



Hyosung POK Biz Division

# I . POKETONE Introduction

## POKETONE Definition

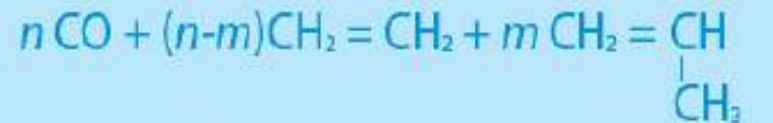
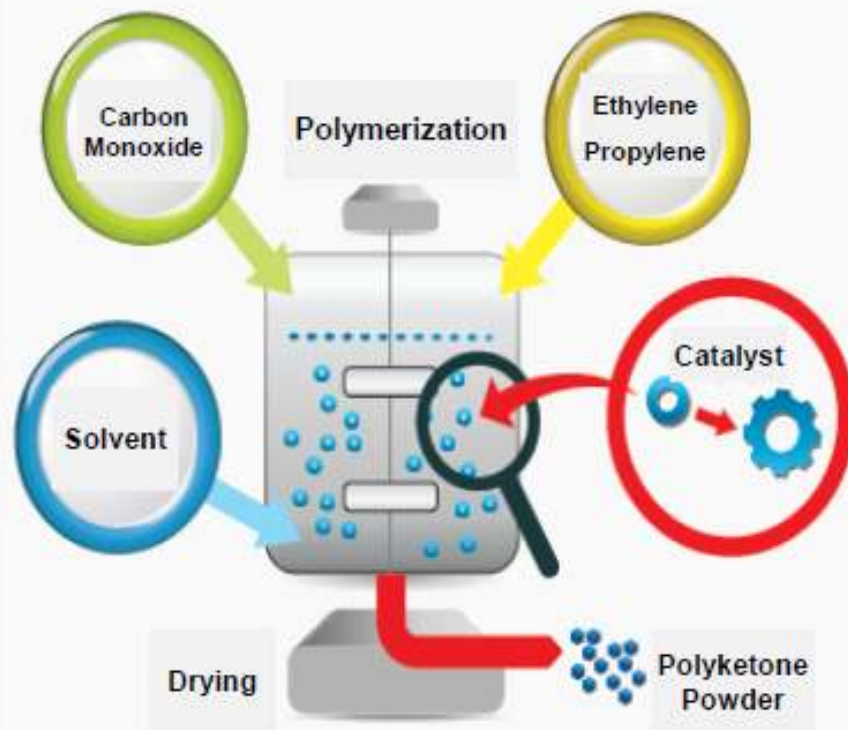
- What is POLYKETONE?

New Green Polymer composed with Carbon Monoxide and Olefins (Ethylene, Propylene)

- What is **POKETONE**?

Brand Name of HYOSUNG Polyketone

Registered its Trademark in 2016 and now on Promoting to diverse industries



Carbon  
Monoxide

Ethylene

Propylene



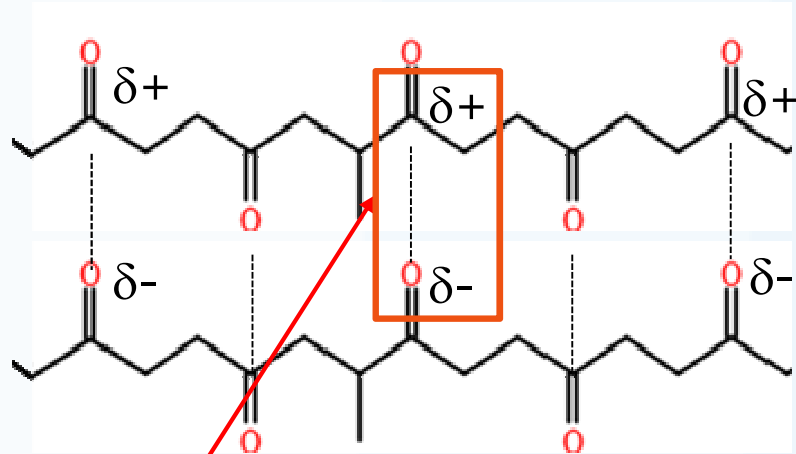
Polyketone



# I. POKETONE Introduction - Structure

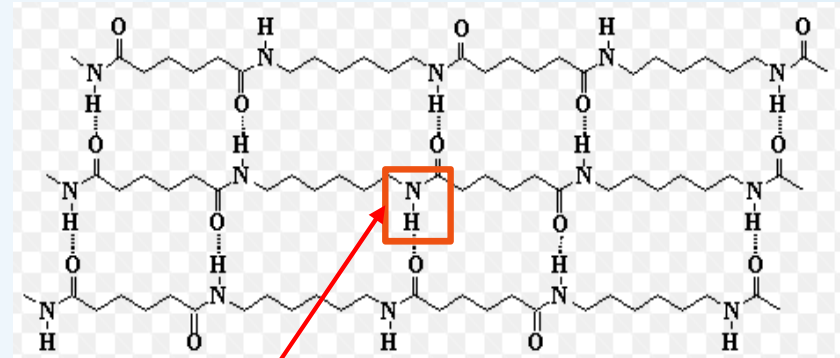
## □ Chemical Structure Comparison: Polyketone vs. Polyamide

PK



Dipole-dipole interaction  
All carbon main chain

PA



Hydrogen bond  
Carbon-Nitrogen main chain

	Polyketone		Polyamide		Property
Bond strength	Dipole-Dipole	<	H-bond	➡	Good strength
Water affinity	Dipole-Dipole	<	H-bond	➡	More water absorption
Flexibility	C-C bond	>	C-N bond	➡	Good toughness

Properties	units	PA66(Dry)	PK
Melting point	°C	260-265	218-223
Saturated moisture content	%	7	2
Tensile Strength	MPa	85	60
Elongation at break	%	<80	>200
N. charpy	kJ/m <sup>2</sup>	4.6	9.0

# I. POKETONE Introduction – Mechanical properties

## Properties comparison

Items	Unit	POKETONE	PA6	PA66	PBT	POM
Density	g/cm <sup>3</sup>	1.24	1.14	1.14	1.30	1.41
Melting Temperature	°C	222	220	260	220	160
Impact Strength	KJ/m <sup>2</sup>	9	5.2	4.1	5.0	6.5
Tensile Strength at Yield	MPa	60	80	80	55	65
Nominal Strain at Break	%	300	17	19	16	35
Flexural Modulus	MPa	1,550	2,600	2,900	2,400	2,500

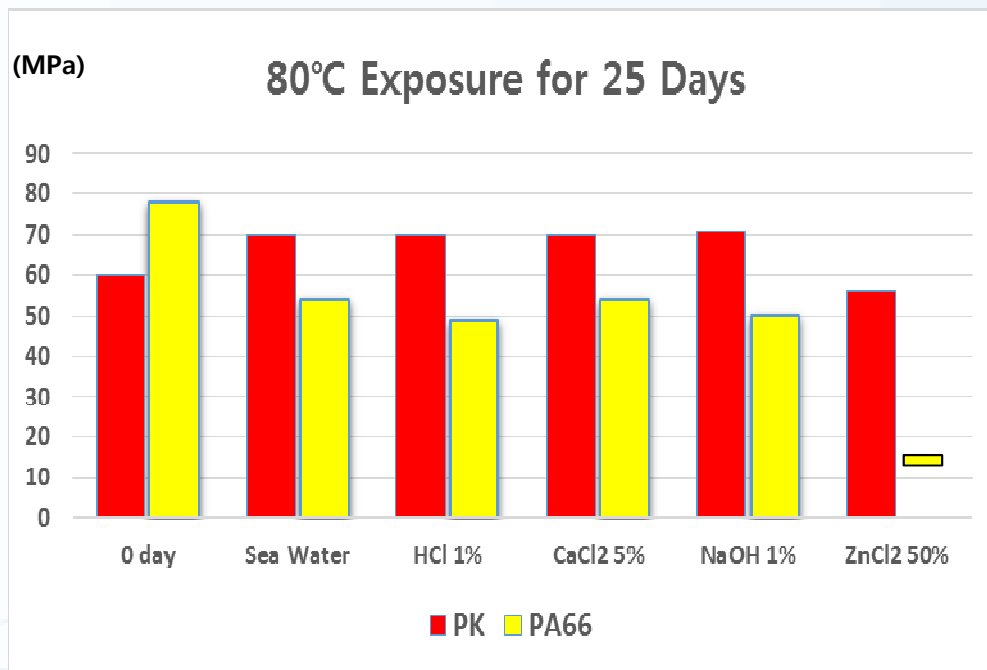
## II. POKETONE Features

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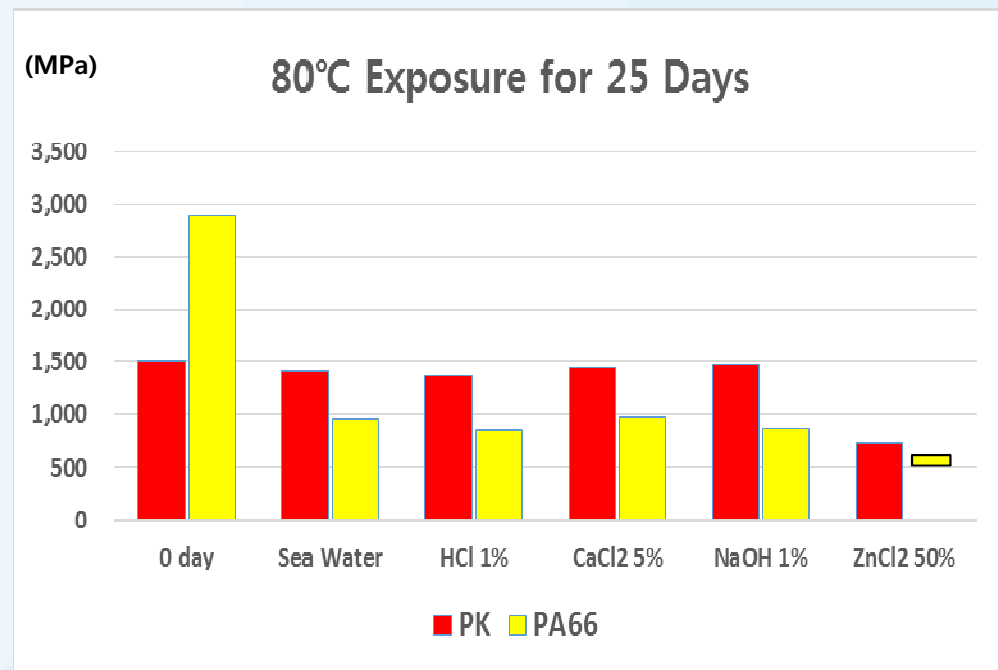
### ***POKETONE – “Chemical and Hydrolysis resistance”***

- POKETONE has good chemical resistance to almost all chemical materials except strong acid/alkali
- Good mechanical property retention at exposure to chemical material
- PA : Amide Group (-NH-CO-) is weak to Water/Acid/Alkaline
- PK : Main Chain is composed with only C-C, so stable to Water/Acid/Alkaline

#### Tensile Strength



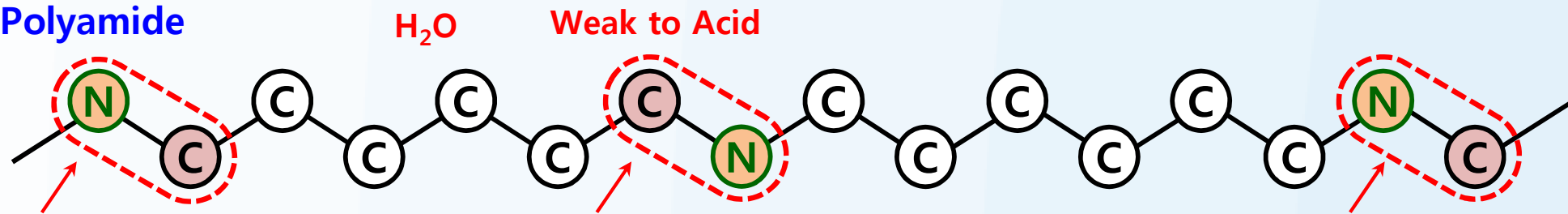
#### Flexural Modulus



## II. POKETONE Features

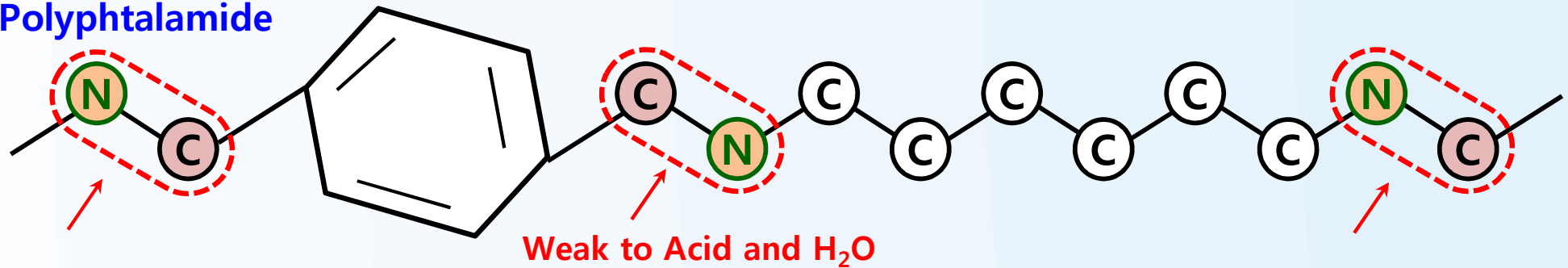
### Difference material and chemical structure

#### Polyamide

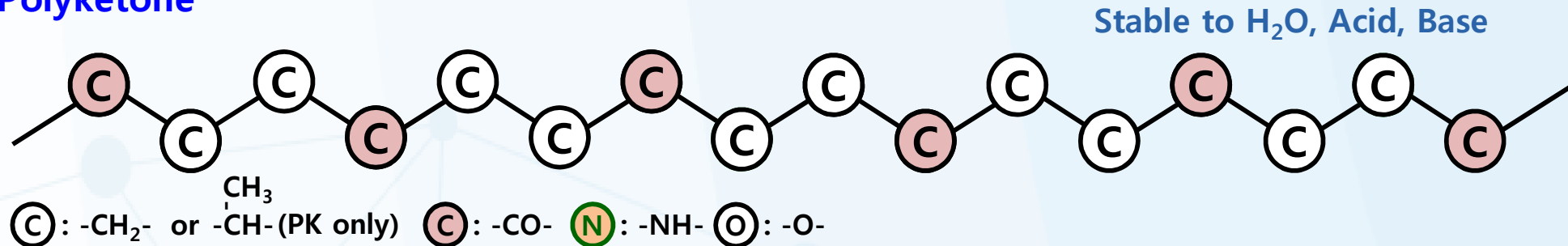


\*Usually PPA means mixing material between Polyphthalamide and PA66

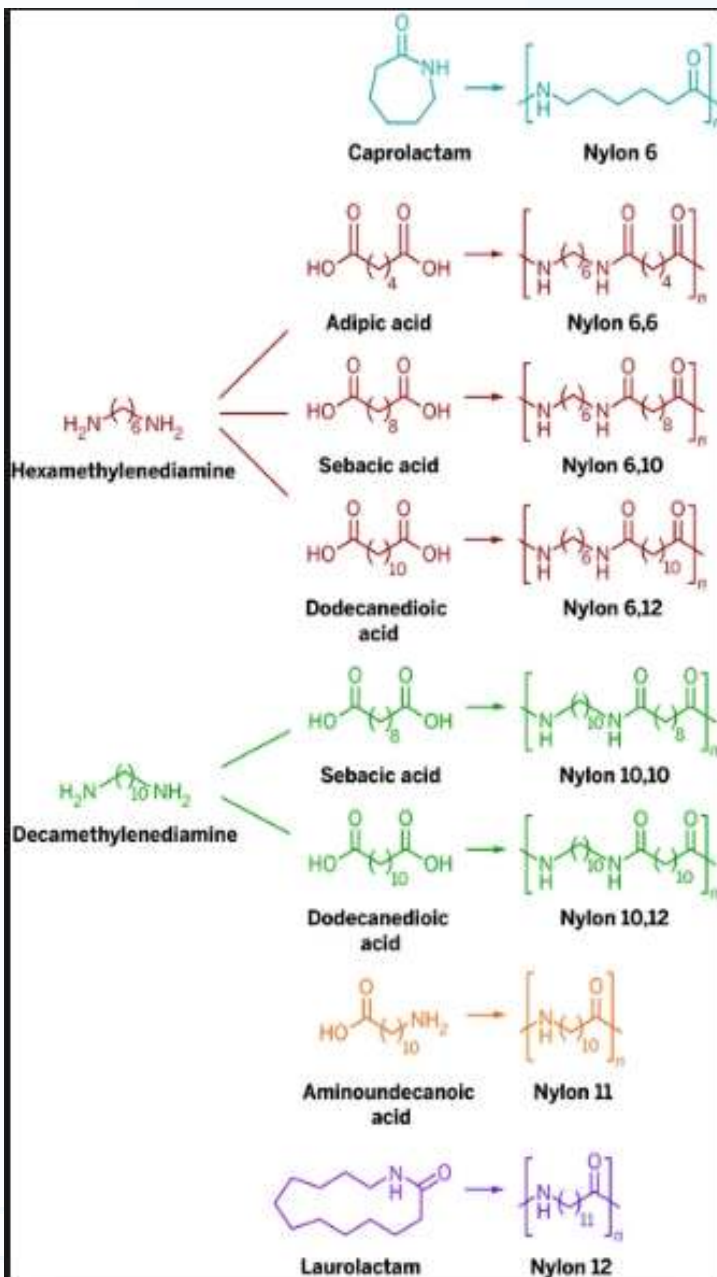
#### Polyphthalamide



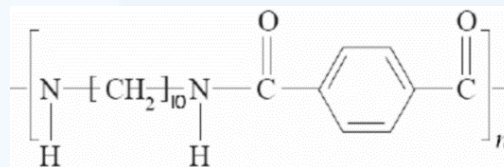
#### Polyketone



# II. POKETONE Features



Materials (Brand name, Producer)		Chemical structure	Thermal properties
PA6-6		 C6 diamine adipic acid	Tm=255°C Tg=50°C
PA4-6 (Stanyl, DSM)		 C4 diamine adipic acid	Tm=290°C Tg=78°C
modified PA6-T	PA6-6T (Arlen C, Mitsui) (Amodel A-4000, Solvay) (Zytel HTN52, Dupont)	 C6 diamine adipic acid terephthalic acid	Tm=310°C Tg=85°C
	PA6-6IT (Amodel A-1000, Solvay)	 C6 diamine adipic acid isophthalic acid terephthalic acid	Tm=310°C Tg=126°C
	PA6M-T (Zytel HTN51, Dupont)	 C6 diamine methylpentane diamine terephthalic acid	Tm=305°C Tg=135°C
PA9-T (Genestar, Kuraray)		 C9 diamine methyloctane diamine terephthalic acid	Tm=263~306°C Tg=125°C



Polymer Chemistry	Reference Here	Tg (C) by DMA	Tm (C) ISO 11357	DTUL@ 1.8MPa (C) ISO 75	%H2O, 24Hrs ISO 62
PA66 (Zytel®)	PA66	65	263	252	1.2%
PA6T/DT ** (Zytel® HTN51)	PPA 1	140	300	264	0.5%
PA6T/6I/66 (Competitive PPA)	PPA 2	125	312	278	0.5%
PA6T/66 (Zytel® HTN52)	PPA 3	90	310	285	0.5%



# II. POKETONE Features

## Mechanical properties comparisons

Properties/Grade		Test Method	Unit	PA66/GF30	POKETONE M33AG6A (M330A/GF30%)	PA66/GF30	POKETONE M93AG8A (M330A/GF40%)	POKETONE M93AG9A (M330A/GF50%)	PPA/GF40	PPA	PPA
				Dry condition	No big difference according to water absorption	Conditioned 2.5% Moisture	No big difference according to water absorption	No big difference according to water absorption		PPA/GF30	PA6T/66
<i>Physical Properties</i>											
Density		ISO 1183	g/cm³	1.37	1.47	1.37	1.57	1.67	1.57	1.47	1.78
Water Absorption	23°C, 50%RH	ISO 62	%	1.9	0.4	6.1(Saturation)	0.3	0.3	0.15	2~4.5	2~4.5
Mold Shrinkage			%	0.3	0.2					-	-
<i>Mechanical Properties</i>											
Tensile Strength at yield	23°C	ISO 527-1	MPa	190	140	140	165	170	243	160~185	250~260
Nominal Strainat Break	23°C	ISO 527-1	%	3	4	-	2.9	2.5	2	2	1.5
Flexural Strength	23°C	ISO 178	MPa	270	190	190	215	200	357	-	-
Flexural Modulus	23°C	ISO 178	MPa	8800	6500	6000	9000	11300	14500		
Notched Izod	23°C	ISO 180/A	kJ/m2	10	13	-	13	11	10	-	-
<i>Thermal Properties</i>											
Melt Temperature		ISO 3146	℃	260	222	-	222	222	323	310	325
Heat Deflection Temperature	18.2 Kg/cm2	ISO 75	℃	250	210	-	210		293	280	290
Melt Flow Index	240°C, 2.16kg		g/10min	-	13	-	19	4		-	-



# II. POKETONE Features

## Chemical Resistance

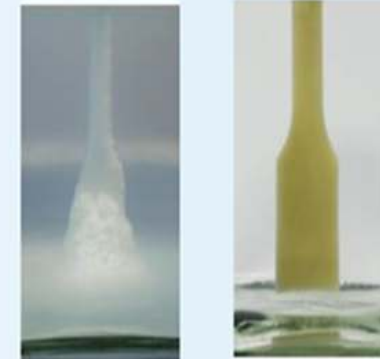
	Semi-Crystalline						
	PK	PA66	PA12	POM	PBT	PPS	PVDF
<b>Hydrocarbons</b>							
Aliphatic	○	○	○	○	○	○	○
Aromatic	○	○	○	○	○	○	○
Halogenated	○	○		○		○	○
<b>Ketones</b>	○	○	○	○	○	○	
<b>Esters/Ethers</b>	○	○	○	○	○	○	○
<b>Aldehydes</b>	○	●	●	○	○	○	○
<b>Aqueous</b>							
Water	○	●	○	○	●	○	○
Weak Acids	○	●	●	●	●	○	○
Weak Bases	○	●	●	○	●	○	●
Strong Acids	●	●	●	●	●	●	○
Strong Bases	●	●	●	○	●	●	●

○ : Resistant

● : Not Resistant

\* Remark : Relative Ranking including Temperature Effects

@ Battery acid (38 % H<sub>2</sub>SO<sub>4</sub>)



<PA66 GF30>   <PK GF30>

## II. POKETONE Features

### ► Chemical Resistance - HOCL(Hypochlorous acid)

- Test Condition : immersion in 250ppm of HOCL solution (23°C, 1008hours)
- Result : POKETONE is superior to PA

Material		Tensile Strength		Elongation		Flexural Strength		Flexural Modulus		Weight [g]
		[MPa]	Retention rate	[%]	Retention rate	[MPa]	Retention rate	[MPa]	Retention rate	
PK	Base	61 → 55	91%	327 → 588	180%	59 → 51	85%	1543 → 1107	72%	28.6 → 29.2 (102%)
	GF30%	125 → 106	85%	3.9 → 4.3	112%	183 → 155	85%	6502 → 5550	85%	33.9 → 34.5 (102%)
	GF50%	163 → 146	89%	2.5 → 3.0	117%	211 → 186	88%	10035 → 8227	82%	38.3 → 38.8 (101%)
PA66	Base	82 → 39	48%	30 → 352	1170%	108 → 29	27%	2631 → 551	21%	26.1 → 27.9 (107%)
	GF30%	187 → 101	54%	3.3 → 3.7	113%	274 → 140	51%	8324 → 3907	47%	31.1 → 32.7 (105%)
	GF50%	238 → 143	60%	3.0 → 3.0	100%	356 → 203	57%	13650 → 6933	51%	36.2 → 37.3 (103%)
PA6	GF30%	163 → 79	48%	3.5 → 5.7	165%	236 → 108	46%	7755 → 3444	44%	31.5 → 33.2 (106%)

# II. POKETONE Features

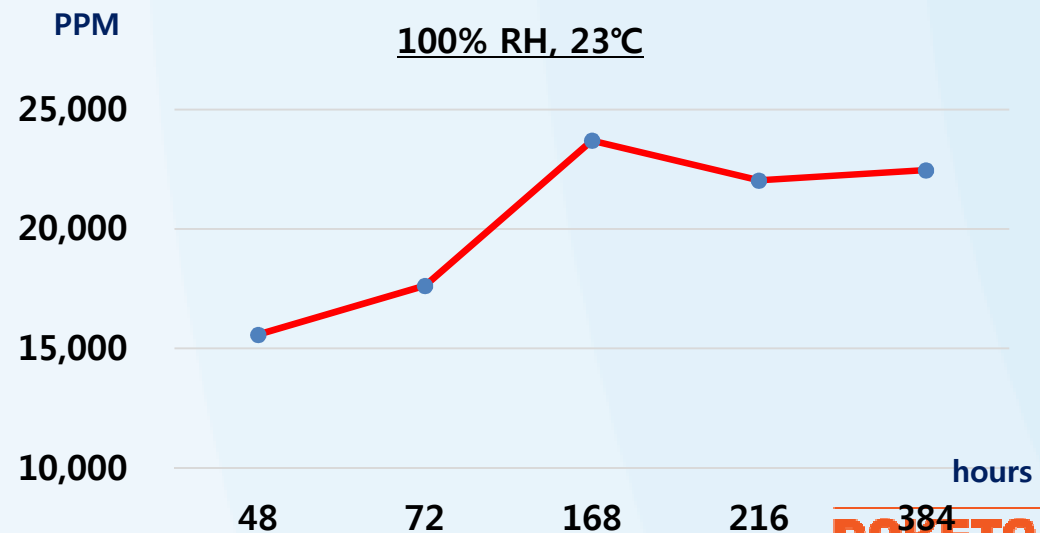
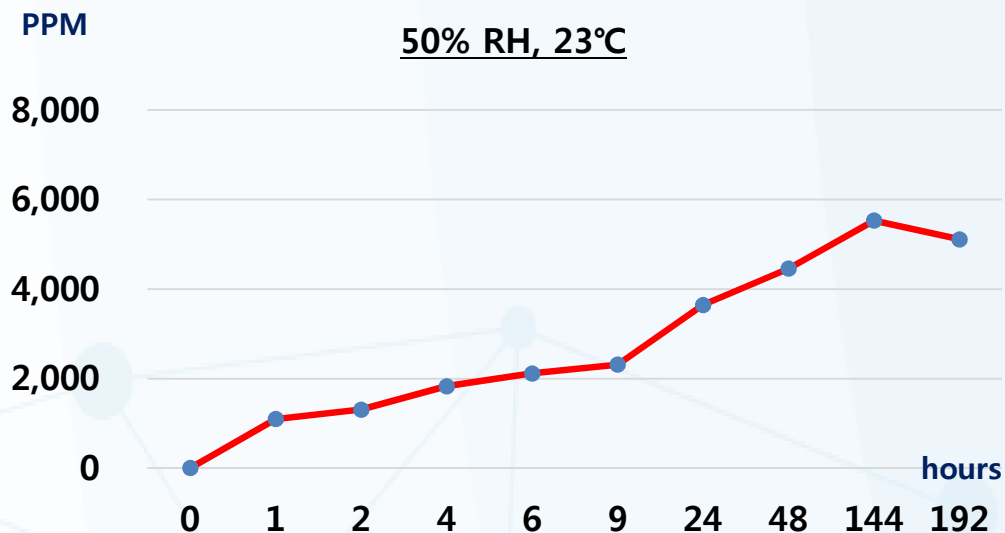
## ► POKETONE Features – Low Water Absorption

### POKETONE water absorption

Similar to PESU / PA12 which are more than \$10/kg, which can provide best cost performance which will lead to cost reduction with same quality

	POKETONE	PA66	PESU	PA12	PSU	PPSU
50%RH, 23°C	0.5%	2.5%	0.8%	0.8%	0.3%	0.5%
100%RH, 23°C	2.2%	8.5%	2.2%	1.6%	0.8%	1.2%

### POKETONE Water Absorption Data

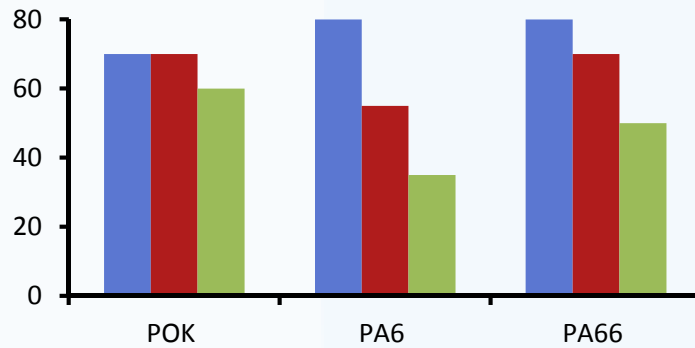


# II. POKETONE Features

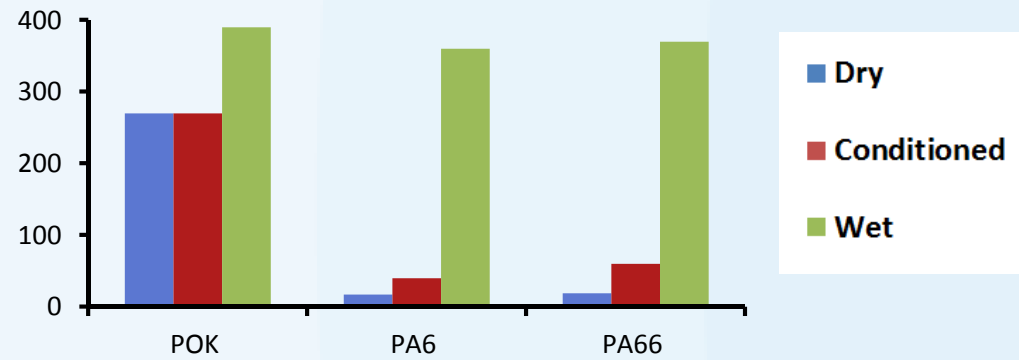
## Properties Retention after immersed water

- Much Less sensitive to Humidity than Polyamides

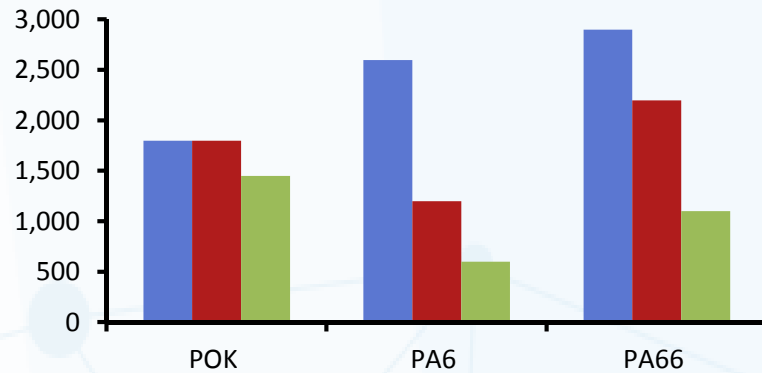
Tensile Strength (MPa)



Tensile Elongation (%)



Flexural Modulus(MPa)



- Dry: 23°C, 50% RH, 24hrs
- Conditioned: 23°C, 50% RH, 60days
- Wet: 23°C, 90% RH, 60days

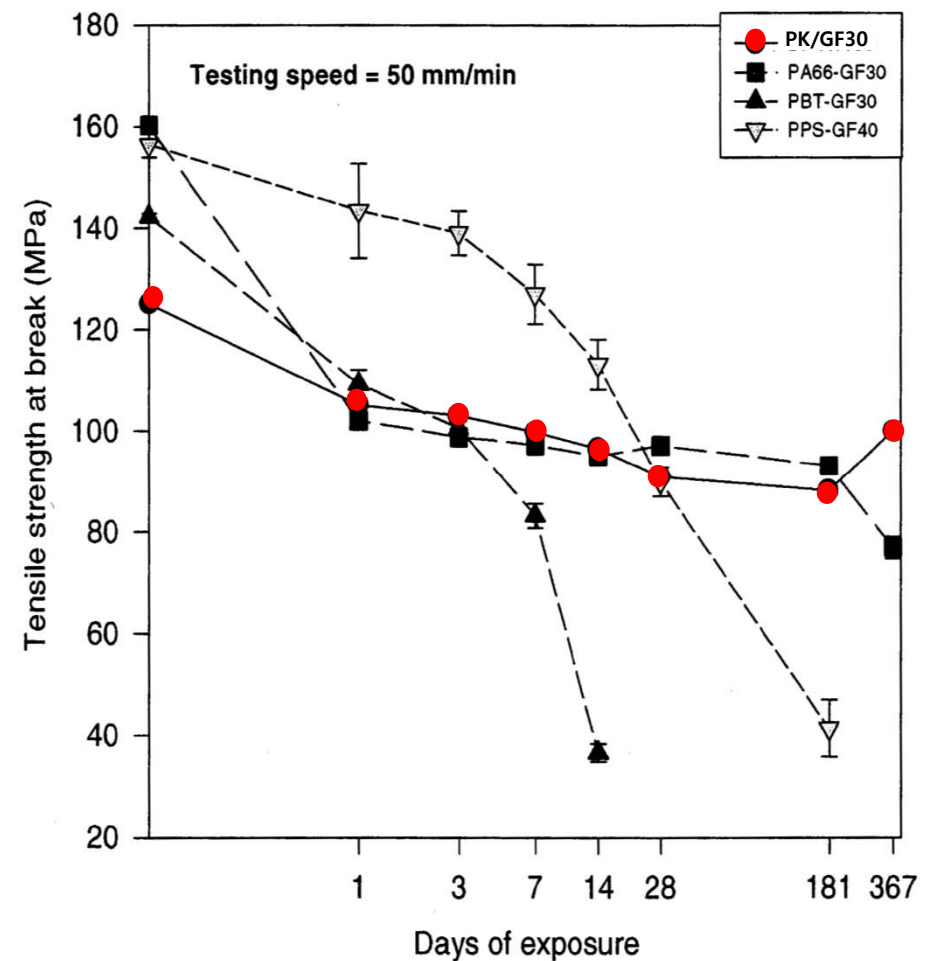
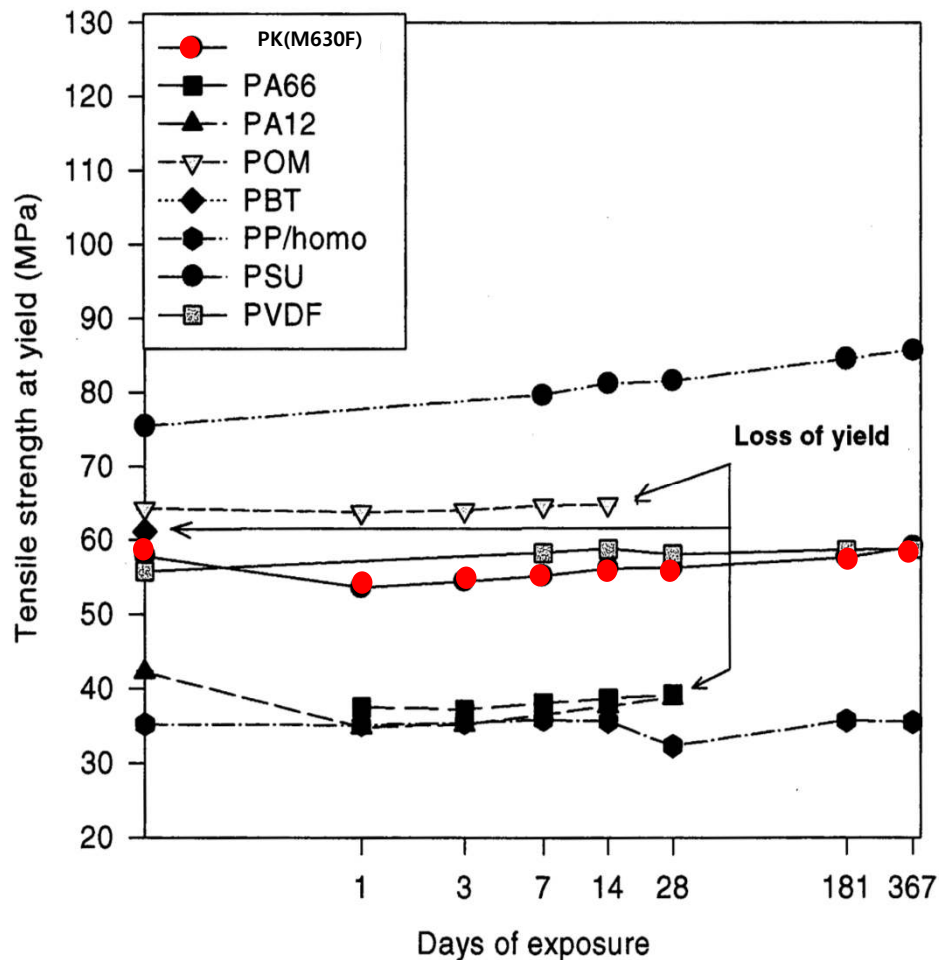
# POKETONE for Plumbing

## POKETONE Features – Stability to Water

### POLYKETONE Mechanical Properties in Hot Water Immersion

Compared with other ENPLAs (Shell data)

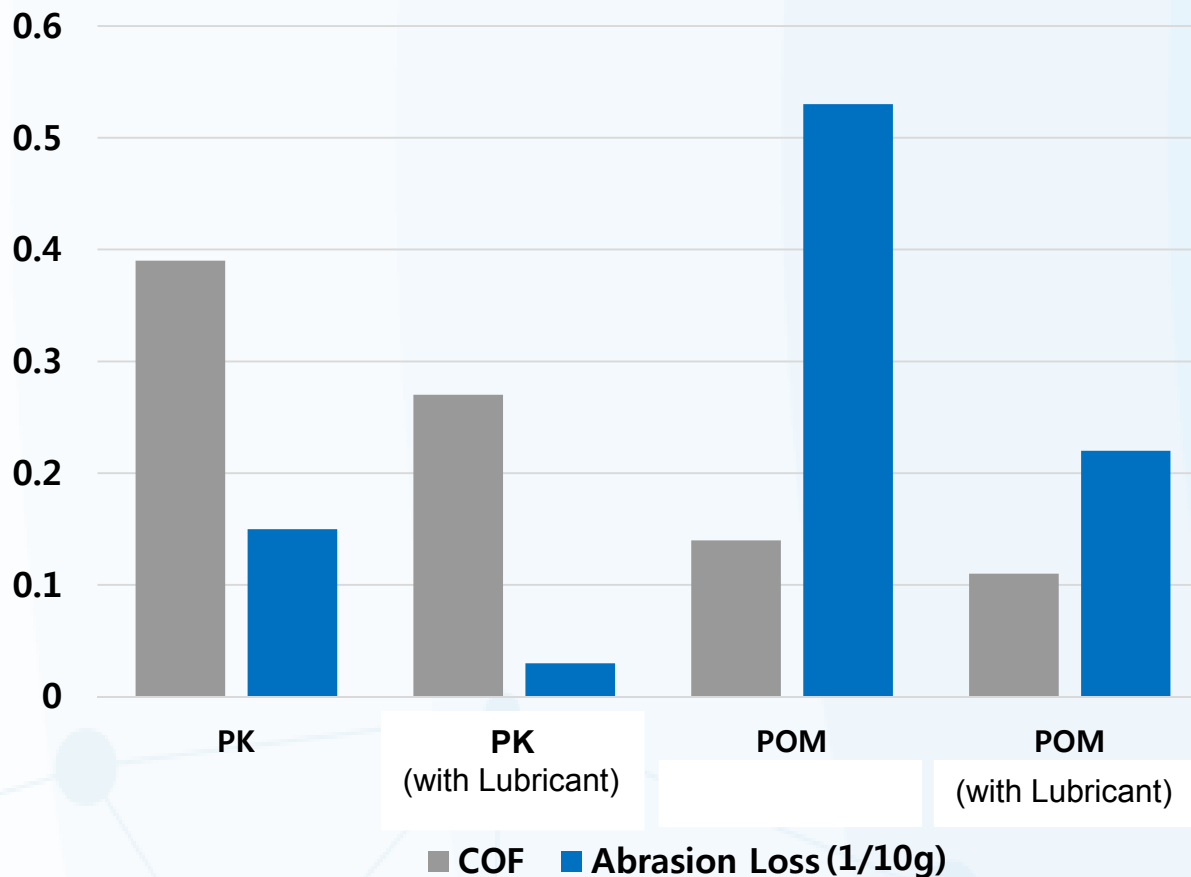
#### Tensile Strength Change in Boiling Water



## II. POKETONE Features

### 2 *POKETONE – “High Wear Resistance”*

- POKETONE has similar or higher anti-abrasion property compared to POM
- Compared to POM, Noise is reduced distinctly



▶ Test Standard : JIS K7218

▶ Vs Same Resin

▶ Speed : 50 RPM

▶ Load : 150 N

▶ Distance : 3.0 km

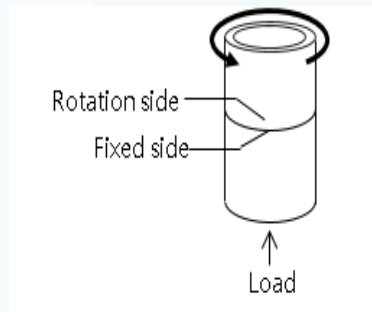
# II. POKETONE Features

## Wear resistance

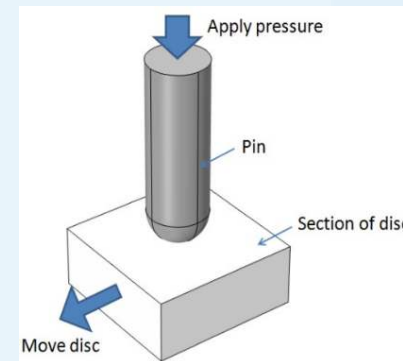
PK shows better abrasion resistance to metal in the presence of humidity

Resin	Coefficient of friction with steel (200N, 50RPM, 100°C, RH 85%)
PK	0.32
PA66	0.32
PA6	0.32

Resin	unit	Wear out depth after 6 hr Steel Pin on disc abrasion (150N, 23°C, RH 50%, 6mm/s)
PK	um	22
PA66	um	150
PA6	um	390



Ring on Ring  
(resin/resin or resin/metal)



Pin on disc  
(resin-metal)



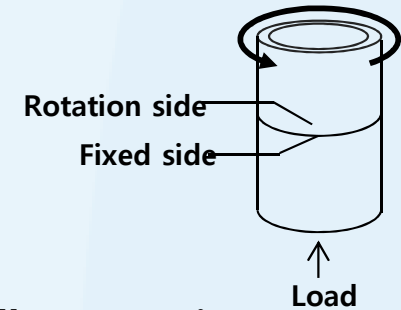
# II. POKETONE Features

## Wear Resistance

### 1) Test Method (Ring on Ring - JIS K7218 standard)

### 2) Test Result

- Wear resistance of PK is at the similar or higher level than that of POM
- Pairing POM with PK as a contacting combination can increase the overall wear resistance.



Materials		Coefficient of friction	Wear Amount (g)	Test Condition
Rotation part	Fixed part			
Lubricated POM	POM	0.15	0.0062	100RPM, 80N, 3.0km
<i>M33AS1E</i>	<i>POM</i>	<i>0.13</i>	<i>0.0013</i>	<i>100RPM, 80N, 3.0km</i>
<i>PK Reinforce(GF10%)</i>	<i>POM</i>	<i>0.10</i>	<i>0.0006</i>	<i>100RPM, 80N, 3.0km</i>
POM/GF25%	POM/GF30%	-	0.0223	100RPM, 80N, 3.0km
<i>PK Reinforce(GF30%)</i>	<i>POM/GF30%</i>	<i>0.20</i>	<i>0.0060</i>	<i>100RPM, 80N, 3.0km</i>
MC Nylon	Steel - S45C	0.4	0.002	50RPM, 150N, 3.0km
POM	Steel - S45C	0.31	0.023	50RPM, 150N, 3.0km
<i>M630A</i>	<i>Steel - S45C</i>	<i>0.46</i>	<i>0.005</i>	<i>50RPM, 150N, 3.0km</i>

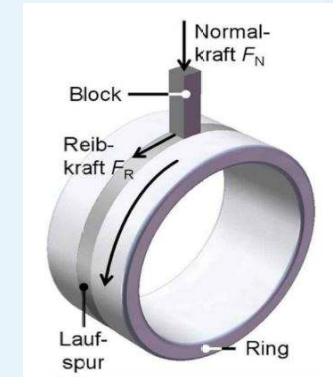
# II. POKETONE Features

## Wear Resistance

### 3) Test Method (Block on Ring - ASTM G 137)

### 4) Test Result

- Wear Resistance of PK is higher than that of POM and PA66
- POM decreases its wear resistance at high temp. due to its low heat resistance



Materials		Wear Amount ( $\mu\text{m}$ )	Test Condition
Block	Ring		
POM	POM	202	0.1MPa, 470RPM, 23°C, 1hr
PA66	PA66	156	0.1MPa, 470RPM, 23°C, 1hr
<i>M630A</i>	<i>M630A</i>	<i>21</i>	<i>0.1MPa, 470RPM, 23°C, 1hr</i>
POM	PA66	53	25MPa, 26.7RPM, 130°C, 1hr
<i>M630A</i>	<i>PA66</i>	<i>21</i>	<i>25MPa, 26.7RPM, 130°C, 1hr</i>
POM	PA66	3,202	15MPa, 26.7RPM, 170°C, 1hr
<i>M630A</i>	<i>PA66</i>	<i>16</i>	<i>15MPa, 26.7RPM, 170°C, 1hr</i>

## II. POKETONE Features

### Wear resistance

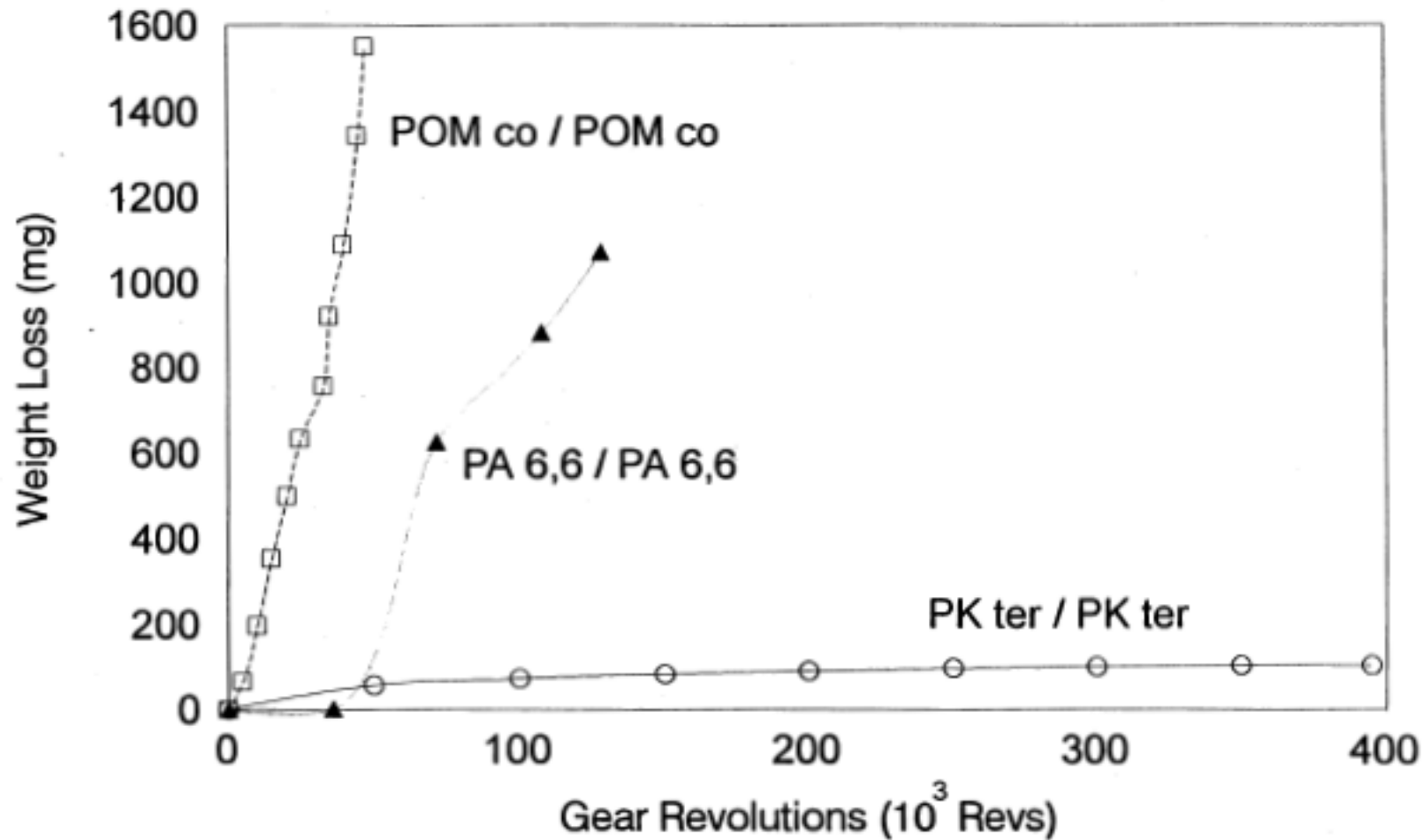


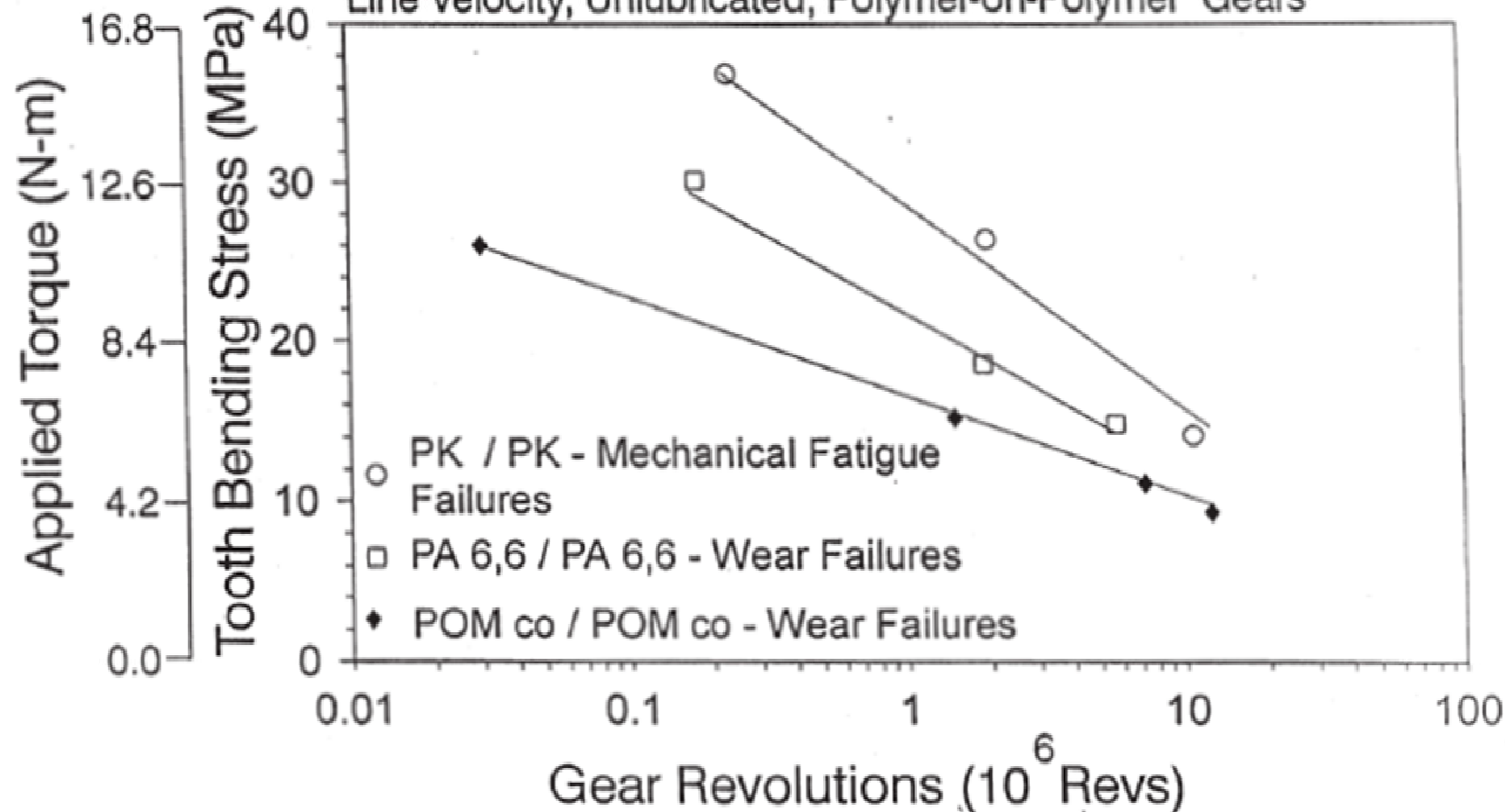
Figure 6. Wear resistance comparison of polyacetal (POM co), polyamide (PA 6,6), and polyketone (PK ter) polymers using polymer-on-polymer spur gears.

## II. POKETONE Features

### Wear resistance

FIGURE 1.  
SPUR-GEAR LIFE DATA

For 12 Diametral Pitch, 20° Pressure Angle, 4.4 m/sec Pitch Line Velocity, Unlubricated, Polymer-on-Polymer Gears



## II. POKETONE Features

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### ***POKETONE – “HDT for thermal stability”***

- Consider HDT of PK reinforced grade, PK/GF Grade has enough thermal stability

■ HDT of Polyketone GF filled grade is around 210°C

It means that there is no problem to use

Polyketone GF filled grade up to 210°C in short term condition

\*HDT : Heat Deflection Temperature, checking short time heat resistance

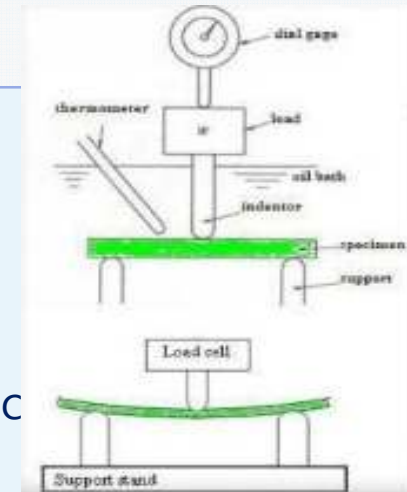


TABLE 3: TYPICAL THERMAL PROPERTIES  
OF POKETONE POLYMER M33AG6A

	Test Method & Conditions		ASTM Values	ISO Values
	ASTM	ISO	SI	SI
Melting temperature	D3418	11357	222°C	222°C
Coefficient of linear thermal expansion, 25°C to 55°C	E831 TD MD	-	9.7*10 <sup>-4</sup> 2.8*10 <sup>-4</sup>	-
Vicat softening point	D1525 5 kg	306/B50 50N	210°C	210°C
Heat deflection temperature	D648 66psi 264psi	75 0.45 MPa 1.8 MPa	215°C 210°C	215°C 210°C

TABLE 3: TYPICAL THERMAL PROPERTIES  
OF POKETONE POLYMER M93AG8H

	Test Method & Conditions		ASTM Values	ISO Values
	ASTM	ISO	SI	SI
Melting temperature	D3418	11357	222 °C	222 °C
Coefficient of linear thermal expansion, 25 °C to 55 °C	E831 TD MD	-	6.6*10 <sup>-5</sup> 2.8*10 <sup>-5</sup>	-
Vicat softening point	D1525 5 kg	306/B50 50N	210 °C	210 °C
Heat deflection temperature	D648 66psi 264psi	75 0.45 MPa 1.8 MPa	215 °C 210 °C	215 °C 210 °C

## II. POKETONE Features

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### ***POKETONE Characteristic – “High Impact Strength”***

- Higher impact strength compared to existing ENPLA(Nylon, PBT)

Items	Unit	<i>PK**</i>	PA6	PA66	PBT	POM
Density	g/cm <sup>3</sup>	<b><i>1.24</i></b>	1.14	1.14	1.30	1.41
Melting Temperature	°C	<b><i>222</i></b>	220	260	220	160
Impact Strength	KJ/m <sup>2</sup>	<b><i>9</i></b>	<b><i>5.2</i></b>	<b><i>4.1</i></b>	<b><i>5.0</i></b>	<b><i>6.5</i></b>
Tensile Strength at Yield	MPa	<b><i>60</i></b>	80	80	55	65
Nominal Strain at Break	%	<b><i>300</i></b>	17	19	16	35
Flexural Modulus	MPa	<b><i>1,550</i></b>	2,600	2,900	2,400	2,500

\*\* PK (POKETONE) : M330A

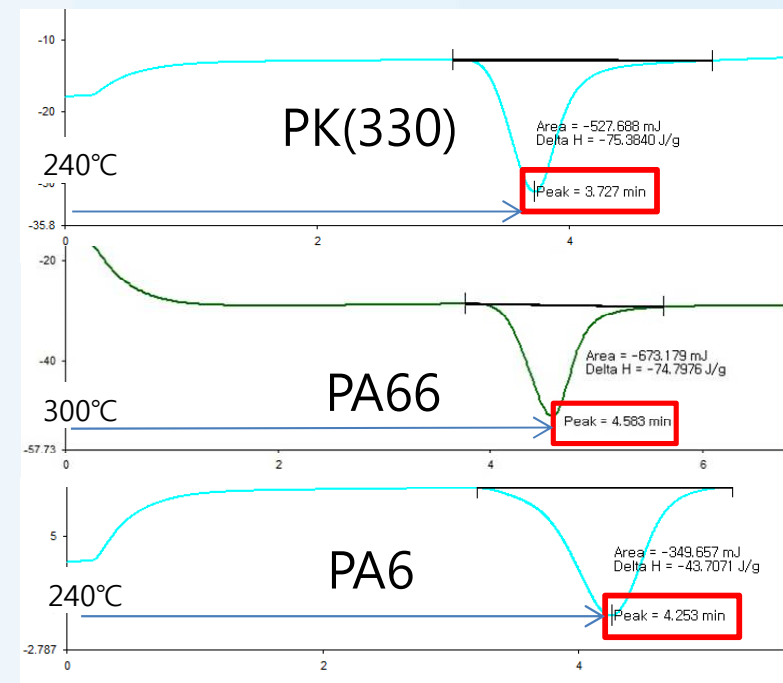
## II. POKETONE Features

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### ***POKETONE – “Productivity”***

- Increase productivity due to cycle time reduction
- Can use the mould that designed for other material like PA or PPA
- Save the electricity cost due to lower drying and processing temperature

Properties in DSC	unit	PK	PA6	PA66
Processing temp.	°C	240	240	300
Crystallization temp	°C	180	160	220
Temperature difference(Melt – peak)	°C	60	80	80
Time for reaching crystallization temp (cooling speed: 20°C/min)	sec	224	255	275

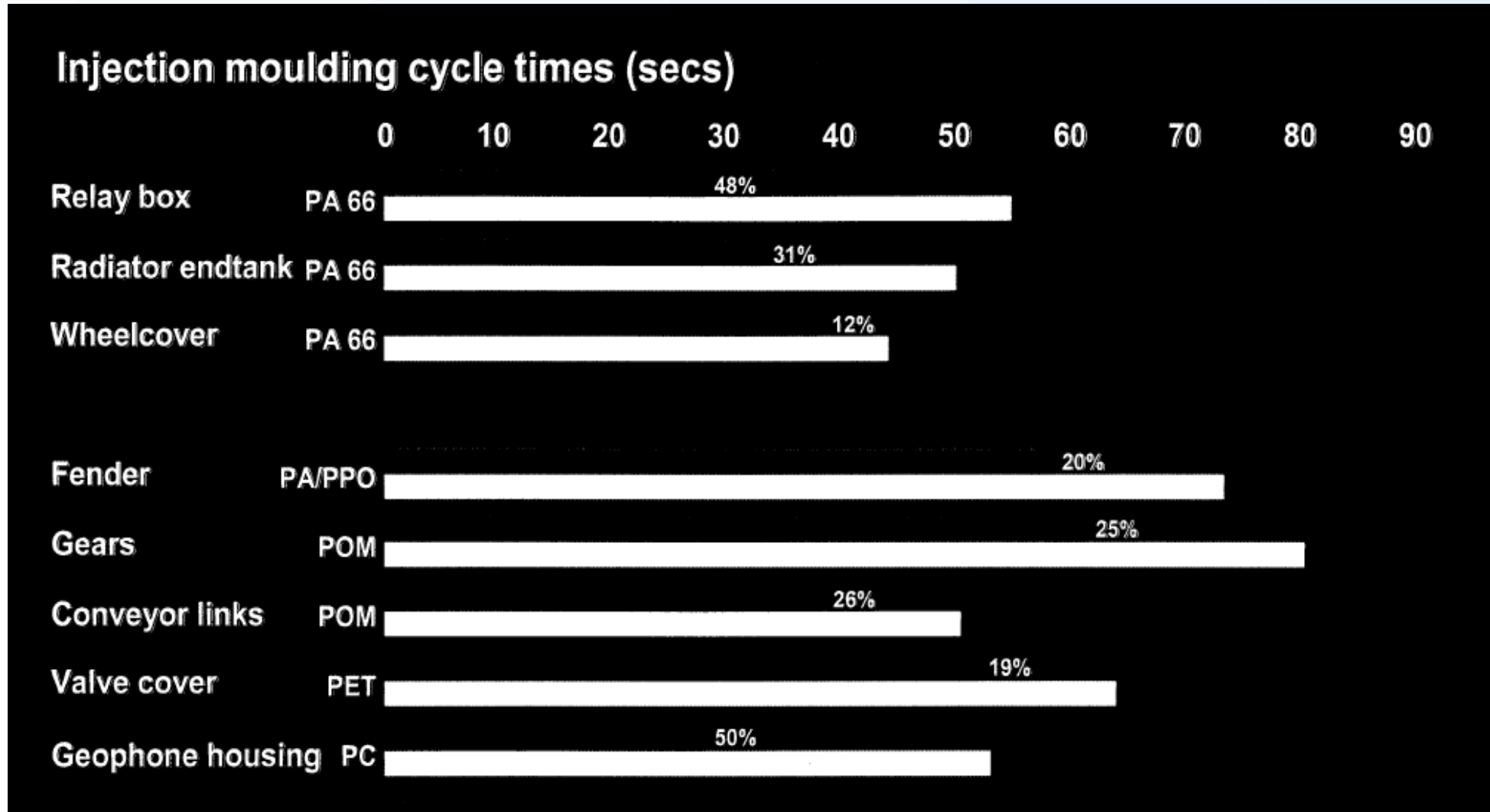


DSC, 2<sup>nd</sup> peak(decreasing temp.)



## II. POKETONE Features

### Shorter cycle times with POKETONE





















# I POKETONE for Plumbing

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## **POKETONE Characteristic – “Water Certificates”**

- PK has almost water contact certification and FDA
- PK doesn't have any toxic substance
- and approved as green material by Korea government

	KTW (Germany)	DVGW, W270 (Germany)	NSF/ANSI 61 (US)	ACS (France)	WRAS (UK)
PA6, 66					
POM					
PA12		Certified		Certified	
PSU/PPSU		Certified		Certified	
<b>POKETONE</b>		Certified		Certified	

 Hot  Warm  Cold

**POKETONE provides all major HOT Water certificates with price competitiveness**

Except super ENPLAs, POKETONE is only material with all hot water certificates

# II. POKETONE Features

## Green certification



This certificate is issued electronically and remains the property of BSI and is loaned to the certificate holder. It is not to be used for any other purpose. The certificate is valid until 2019-09-27. The certificate is issued to the company on the condition that it will maintain the system in accordance with the requirements of the standard. The certificate is issued to the company on the condition that it will maintain the system in accordance with the requirements of the standard. The certificate is issued to the company on the condition that it will maintain the system in accordance with the requirements of the standard.



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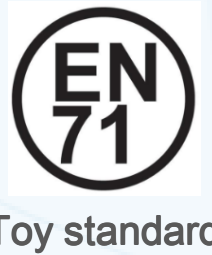
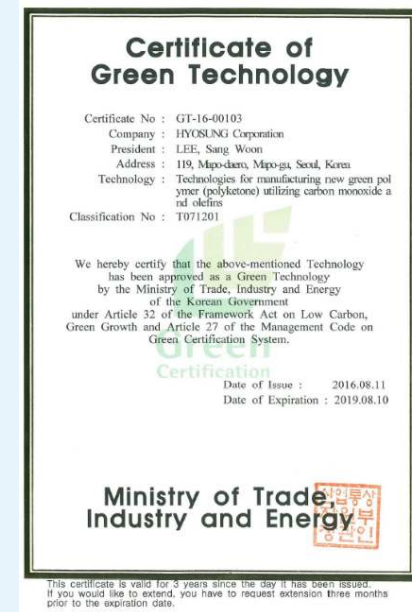
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This certificate is issued electronically and remains the property of WRAS and is loaned to the certificate holder. It is not to be used for any other purpose. The certificate is valid until 2019-09-27. The certificate is issued to the company on the condition that it will maintain the system in accordance with the requirements of the standard. The certificate is issued to the company on the condition that it will maintain the system in accordance with the requirements of the standard. The certificate is issued to the company on the condition that it will maintain the system in accordance with the requirements of the standard.



# POKETONE for water contact application

## POKETONE Features



### WATER CERTIFICATES

Providing all major water cert.

- KTW / W270 (Germany)
- NSF61 (United States)
- WRAS (United Kingdom)
- ACS (France)



### HIGH PRODUCTIVITY

Easy injection molding  
Low processing temperature  
Cycle time reduction  
(240°C)



### STABILITY

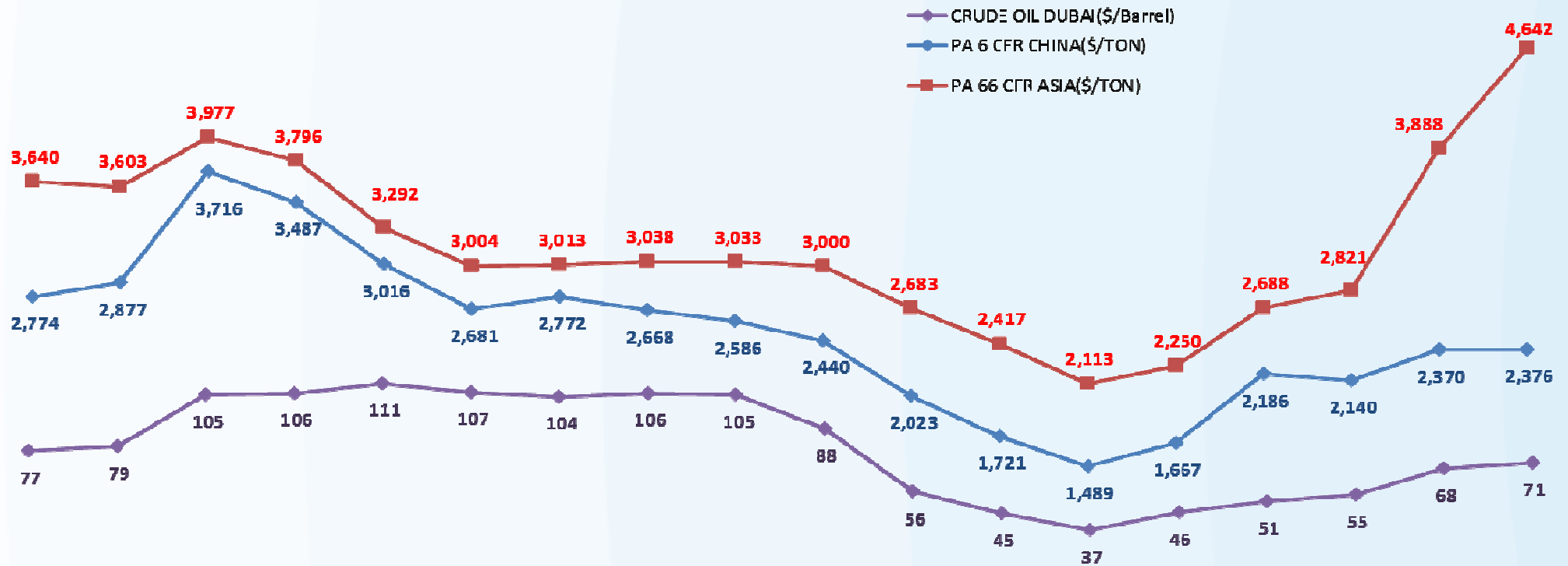
Low water absorption  
High hydrolysis resistance  
Chemical resistance



### PRICE COMPETITIVE

Sulfonic polymers : 10-30\$  
PA12 : 10\$  
PK : 5\$ (Up to grade)

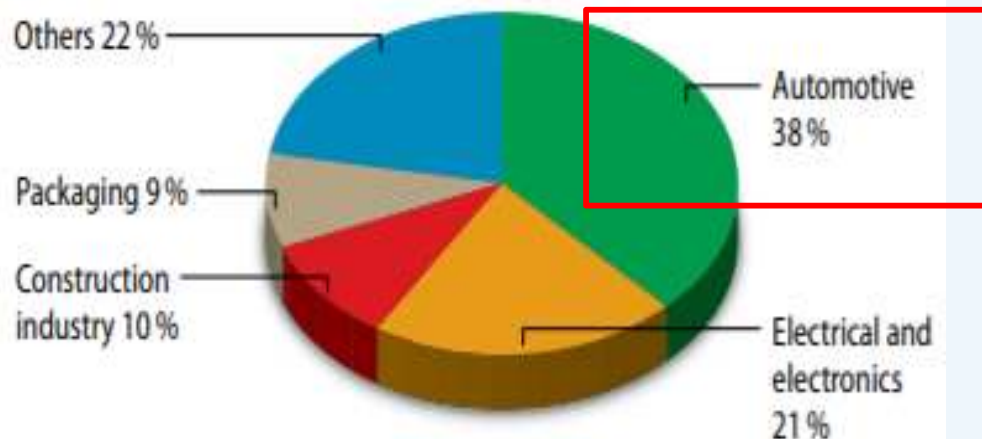
# PRICE OF POLYAMIDE66



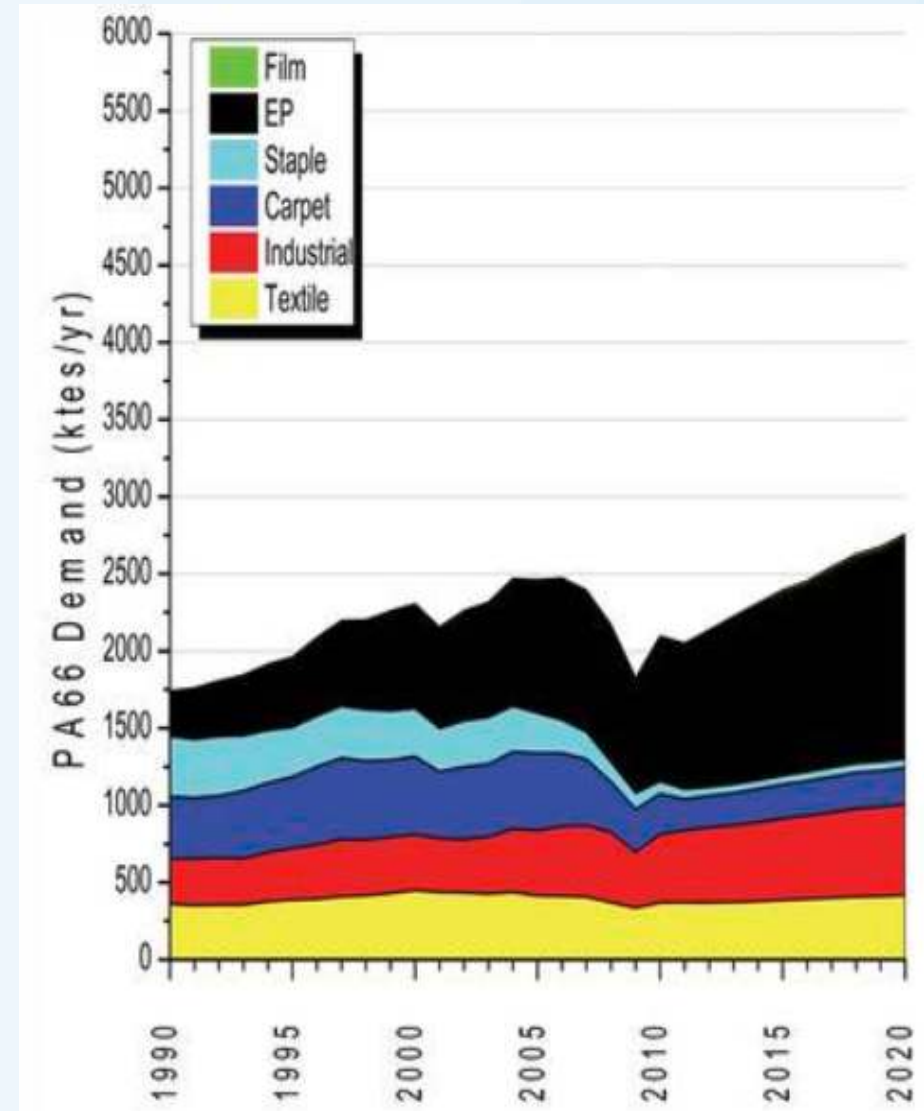
- Many experts think that this situation will last over two years at least.
  - And if this PA66 Shortage issue disappear, this situation should come again.
- Need to find alternative material quickly to reduce this risk

# PRICE OF POLYAMIDE66

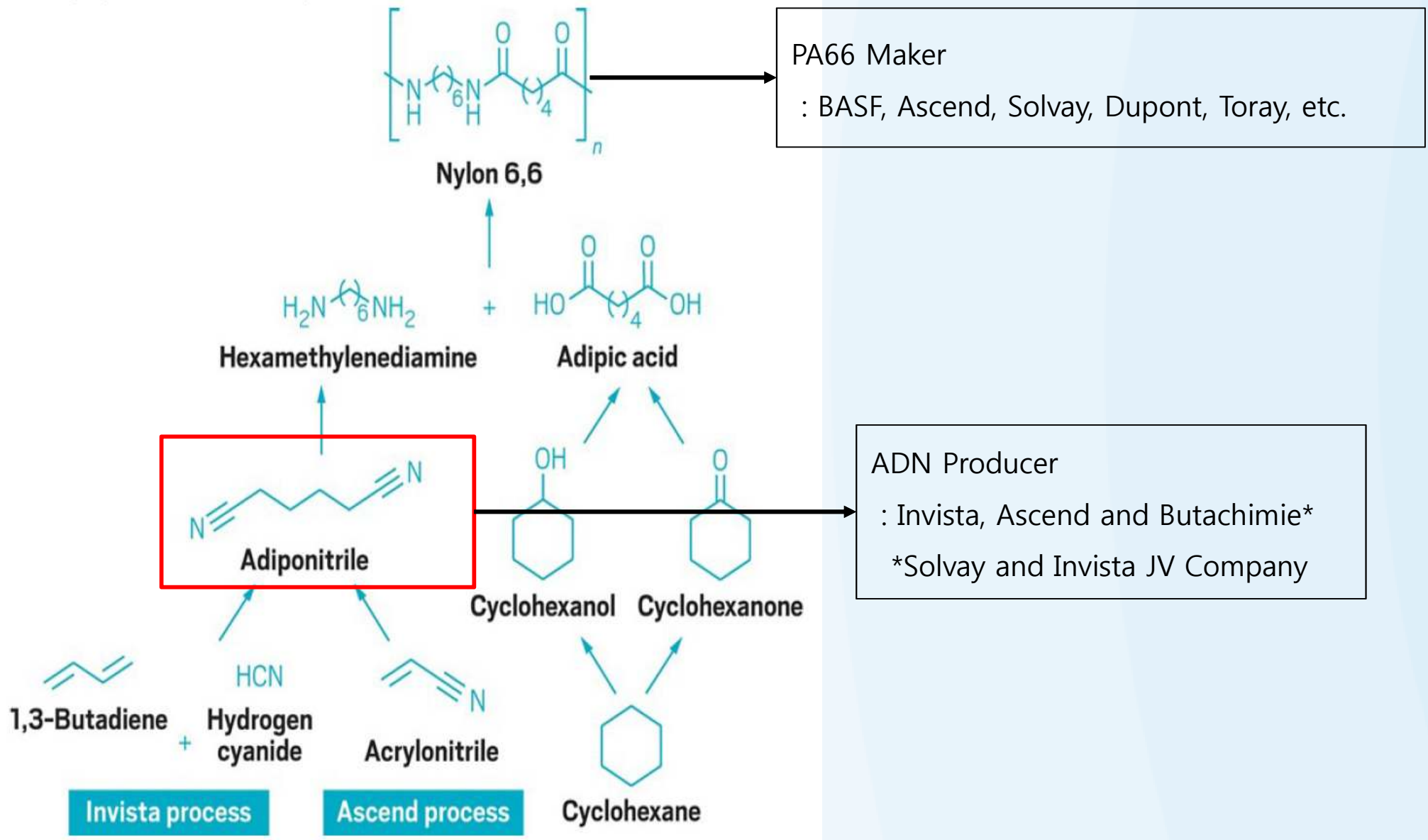
## ▪ Demand of PA66



- Demand of PA66 is around 2,300 kilotons per year in 2015
  - This PA66 consumption continuously increase about 3% every year
  - For light weight, Automotive companies increase using plastic material and this trend is reinforce in Electric car area
- Increasing of PA66 demand will continue



# PRICE OF POLYAMIDE66





# PRICE OF POLYAMIDE66

## Nylon 66 shortage issue

July 13, 2018 UPDATED 3 DAYS AGO

### Nylon 6/6 shortage looking worse: Ascend declares force majeure following plant fire

By MICHAEL LAUZON



Materials Materials Suppliers



Ascend Performance Materials  
Ascend is one of the world's largest fully integrated manufacturers of nylon 6/6.

Nylon 6/6 customers need to pull in their belts another notch as markets for the engineering plastic just got tighter.

Ascend Performance Materials has declared force majeure on shipments of its nylon 6/6 resins, compounds and industrial fibers due to a July 10 fire at its Pensacola, Fla., complex.

Ascend claims the Pensacola site contains the world's largest production facility for adipic acid, a key monomer for nylon 6/6 resins. The site also has a hexamethylene production plant, one of

Ascend's two plants making the comonomer for nylon 6/6. The other is located in Decatur, Ala.

In an email, Ascend spokeswoman Alison Jahn confirmed the force majeure declaration.

"At this point we are assessing when our polymerization units will restart," Jahn said in the email. She provided no further details on the declaration or the fire.

## Plastics News

### Solvay says low river levels to impact nylon production

By: Shahrzad Pourriahi

August 22, 2018



Belgian material supplier Solvay SA expects its nylon production activities to be temporarily impacted by the severe drop in water levels along the Rhine River following the persistent heat and drought in Central Europe.

The company, which has three nylon production sites in French towns of Chalampé (Haut-Rhin), Lyon and Valence, near the Rhine, said the situation was "affecting raw materials supplies and is generating production losses of intermediates required for the company's nylon and isocyanate chains."

Solvay said it expected that may not be able to honor all its confirmed orders for adiponitrile, hexamethylene diamine, nylon salt and adipic acid as well as certain nylon resins, fibers and compounds over the coming days and weeks.

# Thank you !