930	60	60
M710	40	40
M730	50	50
Compounds		
M33A(F)G3A	140	135
M33A(F)G6A	190	185
M63AG6A	180	175
M93AG8H	220	215
M93AG9A	230	230
M33AF2Y	58	56
M93AG6P	190	185
M33AG2Y	79	78
M33AS1A	57	56
M63AS1A	56	55
M33AR3B	45	44

Table 2.2.1.2 Flexural moduli

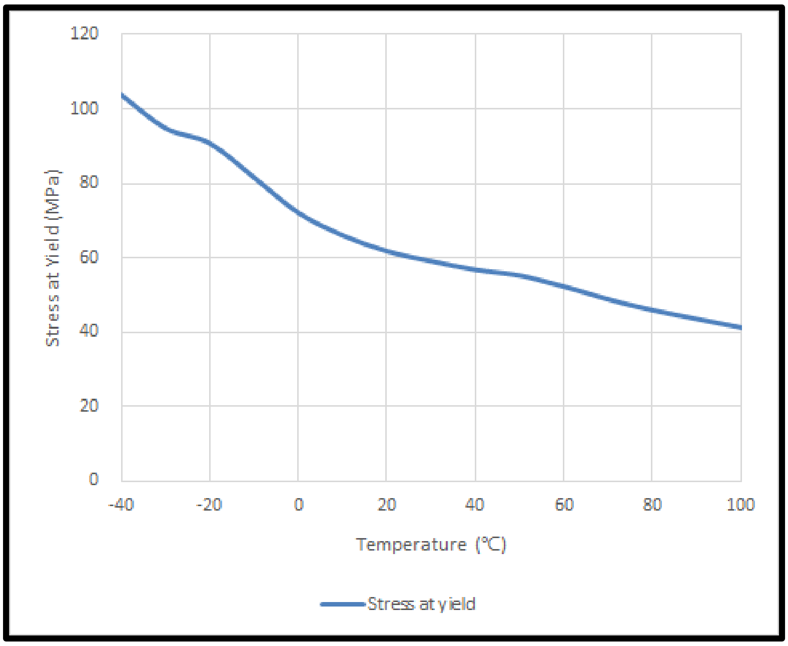
Grade	ASTM D790 Flexural Modulus MPa	ISO 178 Flexural Modulus MPa
Resins		
M630	1,350	1,250
M330	1,500	1,400
M930	1,550	1,450
M710	900	850
M730	1,250	1,200
Compounds		
M33A(F)G3A	4,000	3,400
M33A(F)G6A	6,700	6,150
M63AG6A	6,050	5,450
M93AG8H	9,000	8,000
M93AG9A	11,100	11,000
M33AF2Y	1,700	1,550
M93AG6P	6,850	6,600
M33AG2Y	2,550	2,200
M33AS1A	1,500	1,400
M63AS1A	1,450	1,300
M33AR3B	1,250	1,050

2.3 Temperature effects

2.3.1 Influence of temperature on yield

Figure 2.3.1 demonstrates that POKETONE Polymer M330A has an exceptionally high strain to yield.
It is also apparent that this feature of the material is maintained across a broad temperature range. This data is derived from testing in accordance with ASTM D638.

Figure 2.3.1 Influence of temperature upon the yield properties of POKETONE Polymer M330A

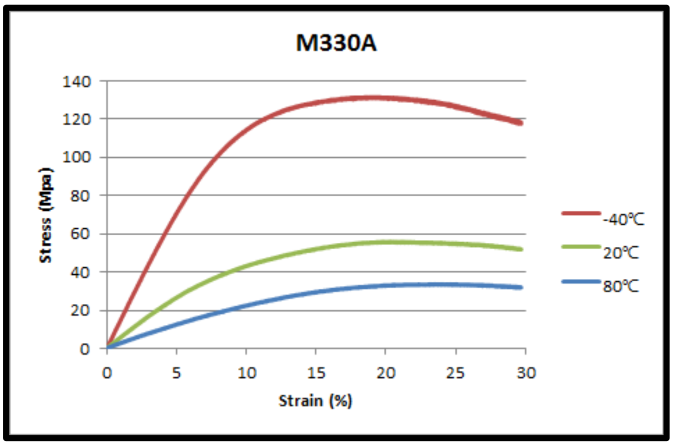


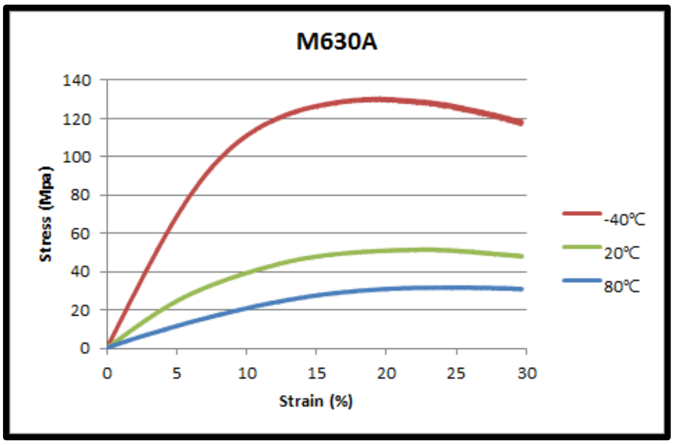
2.3 Temperature effects

2.3.2 Influence of temperature on Flexural properties

Figure 2.3.2 demonstrates the Flexural properties of POKETONE Polymer (M330A & M630A). This data is derived from testing in accordance with ASTM D790.

Figure 2.3.2 Influence of temperature upon the failure properties of POKETONE Polymers (M330A & M630A)



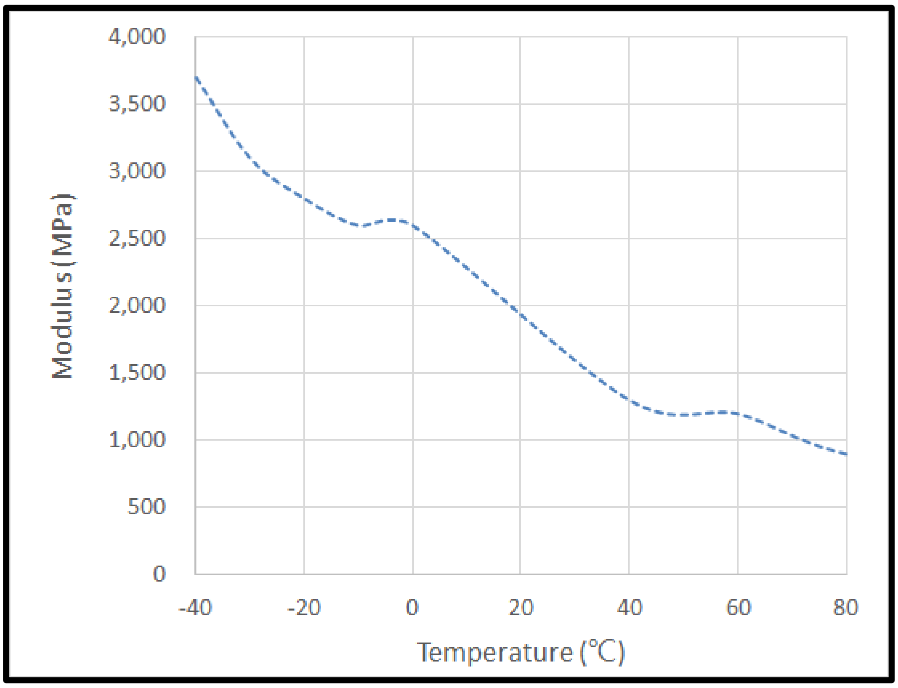


2.3.3 Influence of temperature on moduli

2.3 Temperature effects

The tensile moduli of POKETONE Polymers are relatively insensitive to temperature change in a typical operating environment of > 20℃. This feature of POKETONE Polymers is attributed to their glass transition temperature, Tg (see section 1.2.2), being below typical operating temperatures. This data is derived from testing in accordance with ASTM D 790.

Figure 2.3.3 Influence of temperature upon the tensile moduli (M330A)



2.4 Toughness and impact

POKETONE Polymers are considered to be inherently "tough" materials. They exhibit high impact performance over a broad temperature range.

2.4.1 Izod impact strength ISO 180/A and ASTM D256

The Izod impact strengths for POKETONE Polymers is measured in accordance with ISO 180/1A and ASTM D256. The measured values are summarized in tables 2.4.1.1 and 2.4.1.2.

Table 2.4.1.1 Notched Izod impact strength at 23℃

Grade	ASTM D256 J/m	ISO 180/1A kJ/m^2
Resins		
M630	220	15
M330	95	7
M930	60	6
M710	120	9
M730	138	10
Compounds		
M33A(F)G3A	85	9
M33A(F)G6A	120	13
M63AG6A	140	16
M93AG8H	110	12
M93AG9A	130	13
M33AF2Y	70	6
M93AG6P	135	14
M33AG2Y	70	6
M33AS1A	76	7
M63AS1A	122	14
M33AR3B	380	21

Table 2.4.1.2 Unnotched Izod impact strength at 23℃

Grade	ASTM D256 J/m	ISO 180/U kJ/m^2
Resins		
M630	N.B.	N.B
M330	N.B.	N.B
M930	N.B.	N.B
M710	N.B.	N.B
M730	N.B.	N.B
Compounds		
M33A(F)G3A	-	70
M33A(F)G6A	-	104
M63AG6A	N.B.	N.B.
M93AG9A	N.B	N.B
M33AG2Y	N.B	N.B
M33AR3B	N.B	N.B

2.4 Toughness and impact

2.4.2 The influence of temperature on notched Izod impact strength ASTM D256

The influence of temperature on notched Izod impact strength ASTM D256 is summarized in table 2.4.2.

Table 2.4.2 Influence of temperature on notched Izod impact strength, ASTM D256

Grade	23°C J/m	-10°C J/m	-30°C J/m
Resins			
M630	220	65	52
M330	95	60	40
M930	60	45	30

2.4.3 Charpy impact ISO 179/1eA

The Charpy impact strength for POKETONE Polymers is measured in accordance with ISO 170/1eU and ISO 179/1eA. The measured values are summarized in table 2.4.3.

Table 2.4.3 Charpy impact strength, ISO 179/1eA and ISO 179/1eU

Grade	ISO 179/1eU Unnotched kJ/m^2 at 23°C	ISO 179/1eA Notched kJ/m^2 at 23°C
Resins		
M630	N.B	17
M330	N.B	8
M930	N.B	6
M710	N.B	14
M730	N.B	16
Compounds		
M33A(F)G3A	N.B	10
M33A(F)G6A	N.B	13
M63AG6A	N.B	17
M93AG8H	N.B	13
M93AG9A	N.B	11
M33AF2Y	N.B	8
M93AG6P	N.B	11
M33AG2Y	N.B	6
M33AS1A	N.B	9
M63AS1A	N.B	16
M33AR3B	N.B	20

2.4 Toughness and impact

2.4.4 .The influence of temperature on notched Charpy impact strength ISO 179/1eA

The influence of temperature on notched Charpy impact strength ISO 179/1eA is summarized in table

Table 2.4.4 Influence of temperature on notched Charpy impact strength, ISO 179/1eA

Grade	23°C J/m	-10°C J/m	-30°C J/m
Resins			
M630	17	4	3
M330	8	4	2
M930	6	2	2

2.5 Fatigue

Mechanical Fatigue behavior

Fatigue testing may be carried out either in a constantload amplitude mode or a constant displacement amplitude mode. In either case, the independent variable is the number of cycles to failure.

Testing in a constant load mode is more suitable for analysis and design. In practice, however, testing in a constant displacement mode is easier to carry out.

Wohler Curves or S-N Curves (stress lever versus number of cycles to failure) may be used to describe the fatigue behavior of a material.

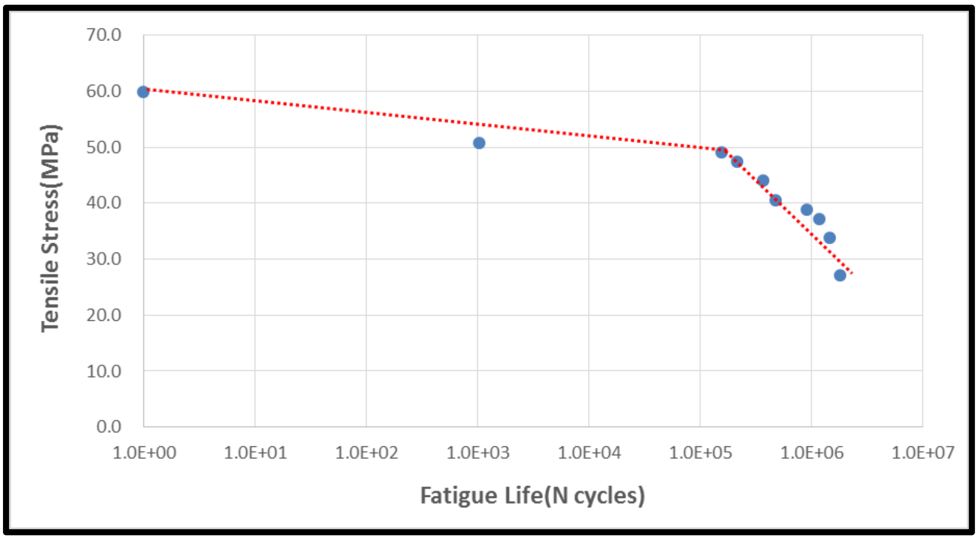
Two types of failures are usually observed. At high load levels, the fatigue life is short and is limited by a ductile failure or thermal fatigue failure. At lower load levels, the fatigue life is limited by the initiation and subsequent propagation of a crack. Hence, most polymers exhibit a transition from ductile to brittle failure mode as the load level and/or frequency is reduced.

2.5 Fatigue

2.5.1 Load-controlled tensile fatigue behavior

Figure 2.5.1 illustrates the fatigue behavior of POKETONE M330A in a load-controlled tensile configuration, at a frequency of 5Hz. The tests were carried out at 23℃ and 50 percent RH. In common with most thermoplastic materials, POKETONE M330A exhibits a ductile to brittle transition in the dynamic loading mode.

Figure 2.5.1 Load-controlled tensile fatigue behavior of POKETONE Polymers (M330A)

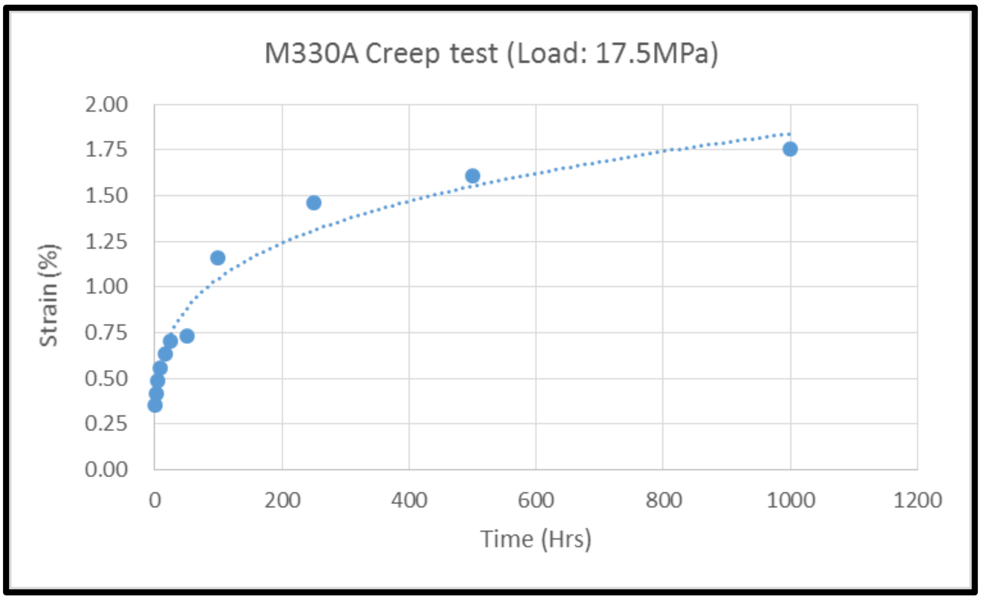


2.6 Creep

2.6.1 Tensile creep ISO 899

A range of basic tensile creep data has been produced for POKETONE Polymers, measured in accordance with ISO 899. These data are represented in the form of basic creep curves (figures 2.6.1.1). The data presented relate to POKETONE Polymers (M330A & M630A) measured at 23℃, 50%RH.

Figure 2.6.1.1 Basic creep curves for POKETONE Polymer M330A & M630A measured at 23℃ and 50% RH (Load: 17.5MPa, Span: 50mm)



3. Tribological and surface properties

3.1 Additional benefits in tribological arrangements

Good friction and wear characteristics with low noise

Parts made from POKETONE Polymers exhibit good friction and wear performance as well as low noise generation characteristics. This makes them very attractive candidates for use in tribological arrangements, such as gears, bearings and cams.

- Tribological arrangements become more attractive if at least one of the components is made from POKETONE Polymers, particularly in cases with plastic-plastic pairing where the application demands operation without lubricants.
- In like pairings (e.g. POKETONE-POKETONE), wear levels can be very much lower than those which would be achieved if other polymers (e.g. polyamides or polyacetals) were paired together. This even applies when comparisons are made with specially lubricated materials.
- POKETONE Polymers provide the possibility for a one material solution in tribological systems. This improves production economies and could ease the recycling process at the end of a product's working life.

Tribological measurements are strongly affected by the method of testing. Parameters such as counterface roughness and composition, sliding velocity, contact pressure and lubrication all substantially influence the properties measured.
Tribological measurements for POKETONE Polymers have been carried out using two different types of test equipment under a variety of conditions. The types of equipment used were pin on disc and thrust washer machines.

Pin on disc measurements were taken using Reciprocal motion type Tribometers. Coefficient of friction (μ) and wear factor (K) were evaluated for POKETONE Polymer in contact with various counterface materials using the following configuration: Disk 40 mm × 20 mm × 3 mm, Pin Ø 5 mm × 12.5 mm, with a contact area of approximately 100 mm^2.

Thrust washer testing was carried out on injection molded specimens using a computer-controlled multi-specimen test machine. In each case, the dimensions of the specimen were consistent with JIS K7218. These requirements result in the common area of interaction being an annulus of area approximately 200mm^2. The average radius of the annulus is approximately 11.4 mm.

- Shrinkage of unfilled POKETONE Polymers is isotropic, and molded parts show little warpage.
  Because of this, gears and bearings made from POKETONE Polymers have a high degree of mold definition and can be molded well within the stringent dimensional tolerances often encountered in the field.
- The inherent ductility and post-molding dimensional stability of POKETONE Polymers imply that components for gears and bearings can be assembled immediately after molding without the need for conditioning or tempering
- The water insensitivity of POKETONE Polymers also ensures that parts retain their mechanical integrity, even in humid environments such as the tropics.
- The resilience of POKETONE Polymers offers further opportunities for component integration and flexibility in design.

3.1 Additional benefits in tribological arrangements

Application development in the field has confirmed the potential of POKETONE Polymers in polymeric gears and bearings. Based on their low wear characteristics and versatile property set, POKETONE Polymers are proving to be interesting candidates in applications such as business machines, domestic and personal care appliances, industrial conveyance units, transportation systems and many other application areas.

3.2 Dynamic coefficient of friction

3.2.1 Pin on disc configuration

Table 3.2.1 summarizes the coefficients of friction obtained using the method described in section 3.2 under the following specific test conditions:

- Sliding speed 0.06 m/sec
- Contact pressure 1.3 MPa
- Ambient conditions 23°C and 50 % RH

Table 3.2.1 Coefficients of friction for various polymers, pin on disc configuration

Counterface material		Dynamic coefficient of friction μ
Polymer		
M630A	M630A	0.21
M33AR3B	M33AR3B	0.45
Steel*		
M630A	S45C	0.36
M33AR3B	S45C	0.32

*The quality of steel shall be S45C specified in JIS G 4051 as a rule. The hardness of the measuring surface of the steel shall be HRC 12 to 25 in the unit of Rockwell C hardness.
Further, the surface roughness shall be about 0.8 ㎛(Ra)

3.2.2 Thrust washer configuration

Table 3.2.2 summarizes the coefficients of friction for POKETONE Polymers when sliding against a steel counterface material. The method used is described in section 3.2 and was carried out under the following specific test conditions:

- Sliding speed 0.12 m/sec
- Contact pressure 0.4 MPa
- Ambient conditions 23°C and 50% RH

Table 3.2.2 Coefficients of friction for various polymers, thrust washer configuration

Counterface material		Dynamic coefficient of friction μ
Polymer		
M630A	M630A	0.34
M33AS1A	M33AS1A	0.17
M33AR3B	M33AR3B	0.35
POM-C	POM-C	0.29
PA66	PA66	0.35
Steel*		
M630A	S45C	0.60
M33AS1A	S45C	0.27
M33AR3B	S45C	0.14
M33AT2E	S45C	0.13
POM-C	S45C	0.17
PA66	S45C	0.39

*The quality of steel shall be S45C specified in JIS G 4051 as a rule. The hardness of the measuring surface of the steel shall be HRC 12 to 25 in the unit of Rockwell C hardness. Further, the surface roughness shall be about 0.8 ㎛(Ra)

3.3 Wear factors

3.3.1 Pin on disc configuration

Table 3.3.1 summarizes results obtained using the method described in section 3.2 under the following specific test conditions:

- Sliding speed 0.06 m/sec
- Contact pressure 1.3 MPa
- Ambient conditions 23°C and 50 % RH

The wear factor K was assessed after 6 hours.

Table 3.3.1 Wear factors for various polymers, pin on disc configuration

Counterface material		Wear factor $mm^3/N \cdot km$
Polymer		
M630A	M630A	0.0074
M33AR3B	M33AR3B	0.0084
Steel*		
M630A	S45C	0.0732
M33AR3B	S45C	0.0684

*The quality of steel shall be S45C specified in JIS G 4051 as a rule. The hardness of the measuring surface of the steel shall be HRC 12 to 25 in the unit of Rockwell C hardness. Further, the surface roughness shall be about 0.8 ㎛(Ra)

3.3.2 Thrust washer configuration

Table 3.3.2 summarizes wear factors obtained when sliding against a steel counterface.
The method used is described in section 3.2 and was carried out under the following specific test conditions:

- Sliding speed 0.12 m/sec
- Contact pressure 0.4 MPa
- Ambient conditions 23°C and 50 % RH

The wear factor was determined after 7 hours according to JIS K7218.

Table 3.3.2 Wear factors for various polymers, thrust washer configuration

Counterface material		Wear factor $mm^3/N \cdot km$ µ
Polymer		
M630A	M630A	0.0044
M33AS1A	M33AS1A	0.0010
M33AR3B	M33AR3B	0.0094
POM-C	POM-C	0.0203
PA66	PA66	0.0023
Steel*		
M630A	S45C	0.0400
M33AS1A	S45C	0.0100
M33AR3B	S45C	0.0030
M33AT2E	S45C	0.0007
POM-C	S45C	0.0030
PA66	S45C	0.0023

*The quality of steel shall be S45C specified in JIS G 4051 as a rule. The hardness of the measuring surface of the steel shall be HRC 12 to 25 in the unit of Rockwell C hardness. Further, the surface roughness shall be about 0.8 ㎛(Ra)

3.4 Hardness

3.4.1 Shore hardness ISO 868: 2003

Table 3.4.1 summarizes the Shore D hardness for POKETONE Polymers.

Table 3.4.1 Shore D hardness

Grade	Shore D hardness
Resins	
M630	76
M330	77
M930	78
M710	75
M730	78
Compounds	
M33A(F)G3A	79
M33A(F)G6A	83
M63AG6A	83
M93AG8H	85
M93AG9A	84
M33AF2Y	76
M93AG6P	83
M33AG2Y	77
M33AS1A	75
M63AS1A	76
M33AR3B	73

3.4.2 Rockwell hardness ASTM D785

Table 3.4.2 summarizes the Rockwell hardness for POKETONE Polymers.

Table 3.4.2 Rockwell hardness

Grade	Rockwell hardness
Resins	
M630	110
M330	110
M930	110
M710	105
M730	105
Compounds	
M33A(F)G3A	110
M33A(F)G6A	113
M63AG6A	111
M93AG8H	114
M93AG9A	112
M33AF2Y	105
M93AG6P	112
M33AG2Y	106
M33AS1A	113
M63AS1A	109
M33AR3B	100

3.5 Abrasion resistance

3.5.1 Taber abrasion resistance ASTM D1044

The abrasion resistance of POKETONE Polymers is determined using a Taber abrasiometer according to ASTM D1044. This technique measures abrasion as the weight of material lost when a specimen is brought into contact with a standard abrasive material under a standardized set of conditions.
Table 3.5.1 summarizes the Taber abrasion resistance for POKETONE Polymers.

Table 3.5.1 Taber abrasion resistance, 1 kg load

Grade	Abrasive disc	Weight loss mg/1000 cycles
Resins		
M630A	CS-17	12
	H-18	56
M330A	CS-17	12
	H-18	82
Compounds		
M33AG6A	CS-17	42

4. Performance in use

4.1 Water absorption

4.1.1 Water absorption ISO 62 & ASTM D570

The water absorption values for POKETONE Polymers are measured in accordance with ISO 62 and ASTM D570.
The values measured are summarized in table 4.1.1.

These data relate to:

- The equilibrium water content at 50 percent RH 23℃
- The equilibrium water content when immersed in water at 23℃.

Table 4.1.1 Water absorption at 23℃

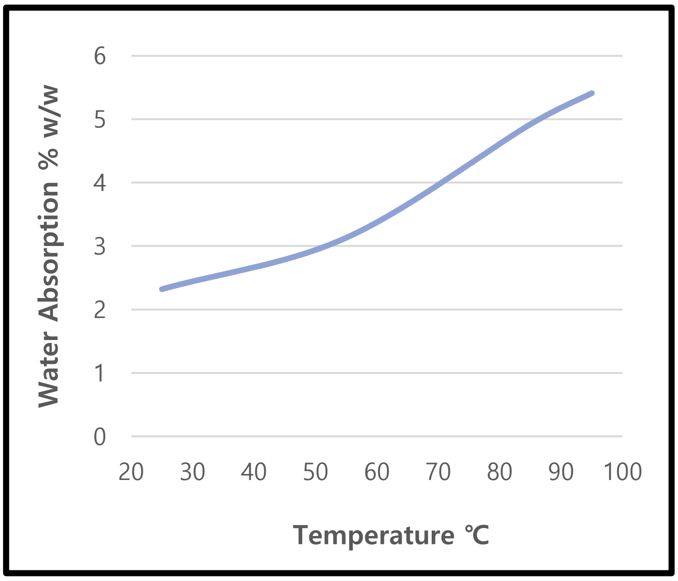
Grade	Equilibrated at 50% RH %	Equilibrated at saturation %
Resins		
M630	0.5	2.1
M330	0.5	2.1
M930	0.5	2.1
M710	0.5	2.2
M730	0.5	2.2
Compounds		
M33A(F)G3A	0.5	1.9
M33A(F)G6A	0.4	1.7
M63AG6A	0.5	1.8
M93AG8H	0.4	1.4
M93AG9A	0.3	1.4
M33AF2Y	0.5	1.9
M93AG6P	0.4	1.6
M33AG2Y	0.5	2.1
M33AS1A	0.6	2.2
M63AS1A	0.6	2.3
M33AR3B	0.5	2.3

4.1 Water absorption

4.1.2 Influence of temperature on water absorption

Figure 4.1.2 illustrates the influence of temperature upon the equilibrium absorption of water in POKETONE Polymer M330A

Figure 4.1.2 Influence of temperature upon equilibrium water absorption

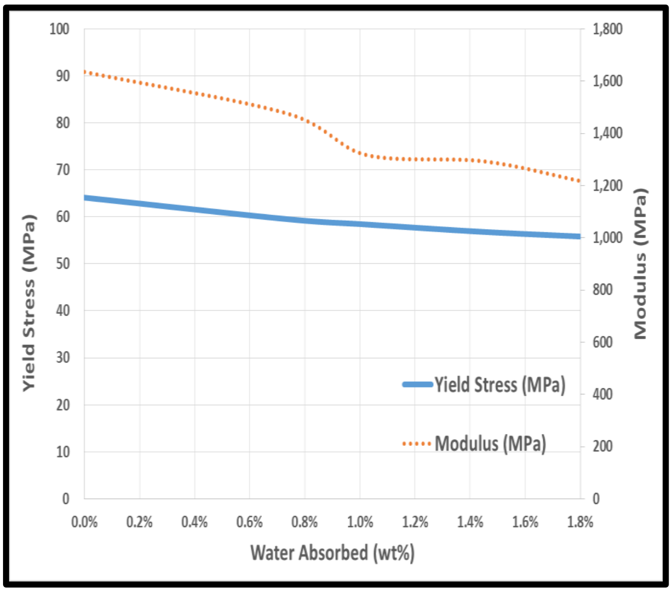


4.1 Water absorption

4.1.3 Influence of water absorption on tensile properties

Absorbed water has a mild plasticizing effect on POKETONE Polymers as is illustrated in figure 4.1.3. The influence of absorbed water upon the tensile yield stress and tensile modulus of POKETONE Polymers is, however, minimal and fully reversible.

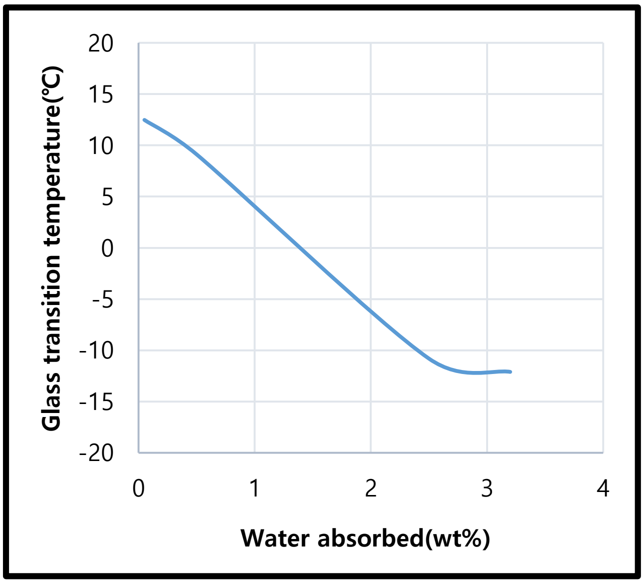
Figure 4.1.3 Influence of water absorption on tensile properties of POKETONE Polymer M330A



4.1.4 Influence of water absorption on Tg

The glass transition temperature of POKETONE Polymers is reduced by the absorption of water from a value of 15℃ when fully dry to - 17℃ by saturation in boiling water. This effect is illustrated in figure 4.1.4.

Figure 4.1.4 Influence of water absorption on the Tg of POKETONE Polymer M330A



4.2 Hydrolytic stability

4.2.1 Hydrolysis in aqueous environments

POKETONE Polymers are not subject to simple hydrolysis (chain scission) in aqueous environments. This stability is related to the backbone structure of POKETONE Polymers i.e. a carbon-carbon chain. POKETONE's stability in aqueous environments is illustrated in table 4.2.1 and table 4.2.2.
While POKETONE Polymers do not undergo simple hydrolysis, they do exhibit some susceptibility to strong acids and bases, particularly at higher temperatures. These effects are often apparent as a change in surface color and/or an increase in tensile modulus and yield stress. This latter point may be seen in table 4.2.1 where 10 percent w/w HCl causes an increase in yield stress.

Table 4.2.1.1 Yield stress values (MPa) measured at 23℃ after 600 hours exposure to at 23℃

	Yield Stress MPa	
Chemical	POKETONE Polymer M630A	Polyamide 66
Control 50 %RH	60	78
1% w/w NaOH	67	55
5% w/w NaOH	63	60
10% w/w NaOH	66	69
1% w/w HCl	65	56
5% w/w HCl	65	36
10% w/w HCl	65	Fail

Tensile testing to ASTM D638 was conducted at 23℃

Table 4.2.1.2 Yield stress values (MPa) measured at 23℃ after 600 hours exposure to at 80℃

	Yield Stress MPa	
Chemical	POKETONE Polymer M630A	Polyamide 66
Control 50 %RH	60	78
1% w/w NaOH	71	52
1% w/w HCl	70	51

Tensile testing to ASTM D638 was conducted at 23℃

4.4 Permeability

Broad chemical resistance

Due to their di-polar nature and semi-crystalline morphology, POKETONE Polymers resist dissolution in, and severe plasticization by, many common chemical environments and are therefore well suited for use in a broad range of applications.
As no engineering thermoplastic is totally insusceptible to all solvent environments, designers should always satisfy themselves that POKETONE Polymers are suitable for a particular application.
The two mechanisms by which chemical environments affect polymers are solvation (or plasticization) and chemical reaction.
Dispersive, polar and hydrogen bonding interactions are primarily responsible for the plasticization or dissolution of a polymer by a specific chemical.
Chemical attack may result from specific reactions such as those catalyzed by acids, bases or oxidizing agents.

4.3.1 Solvation

There are few known solvents for POKETONE Polymers.
For laboratory purposes, Hexafluoro-Isopropanol is used as a room-temperature solvent. In this case, solvation is driven by the strong hydrogen bonding character of the fluorinated alcohol. At high temperatures, reagents such as m-cresol can dissolve POKETONE Polymers via similar hydrogen bonding reactions.

4.4 Permeability

4.3.2 Plasticization of POKETONE Polymer M630A in organic environments

Table 4.3.2 shows the yield stress and weight gain recorded for POKETONE Polymer M330A samples after exposure to various organic solvents at 85℃ for 15 days.

Common hydrogen bonding solvents such as water, methanol and ethanol show little effect on the polymer's ultimate tensile strength.

In general, the plasticization of POKETONE Polymers by solvents with similar chemical structure, such as ketones and esters, is minor. Like alcohols, 15-day exposure to ketones and esters at elevated temperatures results in 17 percent reduction in tensile strength. This contrasts sharply with some chemically-resistant polymers such as poly-vinylidene fluoride (PVDF) which are highly plasticized and may even be dissolved by ketones and esters.

Chemical reagents which significantly swell and plasticize POKETONE Polymers are also included in table 4.3.2. Polar aprotic solvents such as dimethyl sulfoxide(DMSO) and n-methyl pyrrolidone(NMP) also have some plasticizing effect

Table 4.3.2 Yield stress values and percentage weight gain for POKETONE Polymer M330A after 15 days exposure to various solvents at 85℃

Chemical	Weight gain % w/w	Yield stress MPa
Control (50 %RH)	-	60
Water	3.0	57
Methanol	3.1	50
Ethanol	3.1	50
N-Methylpyrrolidone	3.4	40
Dimethyl sulfoxide	3.5	40

Tensile testing to ASTM D638 was conducted at 23℃

4.4 Permeability

4.3.3 Plasticization in aqueous environments

POKETONE Polymers are particularly insensitive to plasticization in most aqueous environments.
In table 4.3.3, the tensile yield stress values for POKETONE Polymer M630A are shown after being exposed to various aqueous solutions at 80℃ for 25 days. For the purposes of comparison, data for polyamide 66 (an engineering resin widely accepted for its strength, toughness and good chemical resistance) are also included in the table.
At room temperature and 50 percent relative humidity, the yield stress of POKETONE Polymer M630A is roughly equivalent to that of polyamide 66. After exposure to aqueous environments, the yield stress of POKETONE Polymer M630A is approximately 80 percent greater than that of polyamide 66 under similar conditions. POKETONE Polymer M630A exhibits superior resistance to plasticization in aqueous environments. This is demonstrated by the fact that it only absorbs 2 percent w/w when at equilibrium in water at 23℃.
POKETONE Polymers also exhibit good hydrolytic stability (see section 4.2).

Table 4.3.3 Yield stress values for POKETONE Polymer M630A and polyamide 66 after 600hour exposure to various aqueous environments at 80℃

Chemical	POKETONE M630A MPa	Polyamide 66 MPa
Control 50 %RH	60	78
Sea water	70	52
5% w/w $CaCl_2$	70	51
50% w/w $ZnCl_2$	56	Fail

Tensile testing to ASTM D638 was conducted at 23℃

Besides their resistance to a very wide range of chemicals, POKETONE Polymers also exhibit:

- Good barrier performance to solvents and fuels.
  This makes them attractive for use in chemical containment applications such as fuel systems, pipe, industrial and other barrier packaging applications.
- Very good resistance to permeation by fluid hydrocarbons such as automotive fuels and their vapors.

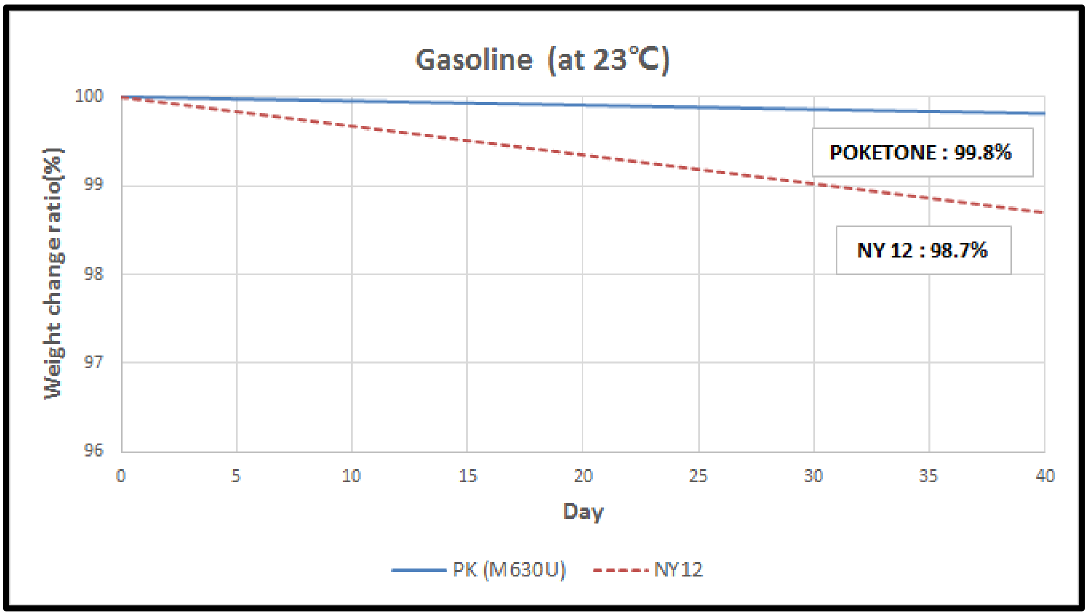
The ever-increasing number of emission regulations for all volatile organic materials continues to place higher demands on the barrier performance of polymers used in automotive fuel systems, chemical containment, industrial packaging as well as other barrier and containment applications. POKETONE Polymers are very well placed to help you respond to these requirements.

4.4 Permeability

4.4.1 Permeability to automotive fuels

The permeability of POKETONE Polymers to automotive fuels is measured in accordance with the requirements of General Motors specification GM 9061-P.
"Permeability test for fuel hoses and tubing".
The data presented in figures 4.4.1.1 to 4.4.1.3 relate to extruded tubing of nominal OD 8 mm and a wall thickness of 1 mm. The total effective length of the tubing, with both ends plugged, was 300 mm.

Figure 4.4.1.1 Permeability to gasoline at 23℃



4.4 Permeability

Table 4.4.1.2 Permeability to 85 % gasoline and 15 % methanol at 23℃

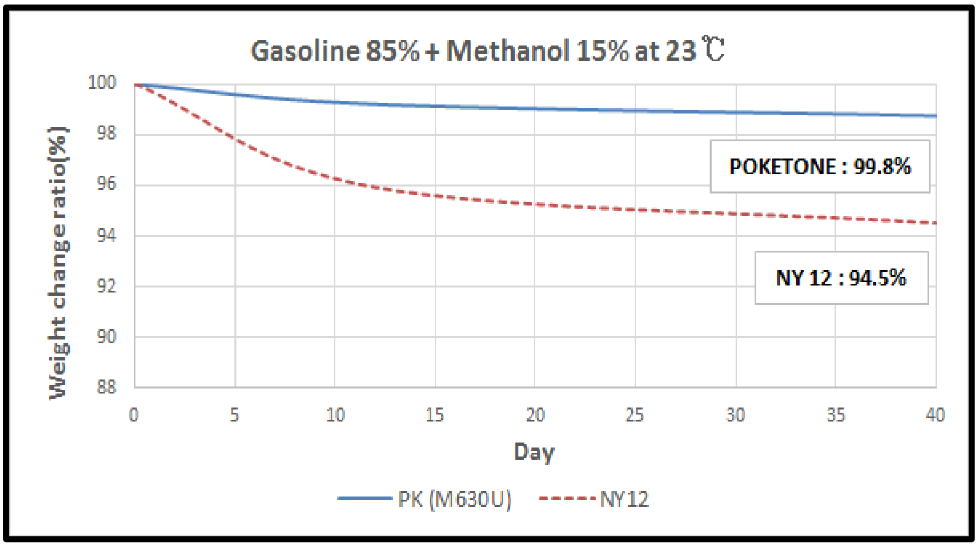
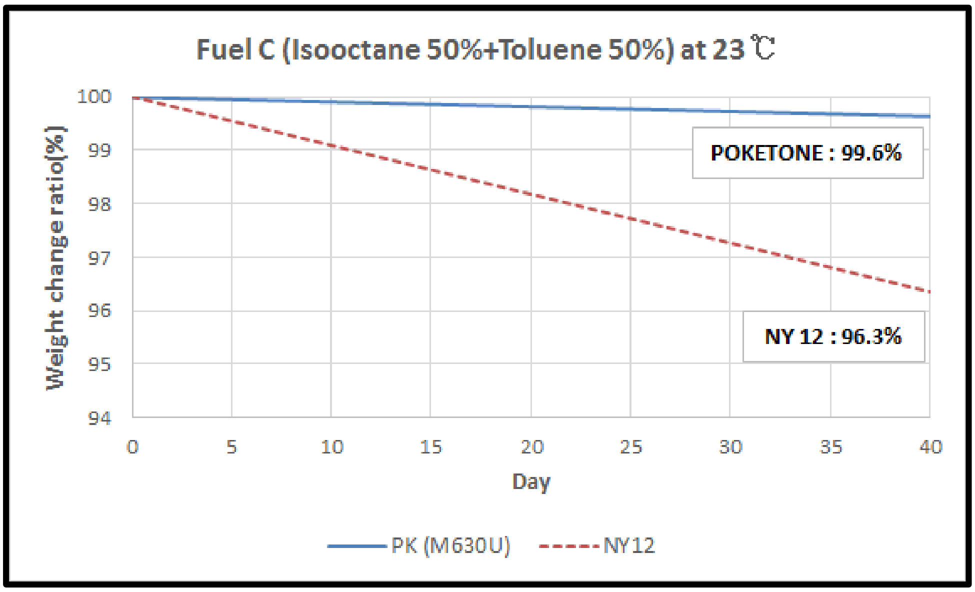


Table 4.4.1.3 Permeability to Fuel C(50 % Isooctane and 50 % Toluene) at 23℃



4.5 UV exposure

4.5.1 UV Exposure

In common with many thermoplastic polymers, aliphatic polyketones are subject to degradation upon exposure to ultraviolet radiation. Therefore neat, generic grades of POKETONE Polymers are not recommended for outdoor use without protection from sunlight exposure. Figures 4.5.1.1 and 4.5.1.2 illustrate the performance of 3 mm-thick injection molded tensile test specimens for current neat POKETONE Polymers such as M330V. M330V Grade (UV resistance grade) has shown that while strain at break decreases initially, tensile strength behavior and tensile elongation are maintained for several weeks in Weather-o-meter aging test. Figure 4.5.1.3 shows the color change performance of M630A and M630V grade.

Figure 4.5.1.1 Influence of Weather-o-meter aging test (SAE J1960/2527) on the tensile strength of 3.0 mm thick POKETONE Polymer M330V grade tensile test specimens

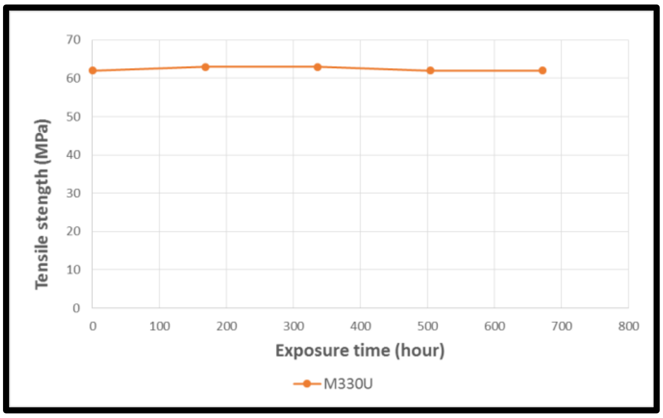


Figure 4.5.1.2 Influence of Weather-o-meter aging test (SAE J1960/2527) on the tensile elongation at break of 3.0 mm thick POKETONE Polymer M330V rade tensile test specimens

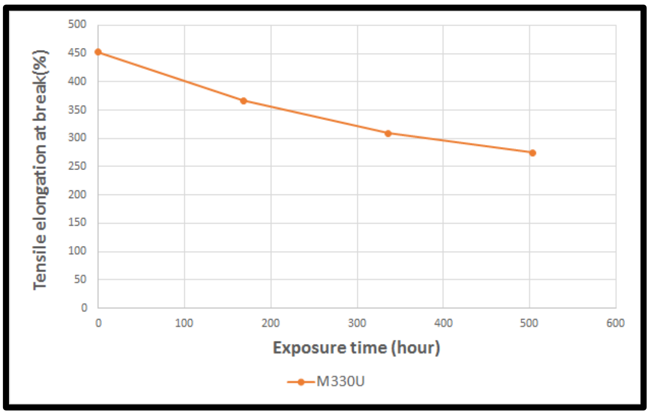
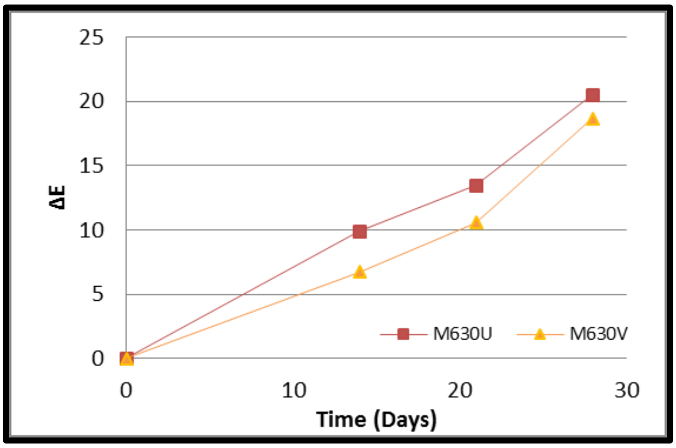


Figure 4.5.1.3 Influence of Weather-o-meter aging test (QUV test) on color change of POKETONE Polymer M630A and M630V grade.



* Test condition: UVA Lamp, 0.68W/m2 at 340nm, 60′C

5. Electrical properties

5.1 Introduction

POKETONE Polymers M630A and M33AG6A both show good electrical insulating properties (Table 5.2.1). The dielectric strength as well as the other dielectric properties show hardly any moisture sensitivity.

Flame retardant POKETONE Polymers for E&E applications – an overview

General features which give flame retardant POKETONE compounds potential for use in E&E applications are as follows:

- High tracking resistance (CTI >400V)
- Very good electrolytic corrosion resistance
- Applications in low/medium voltage insulation parts for switches and connectors
- Good balance between flame resistance, electrical properties, stiffness, toughness and ultimate elongation
- UL94 V-0 Classification
- High glow-wire temperature
- Low smoke density
- Non mineral based flame retardants
- No corrosive flue gases
- Relatively low loading of flame retardants required, hence material properties are retained

5.2 Resistivity

5.2.1 Volume resistivity ASTM D257

Rs, Ω cm is the resistance to current leakage through the bulk of an insulator. Volume resistivity varies with the temperature. Table 5.2.1 summarizes the volume resistivity of POKETONE Polymers at 23℃.

Table 5.2.1 Volume resistivity

Grade	Volume Resistivity* Ω·cm
Resins	
M630	10^{14}
M330	10^{14}
M930	10^{14}
M710	10^{14}
M730	10^{14}
Compounds	
M33A(F)G3A	10^{14}
M33A(F)G6A	10^{14}
M63AG6A	10^{15}
M93AG8H	10^{14}
M93AG9A	10^{14}
M33AF2Y	10^{13}
M93AG6P	10^{14}
M33AG2Y	10^{14}
M33AS1A	10^{13}
M63AS1A	10^{14}
M33AR3B	10^{14}

*Measured at 23℃ and 500 V

5.2 Resistivity

5.2.2 Surface resistivity ASTM D257

Rs, Ω is defined as the resistance to current leakage along the surface of an insulator. It is very sensitive to humidity and temperature. Table 5.2.2 summarizes the surface resistivity of POKETONE Polymers at 23℃.

Table 5.2.2 Surface resistivity

Grade	Surface Resistivity Ω*
Resins	
M630	10^{17}
M330	10^{17}
M930	10^{17}
M710	10^{17}
M730	10^{17}
Compounds	
M33A(F)G3A	10^{17}
M33A(F)G6A	10^{17}
M63AG6A	10^{14}
M93AG8H	10^{17}
M93AG9A	10^{16}
M33AF2Y	10^{17}
M93AG6P	10^{17}
M33AG2Y	10^{15}
M33AS1A	10^{17}
M63AS1A	10^{17}
M33AR3B	10^{16}

*Measured at 23℃ and 500 V

5.3 Electric strength

5.3.1 Electric strength ASTM D149

Electric strength, kV/mm is a measure of the breakdown resistance under an applied voltage. It is defined by the ratio between the voltage at breakdown and the material thickness. The electric strength is not a material constant but relies strongly on the electrode geometry, the surrounding medium and the sample thickness. Table 5.3.1 summarizes the electric strength of POKETONE Polymers at 23℃ in silicone oil.

Table 5.3.1 Electric strength of ASTM D149

Grade	Electric strength kV/mm*	
	2mm	3mm
Resins		
M630	19	15
M330	19	15
M930	19	15
M710	19	15
M730	20	16
Compounds		
M33A(F)G3A	23	21
M33A(F)G6A	22	17
M63AG6A	29	26
M93AG8H	25	22
M93AG9A	-	21
M33AF2Y	22	16
M33AG2Y	-	18
M93AG6P	28	24
M33AS1A	19	16
M63AS1A	20	16
M33AR3B	-	17

*Measured at 2mm brass electrodes in silicone oil

5.4 Dielectric constant and dissipation factor

5.4.1 Dielectric constant (ε_r) and Dissipation factor (tan δ) ASTM D150

Dielectric constant (ε_r) or Relative permittivity is defined as the ratio of the parallel capacitance of the Insulating material (C_p) to the capacitance of a dimensionally equivalent vacuum (C_v). Table 5.4.1 summarizes the dielectric constant and dissipation factor of POKETONE Polymers.

Table 5.4.1 Dielectric properties ASTM D150

Grade	Dissipation factor tan δ	Dielectric constant ε_r
Resins		
M630	0.009	6.1
M330	0.008	6.2
M930	0.012	6.0
M710	0.014	6.4
M730	0.014	6.2
Compounds		
M33A(F)G3A	0.011	6.0
M33A(F)G6A	0.011	6.3
M63AG6A	0.009	6.2
M93AG8H	0.008	5.7
M93AG9A	0.007	5.0
M33AF2Y	0.015	5.7
M93AG6P	0.009	5.8
M33AG2Y	0.014	5.3
M33AS1A	0.014	6.1
M63AS1A	0.013	6.3
M33AR3B	0.013	5.8

*Measured at AC 500V, 60Hz.

5.5 Tracking resistance

5.5.1 Comparative tracking index IEC 112

Tracking resistance is the resistance of an insulator to the formation of a conductive path across its surface, Tracking occurs by surface discharges as a result of moisture or dirt deposition. The low-voltage tracking resistance is expressed by the Comparative Tracking index (CTI). It is defined as the maximum voltage at which a material can withstand the deposition of 50 drops of an electrolyte without showing tracking (i.e. the flow of a current of at least 0.5 A for a minimum of 2 s in a specific test set-up). The maximum voltage which can be applied is 600 V. Table 5.5.1 summarizes comparative tracking index data for POKETONE Polymers.

Table 5.5.1 Comparative tracking indices IEC 112

Grade	Comparative Tracking Index (CTI)
Resins M330	600
Compounds M33AF2Y	600

6. Fire resistance

6.1 Introduction

POKETONE Polymer M630A can be classified as horizontal burning in the UL94 flammability test, and possesses a glow-wire temperature of 700℃.

The smoke gas toxicity is low due to the structure of the polymer which is based only upon carbonyl and olefin groups. This means that burning results predominantly in the formation of CO_2 and H_2O.

6.2 Flammability indices

6.2.1 UL94 flammability index

The UL94 indices for POKETONE Polymers are summarized in table 6.2.1. All measurements are carried out using 0.8mm, 1.5mm, and 3.0mm test pieces.

Table 6.2.1 UL94 Flammability indices

Grade	0.8mm	1.5mm	3.0mm
Resins			
M630	HB	HB	HB
M330	HB	HB	HB
Compounds			
M33AG6A	HB	HB	HB
M33AF2Y	V-0	V-0	V-0
M33AG2Y	V-0	V-0	V-0

6.3 Glow-wire flammability and ignition temperature

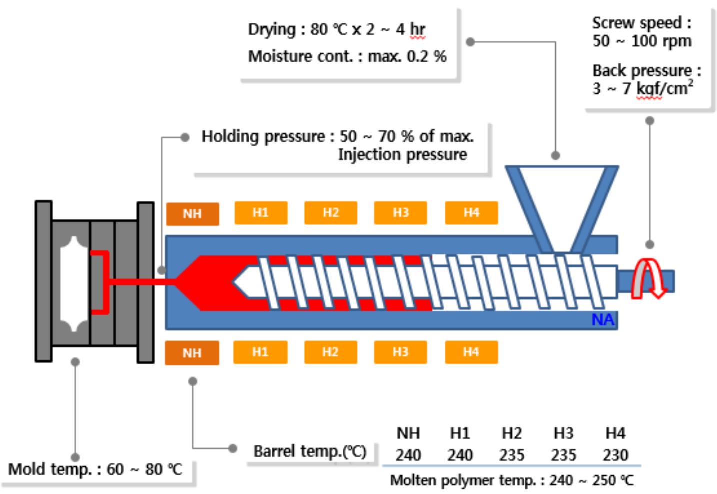
6.3.1 Glow-wire flammability index (IEC 60695-2-12) and ignition temperature (IEC 60695-2-13)

The glow-wire flammability index and glow-wire ignition temperatures for POKETONE Polymers are measured in accordance with IEC 60695-2-12, IEC 60695-2-13 at a thickness of 1mm, 2mm and 3mm. The resulting values are summarized in table 6.3.1.

Table 6.3.1 Glow-wire flammability index and ignition temperature

Grade	Flammability Index ℃	Ignition Temperature ℃
Resins		
M330	700 (0.8mm)	725(0.8mm)
Compounds		
M33AF2Y	960(1mm)	825(1mm)
M33AG2Y	960(0.8mm)	825(0.8mm)

7. Manufacturing
-primary process



7.1 Introduction

7.1 Melt processing

POKETONE Polymers may be processed by many conventional melt-processing methods.

For the majority of processing techniques, no special modification to the equipment or process will be necessary. As with all polymers, however, some processes will require modification to achieve fully optimized products.

7.2 Injection molding

7.2.1 What is the Injection Molding?

- Injection molding is a manufacturing process for producing parts by injecting material into a mold. Injection molding can be performed with a host of materials mainly including metals (for which the process is called die-casting), glasses, elastomers, confections, and most commonly thermoplastic and thermosetting polymers.

- Material for the part is fed into a heated barrel, mixed, and forced into a mold cavity, where it cools and hardens to the configuration of the cavity. After a product is designed, usually by an industrial designer or an engineer, molds are made by a mold-maker (or toolmaker) from metal, usually either steel or aluminum, and precision-machined to form the features of the desired part.

- Injection molding is widely used for manufacturing a variety of parts, from the smallest components to entire body panels of cars. Advances in 3D printing technology, using photopolymers which do not melt during the injection molding of some lower temperature thermoplastics, can be used for some simple injection molds.

- Parts to be injection molded must be very carefully designed to facilitate the molding process; the material used for the part, the desired shape and features of the part, the material of the mold, and the properties of the molding machine must all be taken into account. The versatility of injection molding is facilitated by this breadth of design considerations and possibilities.

7.2.2 Factors for good injection molding

- In order to process successfully injection molding, four key factors are very important simultaneously; Material, Processing, Mold and Product design.

- Plastic material is defined by that it's chemical structure, molecular characteristics, ingredients and fillers, of course the key point of polymer processing is the flow ability at the stable processing temperature.

- Most molders are using the regrind resin with limited content, so regrind resin or recycled resin could be also a big factor.

- Mold and injection machine should be matched up correctly to product design and plastic materials.

- Product design is sometime to be a key solution for the best quality, when other factors could not control the quality issue, CAE (Computer Aided Engineering) could help how to modify the mold design.

7.2.3 Preparing – Machine / Mold Screw Design

- Use standard metering screws with L/D ratios from 18:1 to 22:1 and compression ratios between 1.75~2.5:1. Free-flowing check rings minimize the possibility of resin overheating. Screws with mixing sections or flow restrictions should be avoided.

Nozzles

- Use conventional or reverse-taper nozzles with polished bores and streamlined flow. Positive shut-off is not usually required.

- Well-controlled heated nozzles as using enough capacity heater and separated thermocouple are strongly recommended to prevent freeze-off problem due to

7.2 Injection molding

polyketone's rapid crystallization.

- Bigger nozzle orifice size is strongly recommended as more than Ø 4.0 mm for small sized injection machine to help better flow and trouble-free like nozzle blocking.

Mold

- **Materials:** Use standard tool steels such as P-20, H-13, and S-7. Polyketone does not emit corrosive compounds during normal processing
- **Gas Vents:** Vent generously to accommodate rapid fill rates. Use vent depths of 0.008-0.013 mm (0.0003-0.0005 in) at final fill points and areas where air traps are likely.
- **Runner, Sprue bushing:** Full-round runners minimize melt chilling during passage through the runner, though trapezoidal and half-round runners also can be used. Keep as short as possible, with a minimum diameter of 6.4 mm (1/4 in). Minimize secondary runner lengths, too, and use 4.8 mm (3/16 in) minimum diameter. Use standard sprue bushings with 2-4° draft angles. The installation of cold slug well at sprue end is strongly recommended for smooth flow like other engineering thermoplastics materials.
- **Gating:** All common gate types such as edge, fan, flash, submarine and pinpoint are suitable. Make gates for medium flow products as large as possible 25 %-50 % larger than those for POM and 40 %-75 % larger than for PA66. Keep land length to a minimum due to polyketone's rapid set-up.
- **Mold Shrinkage:** Transverse shrinkage of unreinforced grades is usually almost same as in flow direction (a little less in flow direction). Mold temperature can help fine-tune part dimensions. Tools designed for acetal are often suitable for POKETONE Polymers.
- **Draft:** In order to facilitate component removal from the mold and hence reduce cycle time, a design should incorporate appropriate draft angles. For untextured surfaces, 0.25 degrees to 2 degrees per side for both inner and outer wall is usually sufficient. In certain applications the use of draw polish on the mold surface may allow a smaller angle. The mold parting line position on the part can often be relocated in order to change or split the required draft. If absolutely no draft is permitted due to dimensional requirements, a cam or slide in the mold may be required.
- **Hot runner:** While most of crystalline engineering thermoplastics polymer including POKETONE Polymer is more heat-sensitive than amorphous polymer, careful treatment in hot runner system is needed.

- The manifold should be well-balanced without dead spot (hold-up) on flow path, and externally heated manifolds are preferred versus internally heated ones, as they allow better streamlining at intersections and generate less shear for the polymer.

- Direct gating on the part surface is not recommended to avoid aesthetic issue on surface such as flow mark, cold slug and other quality issues.

- The hot runner manifold channels should be unrestricted without sharp corners or flow obstructions. Flow restrictions will increase the shear on the material and may result in discoloration or degradation of the melt resin.

- Any hold-up spot in flow path, which will tend to thermally degrade due to excessive residence time, should be avoided, and also

7.2 Injection molding

needed to be polished in flow path. Excessive residence time in the hot runner manifold should be avoided as it can result in material degradation which can make poor surface issue and easily part broken.

- Separate temperature controllers for each drop and each location on the manifold is essential. The controlling thermocouple for each heat source in the manifold should be close to the melting resin.

- More precisely heat controlling at nozzle tip both in hot runner and cold runner is strongly recommended due to fast solidification at Tc for POKETONE Polymers, as using separated thermocouple and full covered heater (enough capacity of heater) on hot drop or nozzle tip.)

7.2.4 Preparing – Materials Drying

- Maximum recommended moisture content is 0.2 %. Satisfactory product drying can usually be obtained using conditions that range from 2 hours at 90℃ to overnight at 60℃.
- Recommended drying condition is 3~4 hours at 80℃.
- Although POKETONE does not be moisture-sensitive, it should be kept dry to prevent poor surface issue like silver streak, drooling or voids.

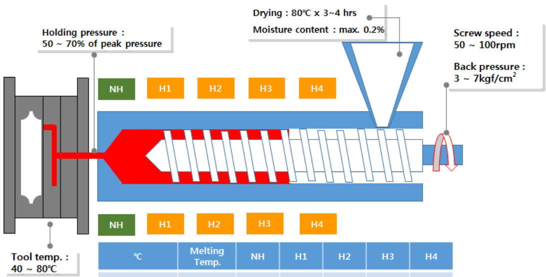
Regrind

- Limit regrind content to a maximum of 25 %. Lab tests show that POKETONE Polymers can be reground several times and exhibit little loss in properties at suggested processing conditions. But for the practical application, it has to be applied after testing by ratio of the regrind material.
- Regrind tends to pick up moisture more, and irregular particles can impair good flow in the hopper.

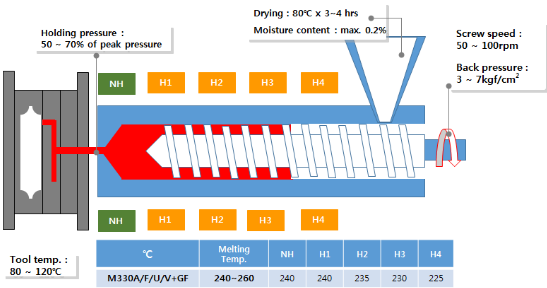
Color master-batch Blending

- If you need the M/B dry blending, we recommend contacting us and discussing about it.
- According to our study, the M/B composed of the POKETONE Polymers as the carrier resin shows the better properties and surface quality than others, so we recommend using POKETONE Polymers carrier M/B.

7.2.5 Injection Processing Guide



℃	Melting Temp.	NH	H1	H2	H3	H4
M330A/F/U/V	235~250	240	230	220	215	210
M630A/F/U/V	240~260	250	240	230	225	220



℃	Melting Temp.	NH	H1	H2	H3	H4
M330A/F/U/V+GF	240~260	240	240	235	230	225
M630A/FU/V+GF	245~265	250	250	240	235	230
M930A/F/U/V+GF	235~255	235	230	225	220	220

Melt & Barrel Temp.

- Balance shot size with barrel capacity to give residence times of 2-10 min.
- Suggested melt- temperature range is 235-250℃

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(460-490˚F).

- Do not exceed 265℃ (509℉). Long residence times at high end of the temperature range can cause thermal degradation & loss of physical properties.
- In extreme cases, crosslinking and large increases in melt viscosity can result.
- Can start with a flat or less at rear side for barrel temperature profile.
- Feed zone can be slightly cooler to aid removal of volatiles or smooth feeding.
- A reverse profile may be better with screw L/Ds above 20:1.

Back pressure

- In most cases, machine hydraulic pressure of 5 bar will achieve uniform melt temperature and consistent shot size. (This assumes a force multiplier of 10 between hydraulic and melts pressure.)
- When using color concentrate, 10 to 15 bar back pressure may be necessary for proper mixing.
- Avoid back pressures above 15 bar since they can lead to hot spots along the screw.

Screw speed

- Use slow to moderate speeds.

Injection speed

- Start with medium speed, Keep in mind POKETONE Polymers rapid set-up times.
- Increase injection rate before increasing melt temperature if lower viscosity is desired to aid part filling.

Holding (packing) time & pressure

- POKETONE Polymers fast set-up allows short holding times.
- Start with packing pressure at 50 %-70 % of maximum injection pressure.
- A minimum cushion (6-12 mm, 0.25-0.50 in) is usually sufficient

Clamping Force

- Use low to moderate pressure of 27-42 MPa (2-3 tons/sq in)

Mold Temp

- Recommend to start at 60-80℃ of mold temperature for successful molding for unreinforced grade and can be achieved good part at 30-150℃ of mold temp. Reinforced grade are recommended to be higher mold temperature as over 120℃ for better surface quality. The higher in mold temperature, the better surface for reinforced grades.
- Rapid crystallization at elevated temperatures allows use of hot molds to improve filling, weld lines and surface finish with little effect on cycle times.
- Mold temperature can be used to help control part shrinkage.

Cycle time

- POKETONE Polymers can reduce cycle time by rapid solidification during cooling time at runner and cavity.
- Typically 15-20 sec for thin-wall moldings (0.6-1.5 mm, 0.025 to 0.060 in), 30-40 sec or less for thicker sections up to 3.2 mm (0.125 in).

7.2 Injection molding

Mold release

- Sticking is rare in well-designed tools. If specific part geometry causes problem, light application of standard release agents may be used.
- For better releasing at mold deep area, well-designed cooling channel is recommended by using bubbler or heat transaction pipe.

Purging

- Strongly recommend immediate cleaning after injection of POKETONE Polymers, using high viscosity HDPE(MI), PCTG(MI) and PP(Hyosung R200P, MI), or resembled resins

Guide Line for downtime during injection molding

- Stop within 20 minutes :

  - Stop molding process while maintaining the processing temperature of injection machine and hot runner.

  - Purge out the molten POKETONE resin several times before re-starting injection molding.

- Stop from 20 minutes within 2 hours :

  - Purge out all the rest of POKETONE material inside barrel and hot runner manifold.

  - Decrease the temperature from current temperature about 20-40℃ on cylinder (and hot runner) temperature and stop injection molding process while turning on heater.

  - When re-starting injection molding, please increase the temperature to setting points and purge out several times when reached to the temperature.

- Stop from 2 hours within 12 hours :

  - Purge out all the rest of POKETONE material inside barrel (and hot runner) and decrease the temperature to 170~180℃ on barrel (and hot runner) temperature, then stop molding process while turning on heater. (For better cleaning, Purge out all the rest of POKETONE Polymers with the purging material inside barrel and hot runner manifold).

  - When re-starting injection molding, please increase the temperature to setting points and purge out several times when reached to the temperature (when increase the temperature, firstly increase barrel temperature and later increase hot runner temperature).

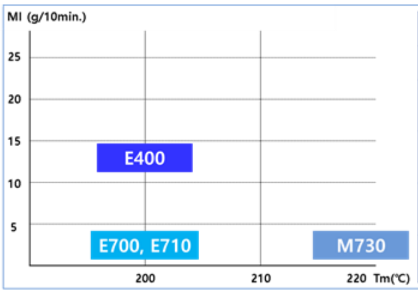
- Stop more than 12 hours :

  - Purge out all the rest of POKETONE Polymers with the purging materials (PCTG, HDPE, PP, etc.) inside barrel (and hot runner manifold).

  - Keep on purging out all the rest of POKETONE Polymers until inside of barrel is completely cleaned, then stop molding operation.

7.3 Extrusion

7.3.1 Preparation



Grade		Application
Grade	MFR	
M730	2~4	Pipe
E710	2~4	Pipe/Tube
E700	-	Blown Film Blow molding
E400	-	Monofilament

Pellet drying

- **Method:** Dry clean air drying, or vacuum drying
- **Temperature:** 70℃(160°F) or 80℃(175°F)
- **Time:** Minimum 4 hours, maximum 16 hours
- **Conveying:** Reduce the contact with ambient air and keep warming

7.3.2 Extrusion Processing Guide

Hopper

- **Temperature:** Set 70℃(160°F) and below, or keep warming
- **Feeding:** Flood feeding or starve feeding using a feeder
- **Throat:** Keep cooling with water circulation (below 50℃)

Extruder

- **Screw design:** Conventional standard single screw extruder(full flight single screw) is recommended. Because POKETONE Polymers is a shear sensitive polymer, the lesser shear force inside an extruder is the better the quality of polymer melt.

  - Length-to-diameter (L/D) ratio: larger than 26
  - Compression ratio (C/R): 2.5 <C/R< 3.0
  - Flight pitch: 1D (Helix Angle 17.66°)
  - Flight width: 0.1D
  - Channel depth in feed section: 0.15~0.20D

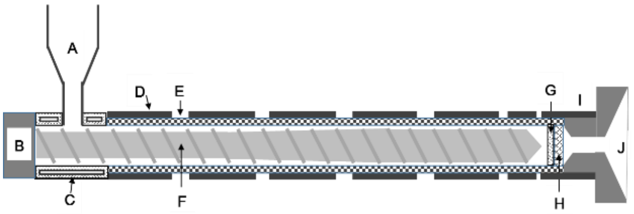
- **Screw section configuration:** The general configuration of single screw is like below.

  We recommend the higher portion of feed and compression section compared to the general because the thermal conductivity of POKETONE is lower than polyolefin polymers so that it needs longer length of feed and compression sections in order to melt evenly.

Item	L/D	Feed	Compress-ion	Meter-ing
Pipe	>26	45%	30%	25%
Film	32	>10D	>11D	<11D
	28	>8D	>10D	<10D
	26	>8D	>9D	<9D

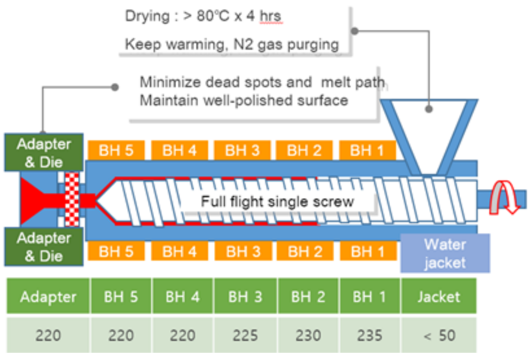
- **Grooved feed:** Basically not recommended.
- **Mixing section:** Basically not recommended. If it was equipped, please check residuals on the surface after trial.
- **Screw cooling:** (option) to avoid the feed bridging problem, 4D screw depth cooling is generally recommended
- **Barrel heater:** 4 to 6 barrel heaters with a cooling jacket

7.3 Extrusion

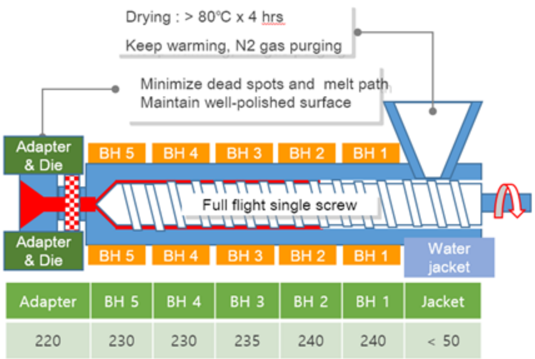


A: Hopper, B: Motor, C: Water cooling jacket, D: Barrel Heater, E: Barrel(or Cylinder), F: Full Flight Screw, G: Screen Pack, H: Breaker Plate, I: Adapter, J: Die

- **Temperature profile:** 1) Primarily reverse temperature profile, 2) Secondarily hump temperature profile.
- **Initial temp. profile for M710 grades:**



- **Initial temp. profile for M730 grades:**



- **Nitrogen purging:** (Option) to reduce the oxidation reaction at the feed section.

Start-up

Initial heating & Start-up: The second step of heating is recommended. Set the temperature to 150℃ in order to avoid the oxidation and degradation of any residue inside the extruder. Move to the 2nd step heating to an initial temperature program before 1 or 2 hours of running the machine. Start the extruder operation using PP(for Pipe), LDPE(for Film) with a MFR of 2-5. For pipe extrusion, when the extrudate gets clean and stable, drain out PP from a hopper and pour PETG and purge. After the PETG extrudate gets clean, directly pour POKETONE pellets into hopper. For film extrusion, when the extrudate gets clean and stable, drain out LDPE from a hopper and directly pour POKETONE pellets into hopper.
Recommend to keep the screw rotation over 30 rpm to avoid a feed bridging problem.

When the extrusion gets stable, check the melt temperature and try to lower it step by step as much as possible.

- **Temperature profile during normal operation for Film**

	Water Cooling Jacket	Barrel Heater1	Barrel Heater2	Barrel Heater3	Barrel Heater4	Adapter Heater
Value	< 50℃	235℃ → 230 → 225 → 220	230℃ → 225 → 220 → 215	225℃ → 220 → 215 → 210	220℃ → 215 → 215 → 210	220℃ → 215 → 215 → 210
Section	Hopper& Feed	Feed	Compression		Metering	Melt Pipe

Purge

7.3 Extrusion

- **Case:** When the following phenomena occur, the purging operation is recommended.

  - Partially cross-linked gels and black specks are rapidly increased

  - The color of the products is getting yellowish

  - The extrudate is rapidly decreasing due to bad feed of the pellets.

  - The melt pressure or the screw torque is abnormally increasing

- **Procedure:** First of all, follow the standard purge procedure you have. And then refer to the following;

  - Drain or pour the POKETONE pellets out and put PP(for Pipe), LDPE(for Film) with MFR of <0.5 for M710F grade into the hopper or the feed throat.

  - Keep the same temperature profile.

  - Continue purging with LDPE until POKETONE Polymers is completely flushed out.

  - For Pipe extrusion, when most defects disappear in the PP melt, directly change to PETG over PP pellet in the feed throat or in the bottom of hopper. For film extrusion, directly change to POKETONE pellets when most defects disappear in the LDPE melt.

- **Melt Flow Rate(Melt Index):**

Grade		Polyketone M710F	Polyketone M510F	LDPE Low MFR	LDPE Medium MFR
Nominal MFR (gram/min)		2 - 4	8 - 20	0.3	3
Tm (℃)		200	200	110	111
MFR (gram/10min)	210℃	2.95	6.59	0.50	5.04
	220℃	3.62	8.81	0.74	6.30
	230℃	5.75	10.64	0.95	8.26
	240℃	5.10	11.72	1.06	9.76

Shut-down

- **Procedure:** First of all, follow the standard shut-down procedure you have. And then refer to the following;

  - For Pipe extrusion, pour the PETG until most defects disappear in the PETG melt and directly change to PP pellets MFR of <0.5.

  - For Film extrusion, drain or pour the POKETONE pellets out and put LDPE with MFR of <0.5 for M710 grade into the hopper or the feed throat.

  - Keep the same temperature profile.

  - Continue purging with LDPE until polyketone is completely flushed out.

  - When most defects disappear in the LDPE melt, the operation of extruder should be stopped when the extruder is filled with LDPE.

- **Option:** In addition, decrease the temperature conditions (185 / 180 / 180 / 180 / 170℃) and continue to purge during several ten minutes using LDPE with MFR of <0.5.

7.4 General safety precautions

For information on the health and safety of POKETONE Polymers, please refer to the appropriate Material Safety Data Sheet (MSDS).

Processing equipment: this brochure is not intended to address the safety considerations of processing equipment. Read and be familiar with all safety information provided by the manufacturer of that equipment. If a question should arise concerning the safety features of the equipment, the equipment supplier should be contacted.

In some manufacturing operations, handling pellets may generate static electricity. Where appropriate, equipment should be properly grounded.

As with any heat-sensitive thermoplastic, care should be taken to follow established industrial safety practices when molding the material. The guidelines on melt temperature and barrel residence tie limited outlined in this brochure should be followed closely.

POKETONE Thermoplastic Polymers: Always read the MSDS for this or any other material you are using before you begin molding operations.

Toxicity testing on POKETONE Polymers indicates that the material is not harmful if swallowed or if it contacts the skin or eyes. Combustion or high-temperature thermal decomposition of hydrocarbon polymers should be avoided as it may produce toxic fumes.

As with all thermoplastics, proper ventilation around the processing equipment is recommended. Exposure to the molten material may cause burns; Pressure build during interruption of production can cause a loud explosive exiting of the melt when open shots are made.

If the material ground during use or recycling, a dust can be generated which could cause irritation to the skin, eyes, throat and lungs due to the abrasive nature of the fine particles produced. Proper engineering controls should be employed or protective clothing worn to avoid exposure to the dust in accordance with the ACGIH recommendations for particulates not otherwise classified