POKETONE™
HYOSUNG POLYKETONE

HYOSUNG

Automotive

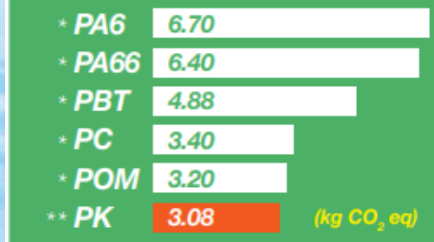
Interiors/Exteriors

EARTH FRIENDLY

Non Toxic
High Efficiency

Acrylate Free
Melamine Free
Bisphenol A Free
Formaldehyde Free
Lead/ Chrome/ Free
Phthalate Free

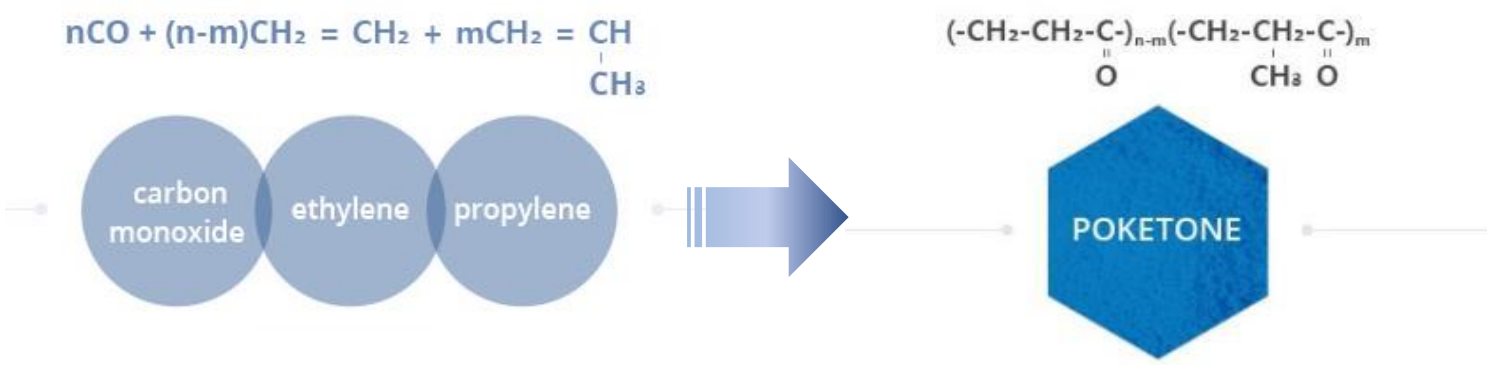
Global Warming Potential



* Other ETP data is based upon the Eco-profiles data from **www.plasticseurope.org**

** PK Data is based upon Korea LCI database and Ecoinvent database.

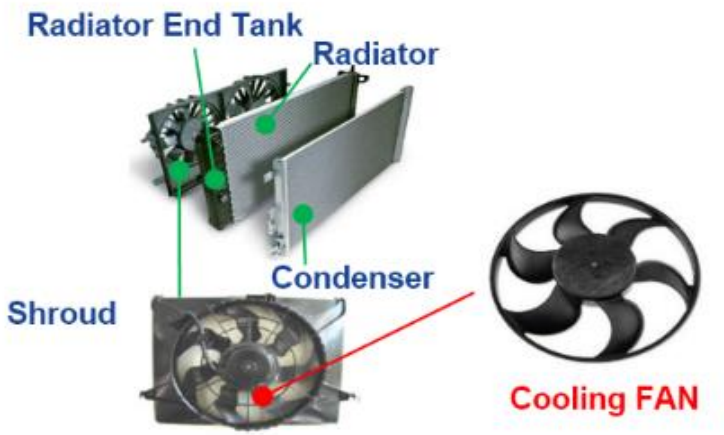
7 Key Values of POKETONE for Automotive



- ☐ Excellent Chemical Resistance for Fuel parts vs PA6, PA66, PBT
- ☐ Better NVH(Noise, Vibration, Harshness) Performance vs PA6, PA66, PBT
- ☐ Low VOCs, Low Odor for Interior Parts vs ABS, POM
- ☐ Better Scratch/Wear resistance for Interior Parts vs ABS, POM
- ☐ Better Dimensional Stability at various Environmental Conditions vs PA6, PA66, POM
- ☐ Excellent impact performance vs PA6, PA66, PBT, POM
- ☐ Superior Hydrocarbon Barrier for Fuel Tube vs PA12

Confidential

Cooling Fan



Issue

- Wear loss, Noise
- Water absorption
- Dimensional stability

PK Value

Customer Benefits: PK+PA6-(GF+GB)

- Weight Reduction : 8%
- Noise reduction : 5dB
- Better Dimensional stability

Status

- Under Development

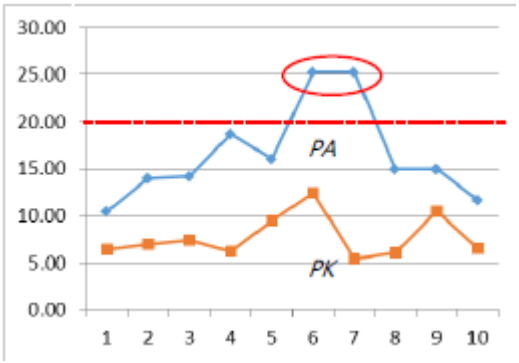
Confidential

Automotive Cooling Fan

Technical description

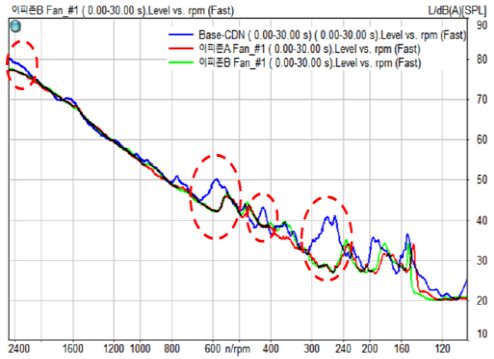
- Polyketone for Automotive Cooling fan
  - Current: PA66-(GF+MD)40%
  - Development: PK+PA6-(GF+GB)27%

Balance comparison (After moisture absorption



※ 55% Improvement in balance
- Up/Down maximum change(g. mm)
  : PA66: 14.8, PK: 8.2

Noise comparison



※ Excellent Damping Effect
- Improvement over 5~10dB(A)

Charac-teristic	▪ Improved NVH performance such as low noise using polyketone material (More than 5dB reduction) ▪ Lighter weight and improved mechanical performance through reinforced hybrid filler(GF+Glass Bubble) ▪ Excellent wear resistance, chemical resistance, and moisture resistance ▪ Improving international competitiveness by localizing materials
Sugges-tion	▪ Apply for high sensitivity, high quality cooling fan ▪ Expand to motorized driving system fan

Benefit

▪ Weight reduction : 8% ▪ Noise reduction : 5dB ▪ Mechanical Properties

Confidential

Physical Properties for cooling fan

HYOSUNG

PK+PA6-(GF+GB) 27% Reinforced grade

Property	Standard	Units	Value
Density	ISO 1183, Method A	g/cm^3	**1.33**
Reinforcing materials Content	ISO 3451-1, Method A @600℃	% by mass	**27**
Tensile Stress at Break	ISO 527-1/2(5mm/min)	MPa	**114**
Strain at Break	ISO 527-1/2(5mm/min)	%	**3.5**
Tensile Modulus	ISO 527-1 (1mm/min)	MPa	**5,800**
Charpy Impact strength Unnotched at +23 ℃	ISO 179/1eU	KJ/m^2	**59**
Charpy Impact strength Unnotched at -30℃	ISO 179/1eU	KJ/m^2	**46**
Charpy Impact strength Notched at +23 ℃	ISO 179/1eA	KJ/m^2	**9.4**
Charpy Impact strength Notched at -30 ℃	ISO 179/1eA	KJ/m^2	**7.5**
HDT(1.8 MPa)	ISO 75	℃	**207**
Crystalline melting point	DSC	℃	**220**

Radiator End Tank

Issue

- Chemical Resistance
- Hydrolytic Stability

PK Value

I Impact Strength	W Wear Resistance	S Safety Non-toxic	H Heat Resistance
C Chemical Resistance	W Water Resistance	B Barrier Property	R Resilience Recovery

Customer Benefits: PK Compound

- Better chemical resistance
- Great dimensional stability

Status

- Under Development

Confidential

Physical Properties for RET

HYOSUNG

PK+GF33% Reinforced grade

Property	Standard	Units	Value
Tensile stress at Break	ASTM D 638	Mpa	**150**
Flexural Strength	ASTM D790	Mpa	**220**
Flexural Modulus	ASTM D790	Mpa	**8,800**
Izod Impact Strength	ASTM D256	J/m	**100**
HDT (1.8 MPa)	ASTM D648	°C	**210**
Crystalline melting point	DSC	°C	**220**
Density	ASTM D792	g/cm^3	**1.42**
Melt Flow Index	ASTM D1238	g/10min	**20**

Confidential

MDPS power-pack Cover

Issue

- Field complaint on NVH Issue
- Low Impact Resistance

PK Value

I Impact Strength	W Wear Resistance	S Safety Non-toxic	H Heat Resistance
C Chemical Resistance	W Water Resistance	B Barrier Property	R Resilience Recovery

Customer Benefits: PK GF 30

- Better NVH Performance
- Weight Reduction

Status

- Commercialized

Confidential

Ball Bearing Retainer

Issue

- Low GWP (Global Warming Potential)
- Good wear resistance
- Water absorption

PK Value

Customer Benefits: PK+GF

- Low GWP (48% of PA66)
- Better Dimensional stability

Status

- Under Development

Confidential

Wheel Bearing Sensor Cap

Issue

· Low Water Absorption
· Good Flowability

PK Value

Customer Benefits: PK+GF

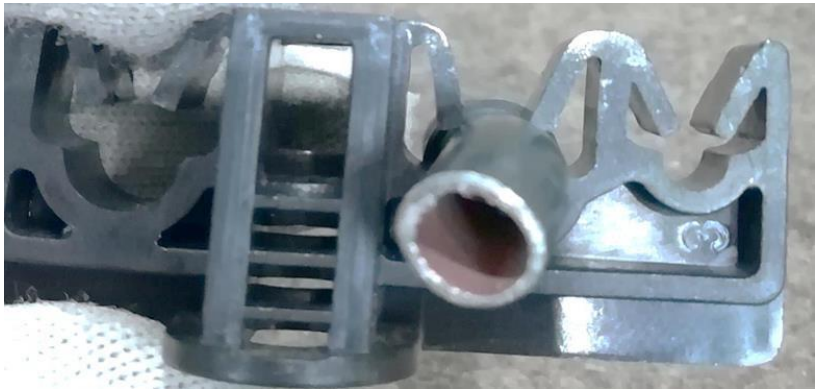
· Low Water Absorption
· Good Dimensional Stability
· Good Physical Property Retention

Status

· Under Development

Confidential

Cable Holder



Issue

- Breakage or not opening
- Dimensional stability
- Brittleness

PK Value

Customer Benefits

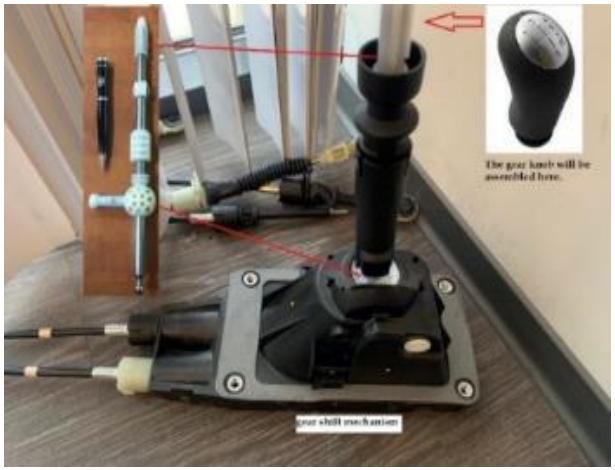
- Low water absorption
- Good flexibility

Status

- Commercialized

Confidential

Bearing in Gear Shift Mechanism



Issue

- Low Impact Strength
- Abrasion resistance

PK Value

I Impact Strength	W Wear Resistance	S Safety Non-toxic	H Heat Resistance
C Chemical Resistance	W Water Resistance	B Barrier Property	R Resilience Recovery

Customer Benefits: PK Base

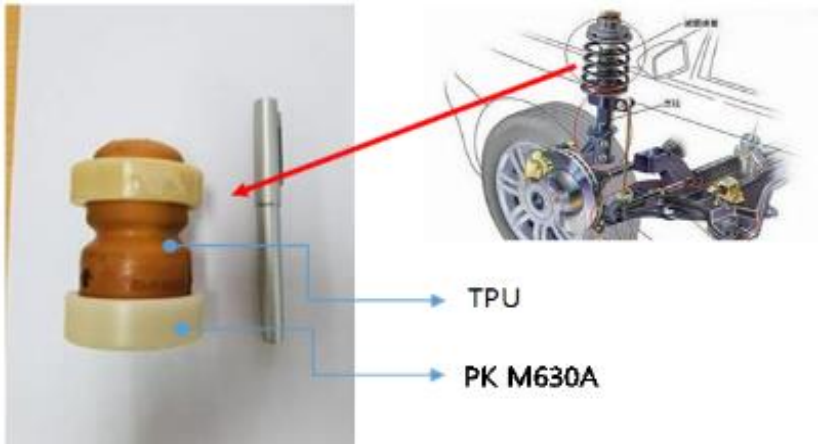
- Good Impact resistance
- Better Resilience

Status

- Commercialized

Confidential

Damping Ring



Issue

· Low Ductility

PK Value

I Impact Strength	W Wear Resistance	S Safety Non-toxic	H Heat Resistance
C Chemical Resistance	W Water Resistance	B Barrier Property	R Resilience Recovery

Customer Benefits: PK Base

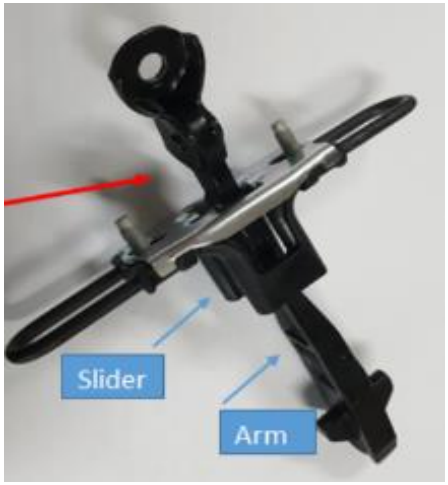
· Better Toughness and Damping Effect
· Weight Reduction

Status

· Commercialized

Confidential

Door Checker Arm



Issue

- Abrasion Resistance
- Water absortion

PK Value

Customer Benefits: PK Compound

- Lower water absorption
- Good Abrasion resistance

Status

- Under Development

Confidential

HYOSUNG

Headrest Rear Cover

PK Value

Issue

- Warpage issue
- Water absorption

Customer Benefits: PK Compound

- Low water absorption
- UV stability

Status

- Commercialized

Confidential

Door Pulley & Carrier Plate

Issue

· High VOCs(metal/odors)
· Wear resistance

PK Value

I Impact Strength	W Wear Resistance	S Safety Non-toxic	H Heat Resistance
C Chemical Resistance	W Water Resistance	B Barrier Property	R Resilience Recovery

Customer Benefits:

· No VOC/toxic metal/odors
· Good wear resistance & mechanical properties

Status

· Under Development

Confidential

Safety belt guide

Issue

- Breakage/ Wear loss
- Water absorption

PK Value

I Impact Strength	W Wear Resistance	S Safety Non-toxic	H Heat Resistance
C Chemical Resistance	W Water Resistance	B Barrier Property	R Resilience Recovery

Customer Benefits

- Better impact strength
- Wear resistance
- Low VOCs

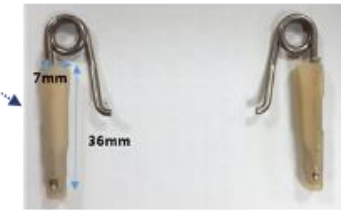
Status

- Commercialized

Confidential

Airbag Mount Clip

Airbag Module



Airbag Mount Clip

PK Value

Issue

- High VOCs/Formaldehyde
- Wear, Breakage

Customer Benefits: PK Base

- Formaldehyde free
- Excellent Impact for Airbag Deployment
- Better Wear Resistance

Status

- Commercialized

Confidential

Fastener and Clip

PK Value

Issue

- Odor
- VOCs Reduction

Customer Benefits: PK Base

- Satisfied strengthened VOCs Regulation
- Odorless
- High Impact Resistance
- Weight reduction

Status

- Commercialized

Confidential

Fuel Pump Flange

PK Value

Issue

- Chemical resistance
- Fuel Exposure resistance

Customer Benefits: PK

- Better Fuel Resistance
- Better Dimensional stability

Status

- Commercialized

Confidential

Cooling Tube

PK Value

Issue

- Extrusion/Thermoform/Laser weld
- Operation Temp : -40~80℃
- Coolant compatibility

Customer Benefits

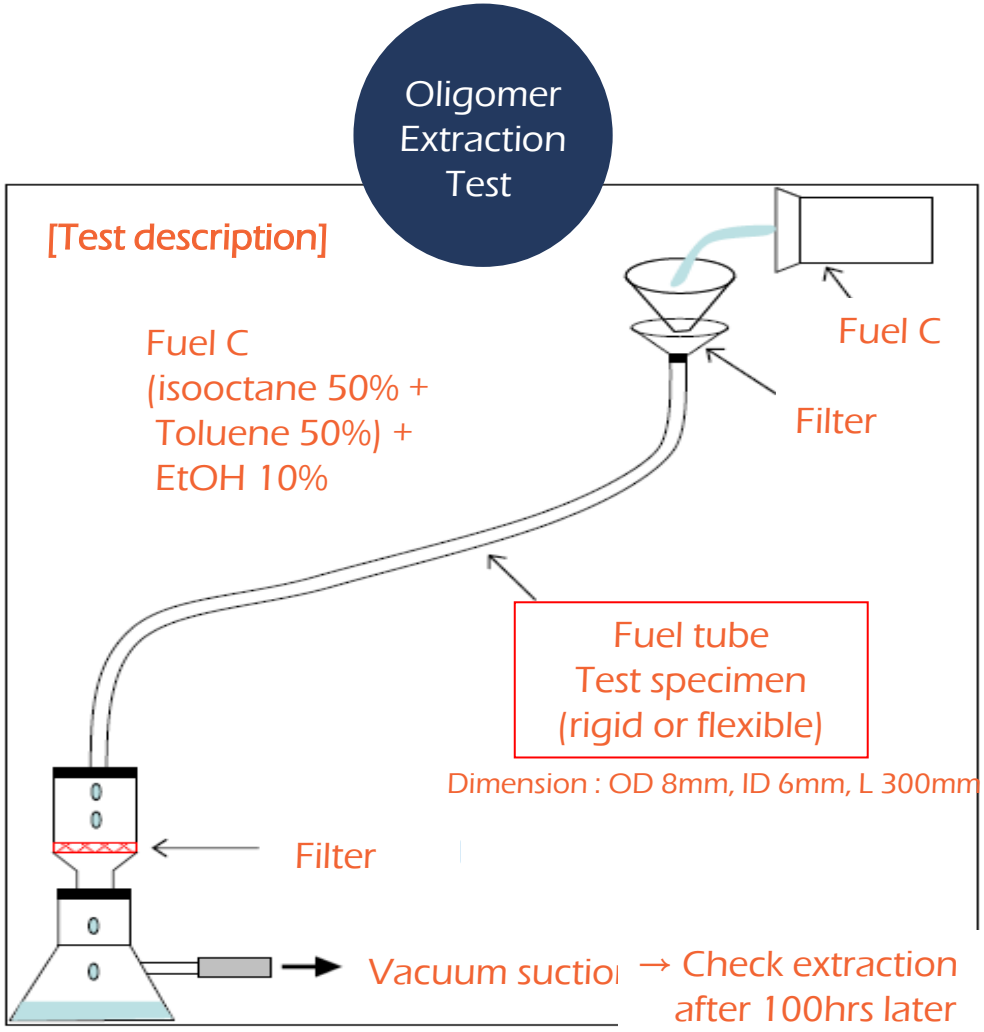
- Good extrusion/Thermoforming /Welding performance
- Better coolant compatiblity

Status

- Under Development

Confidential

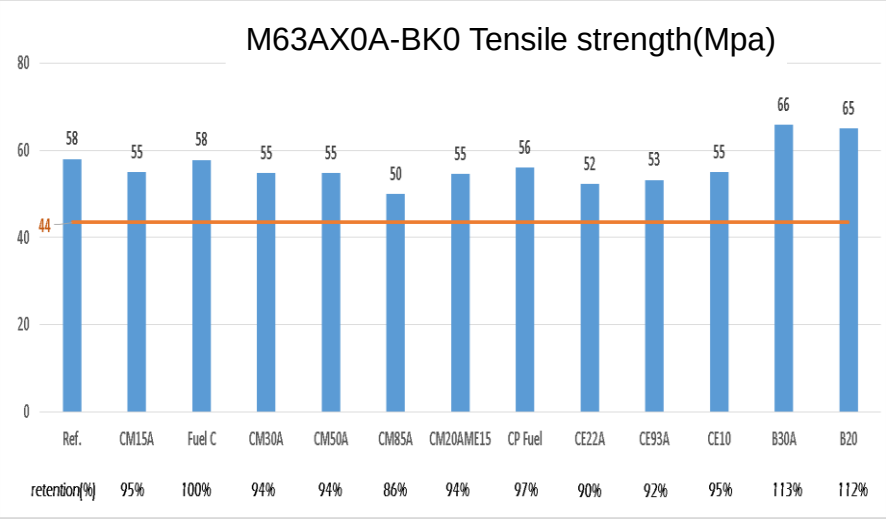
Oligomer Extraction vs PA12

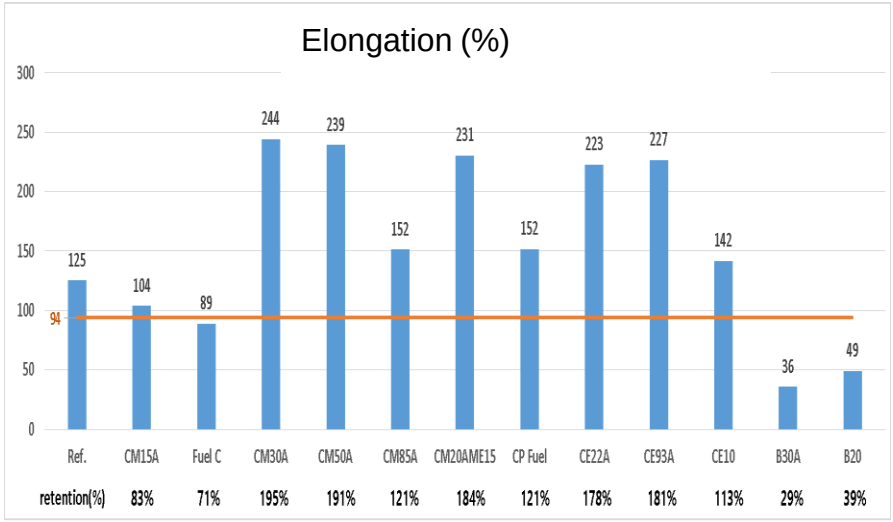


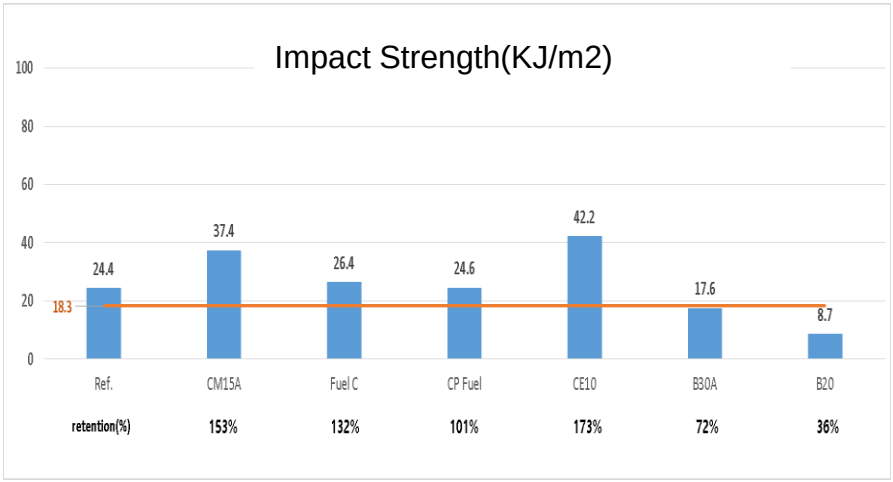
Grade	Extraction amount after 100hrs (unit : mg)
PA12 (D社)	22.3
PA12 (U社)	60.9
PK base resin	14.2
PK Flexible 1	23.5
PK Flexible 2	11.8

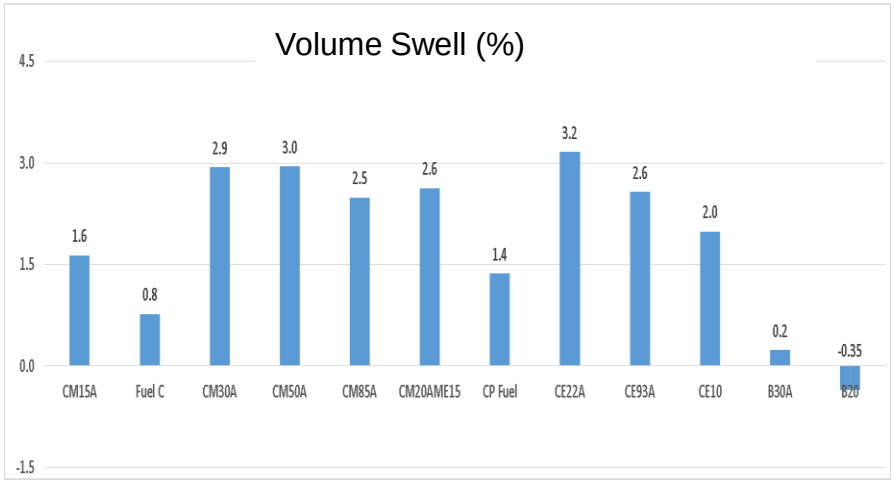
Confidential

Fuel Resistance to various Fuel Type









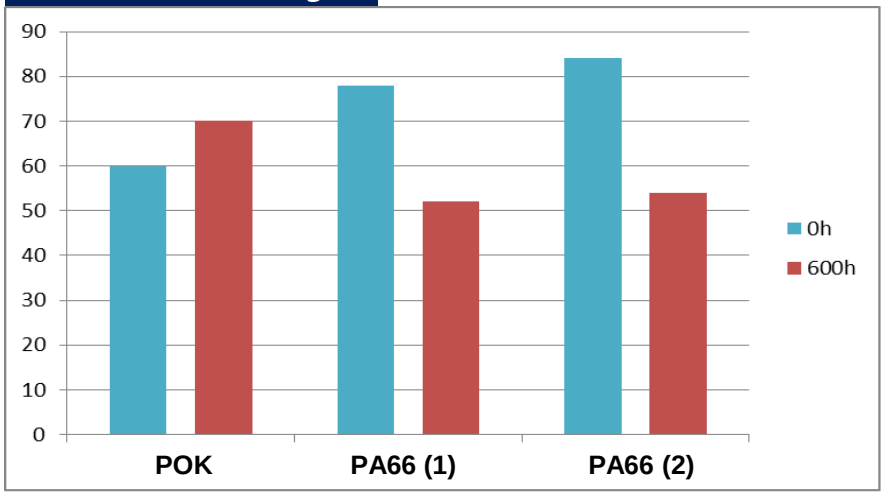
Confidential

POKETONE Technical data

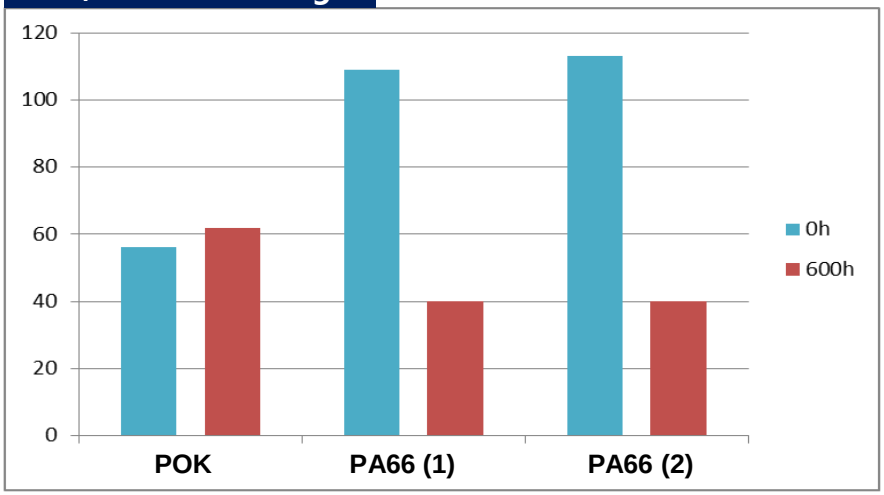
1. Chemical Resistance Test

Ⅰ. Sea Water @ 80℃

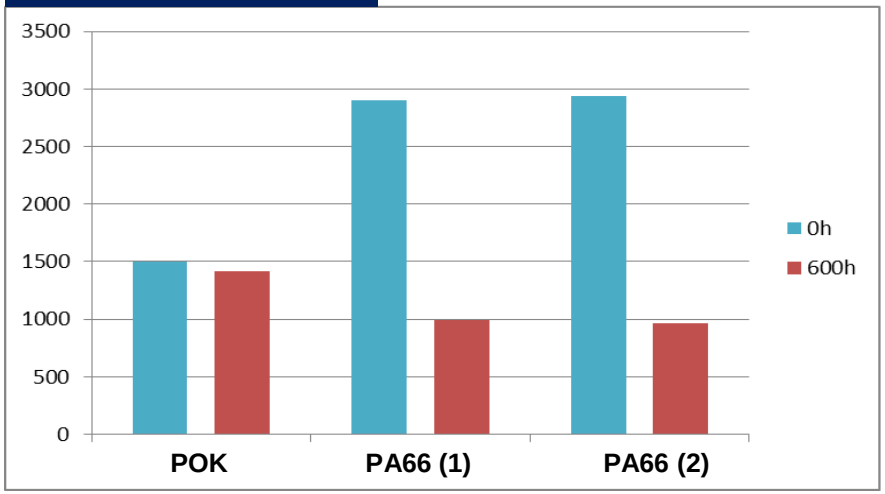
MPa, Tensile Strength



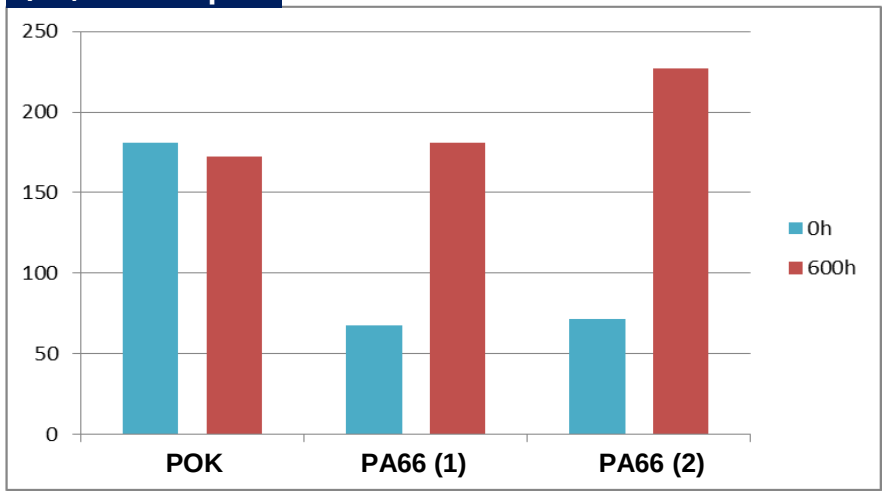
MPa, Flexural Strength



MPa, Flexural Modulus



J/m, Izod Impact

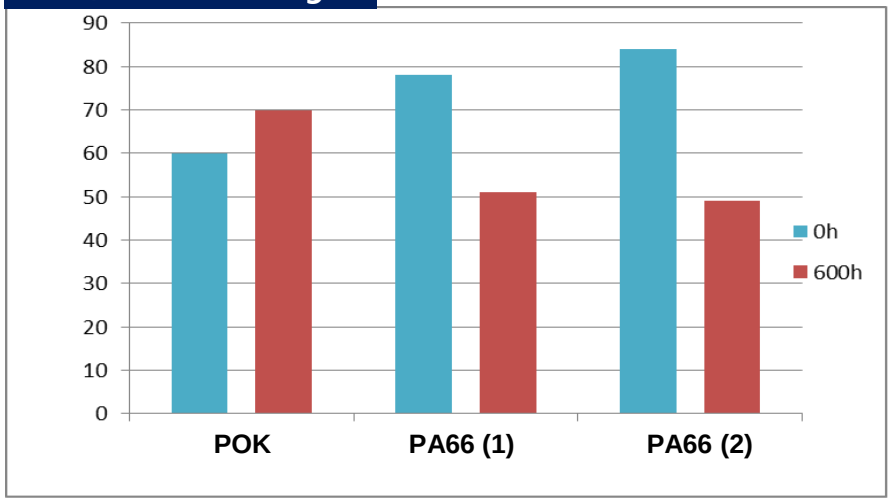


Outstanding Properties of chemicals @80℃(Sea water)

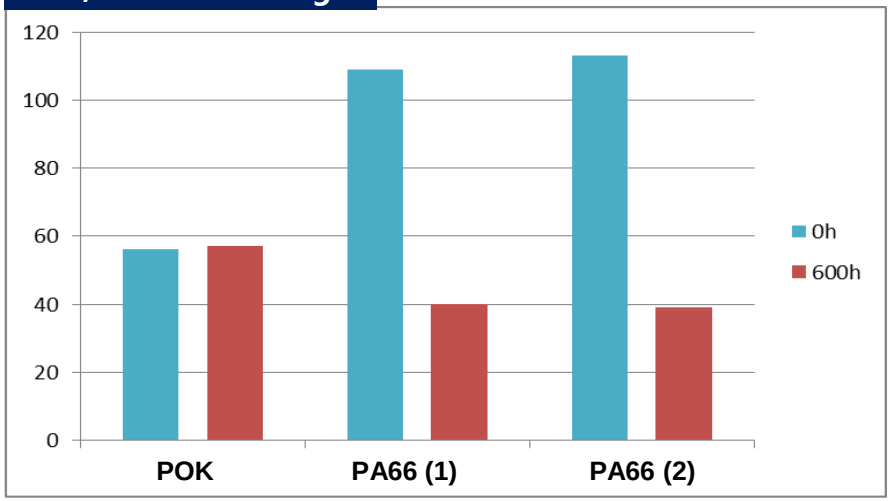
Confidential

Ⅱ. 1% HCl @ 80℃

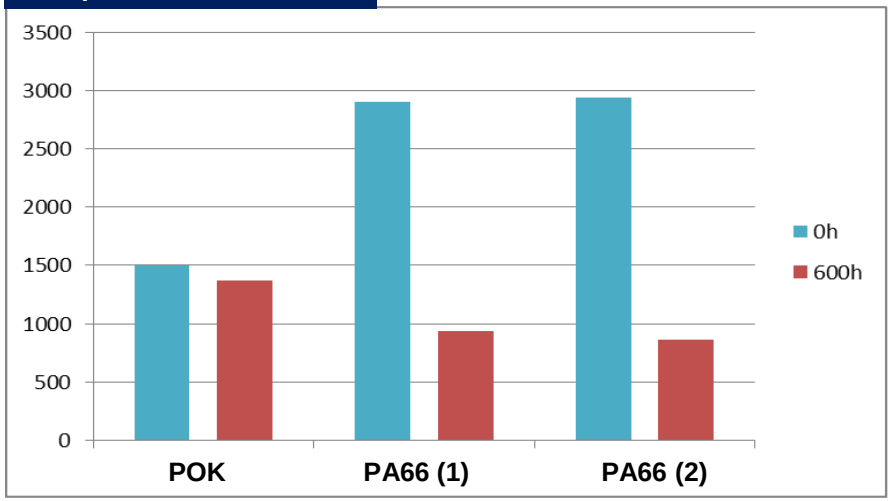
MPa, Tensile Strength



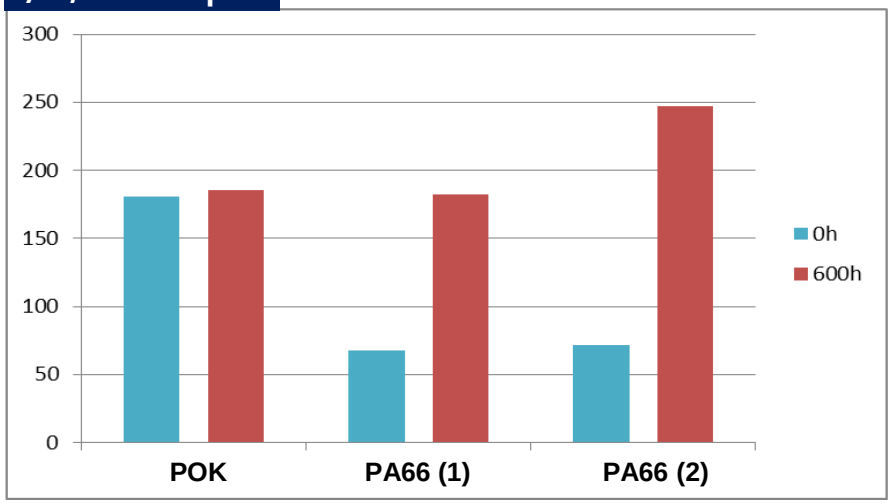
MPa, Flexural Strength



MPa, Flexural Modulus



J/m, Izod Impact

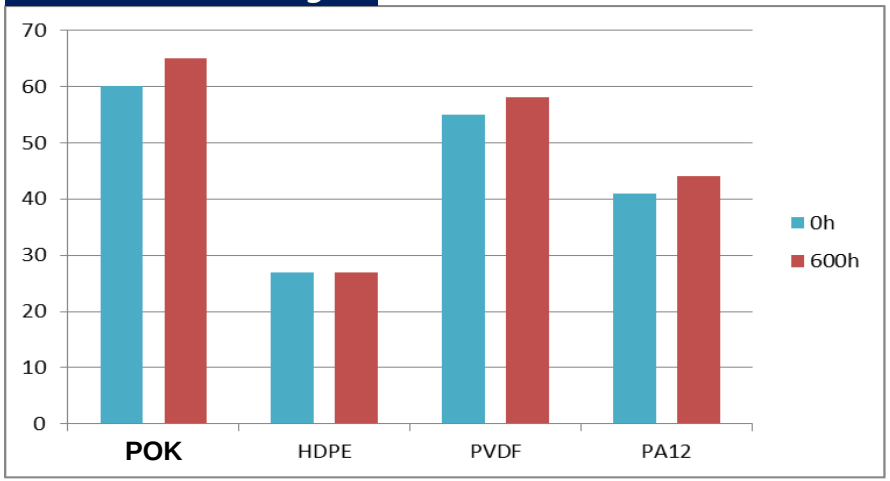


Outstanding Properties of chemicals @80℃(1% HCl)

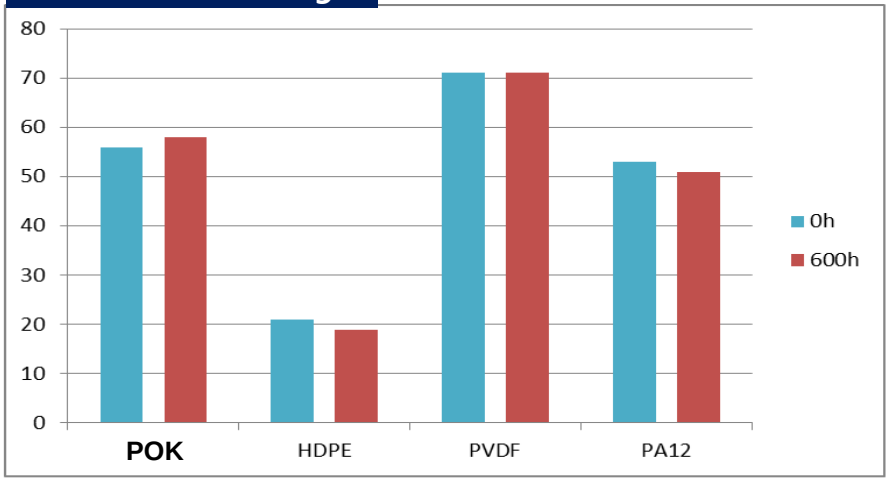
Confidential

Ⅱ. 1% HCl @ 80℃

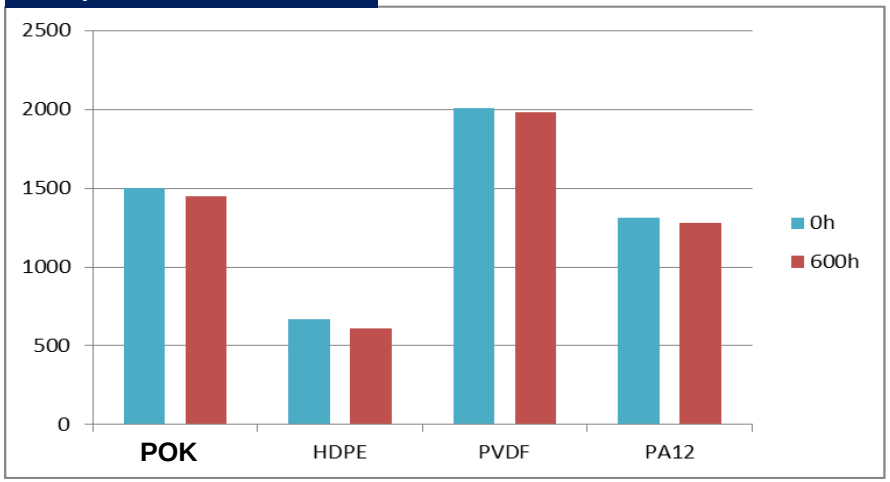
MPa, Tensile Strength



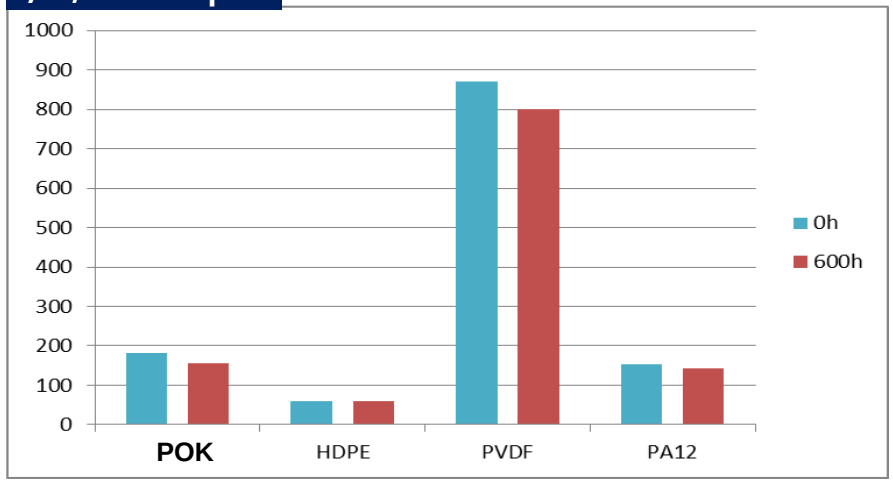
MPa, Flexural Strength



MPa, Flexural Modulus



J/m, Izod Impact

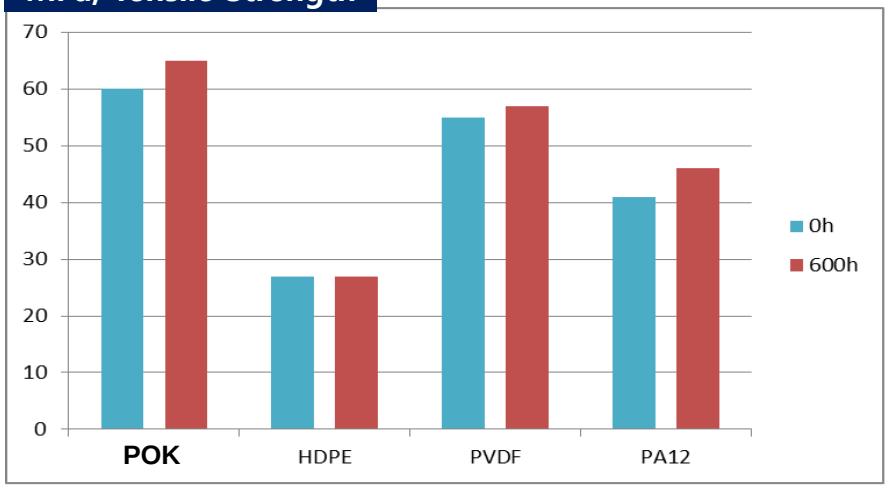


Equivalent Properties of chemicals @80℃(1% HCl)

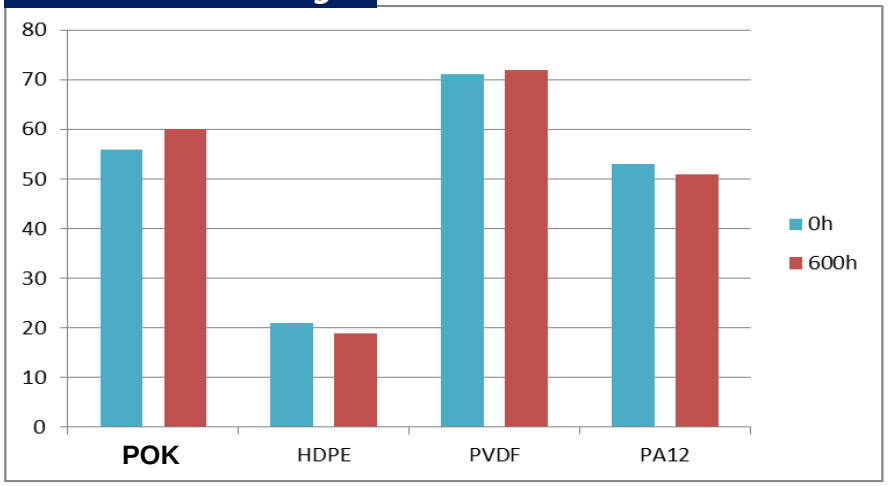
Confidential

Ⅲ. 5% HCl @ 80℃

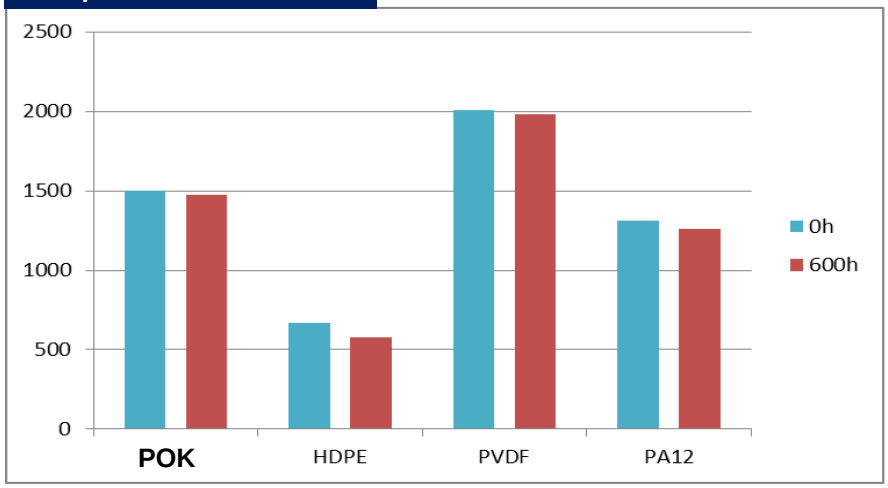
MPa, Tensile Strength



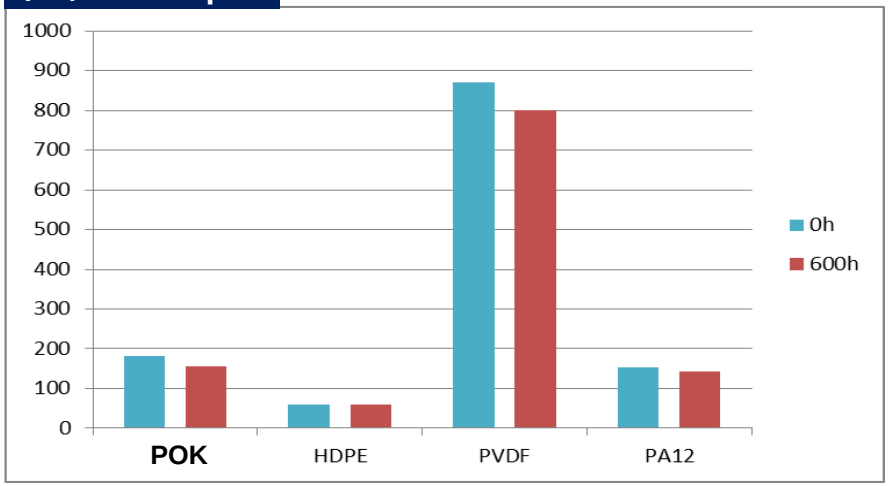
MPa, Flexural Strength



MPa, Flexural Modulus



J/m, Izod Impact

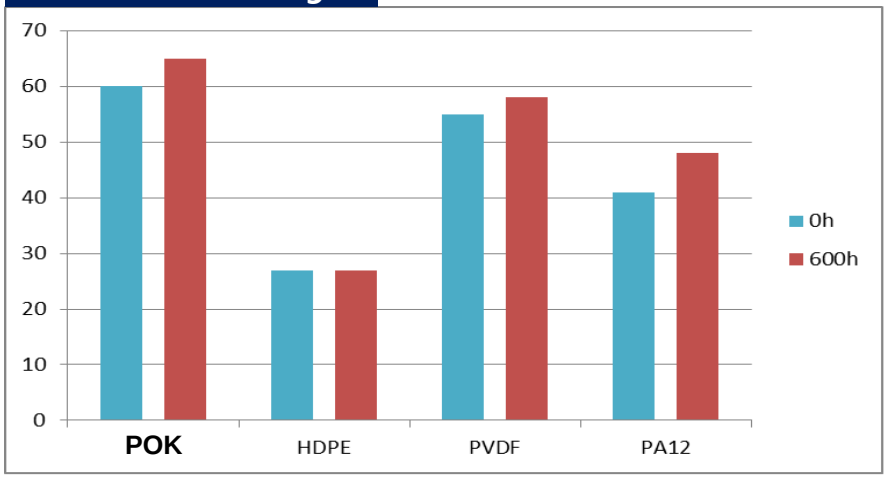


Equivalent Properties of chemicals @80℃(5% HCl)

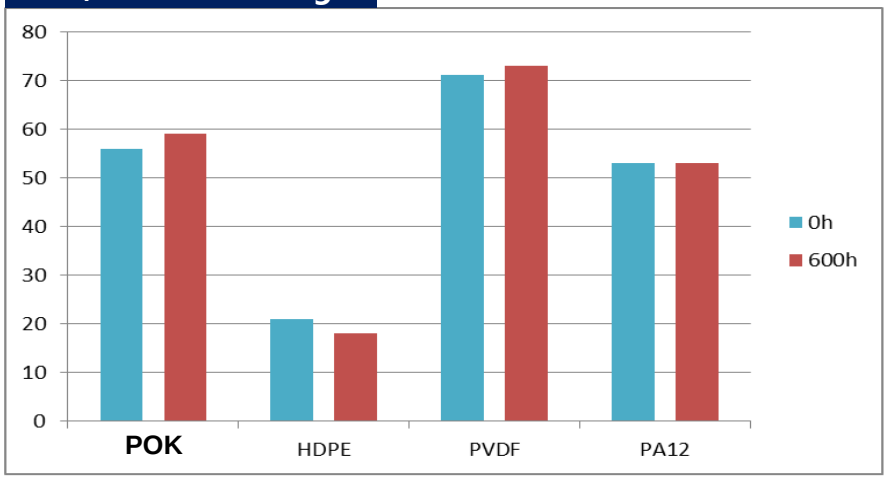
Confidential

IV. 10% HCl @ 80℃

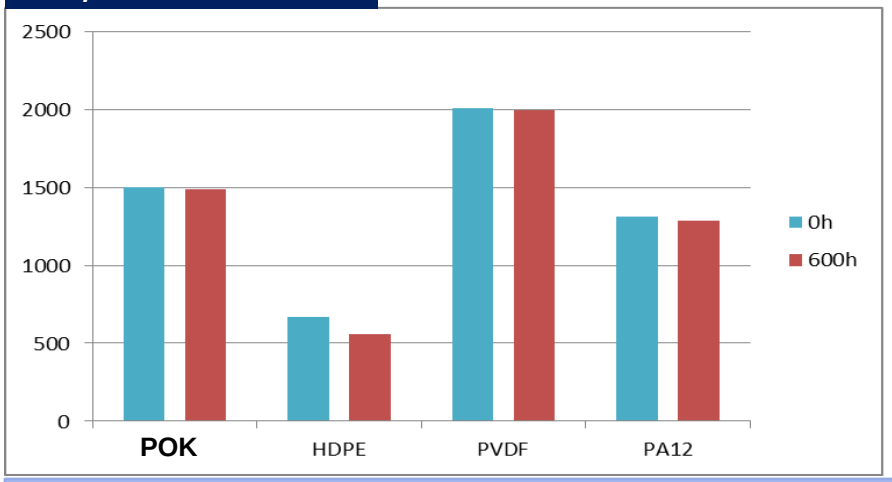
MPa, Tensile Strength



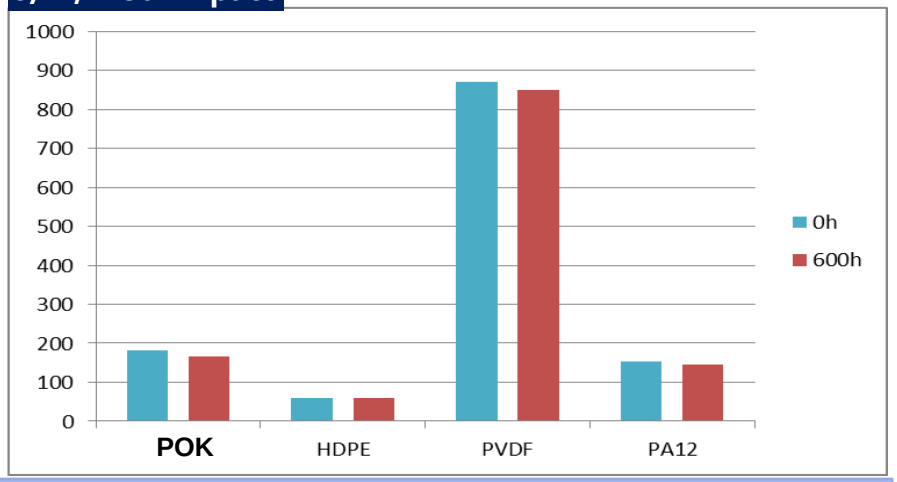
MPa, Flexural Strength



MPa, Flexural Modulus



J/m, Izod Impact

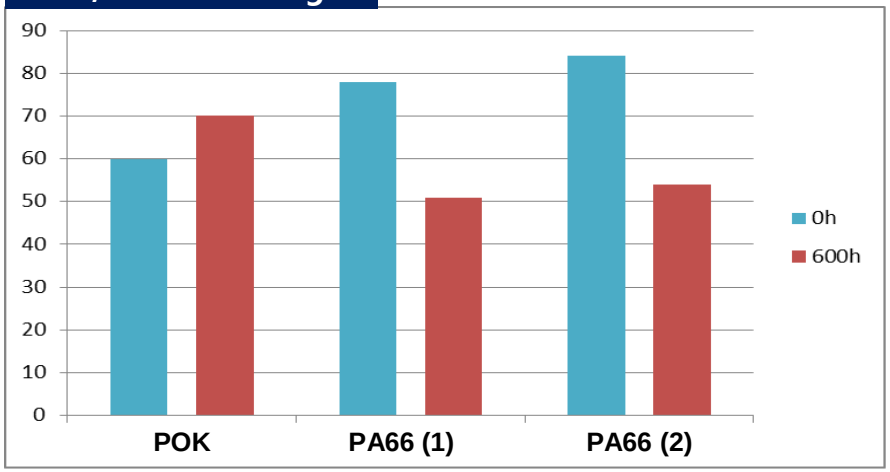


Equivalent Properties of chemicals @80℃(10% HCl)

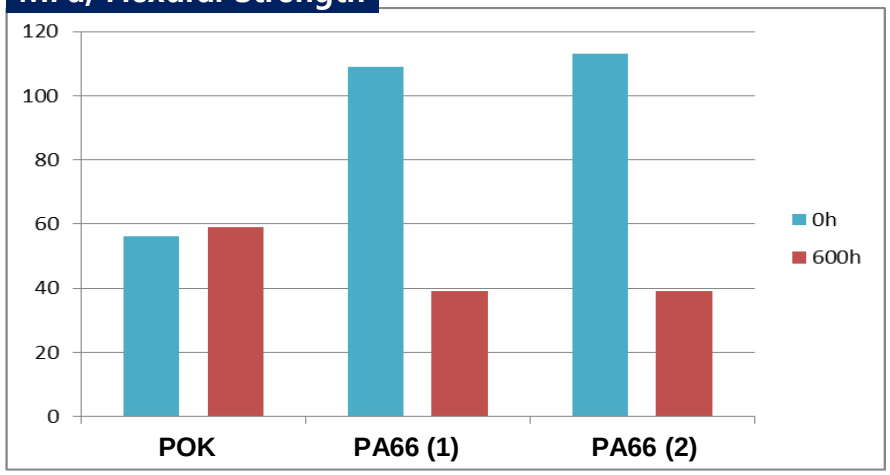
Confidential

V. 5% $CaCl_2$ @ 80℃

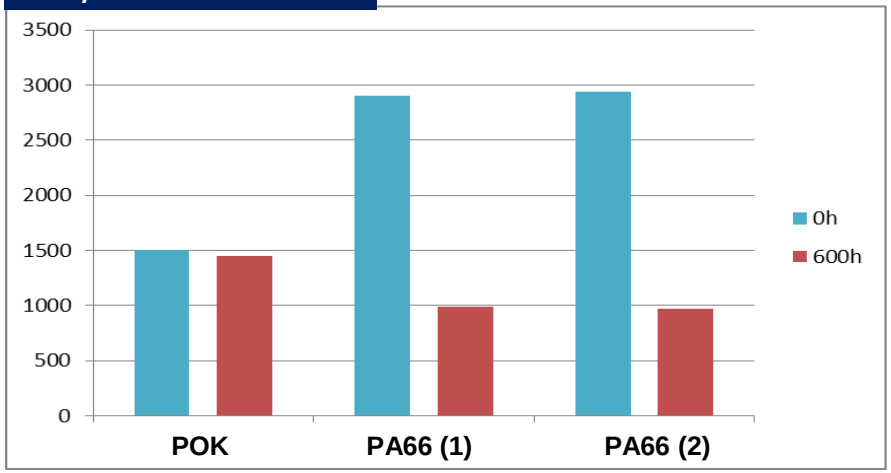
MPa, Tensile Strength



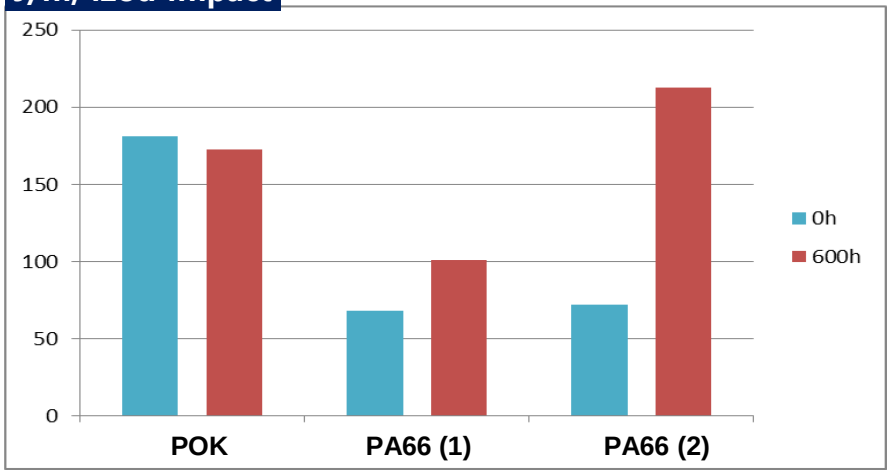
MPa, Flexural Strength



MPa, Flexural Modulus



J/m, Izod Impact

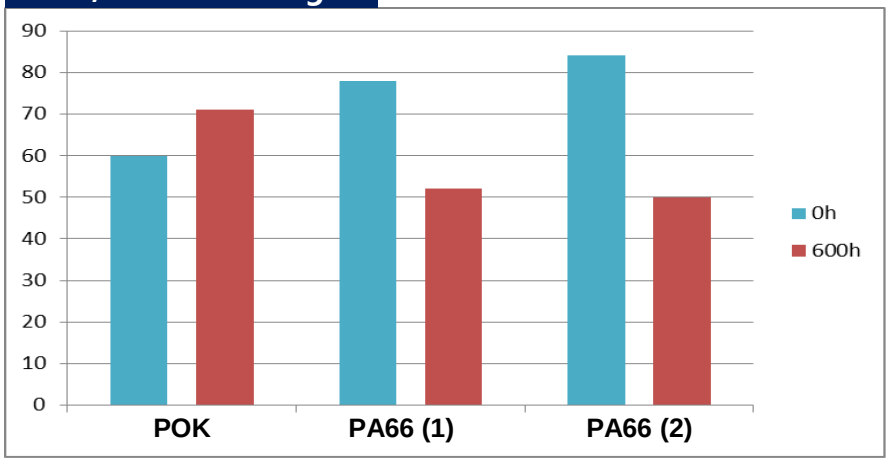


Outstanding Properties of chemicals @80℃(5% CaCl2)

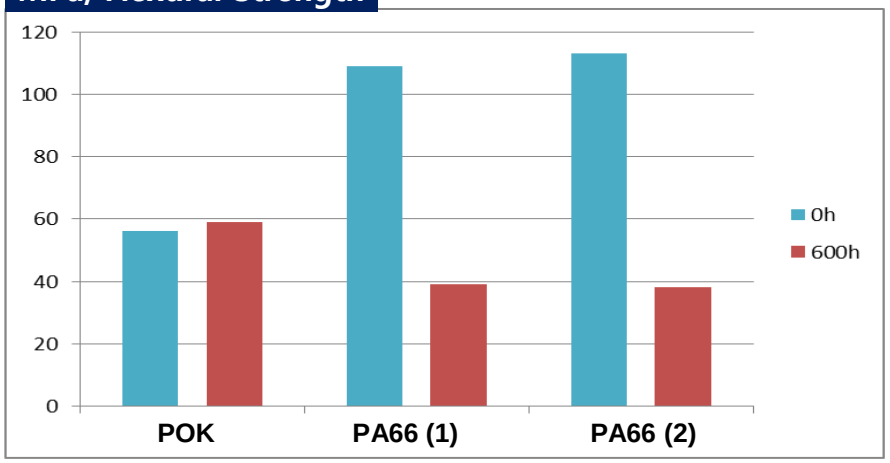
Confidential

VI. 1% NaOH @ 80℃

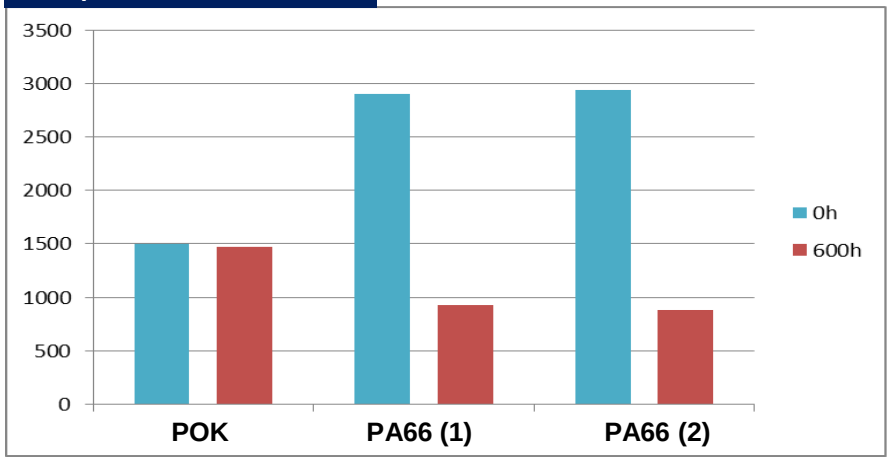
MPa, Tensile Strength



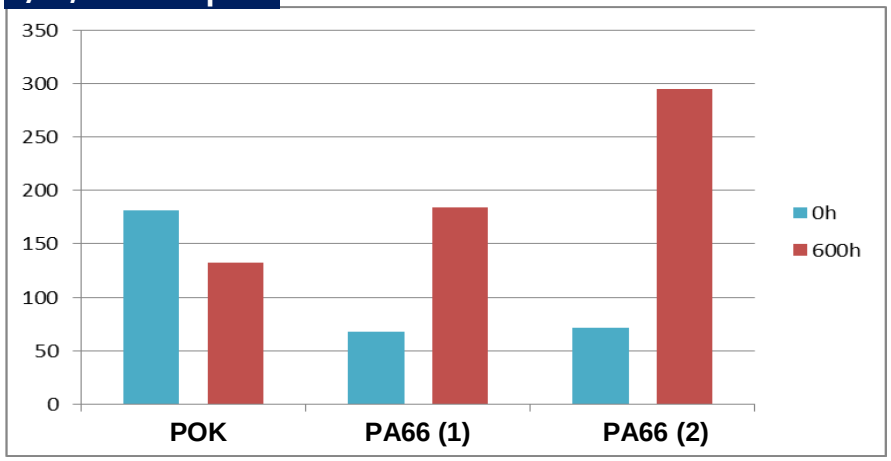
MPa, Flexural Strength



MPa, Flexural Modulus



J/m, Izod Impact

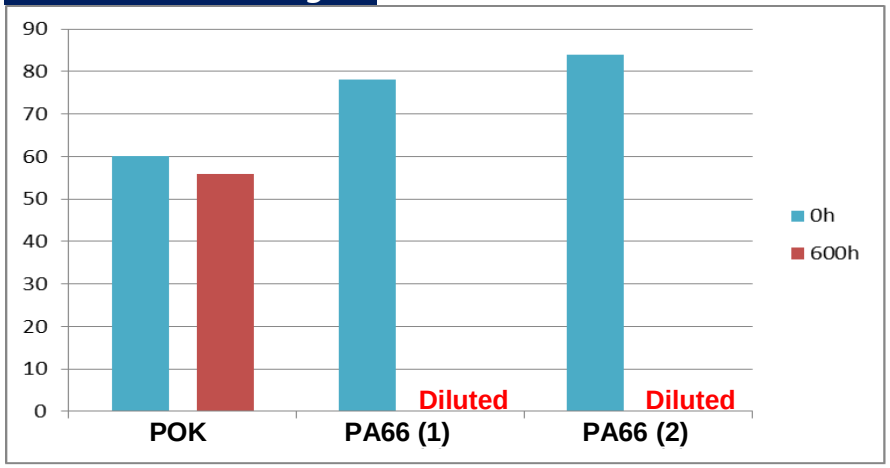


Outstanding Properties of chemicals @80℃(1% NaOH)

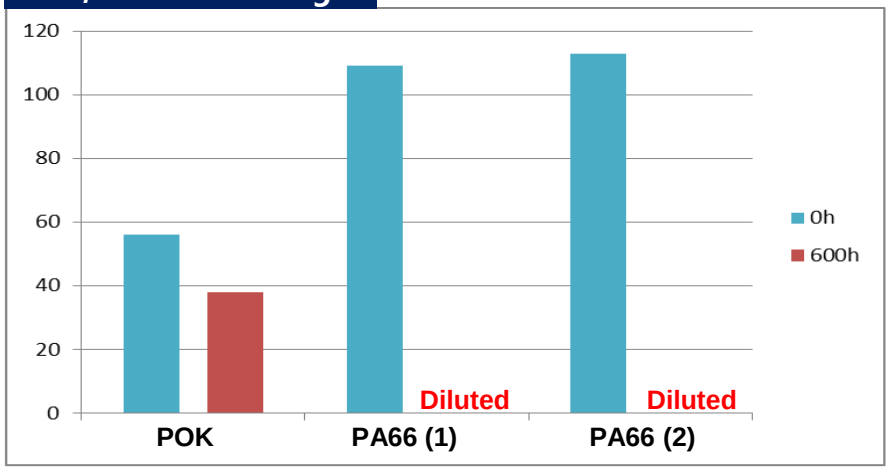
Confidential

Ⅶ. 50% $ZnCl_2$ @ 80℃

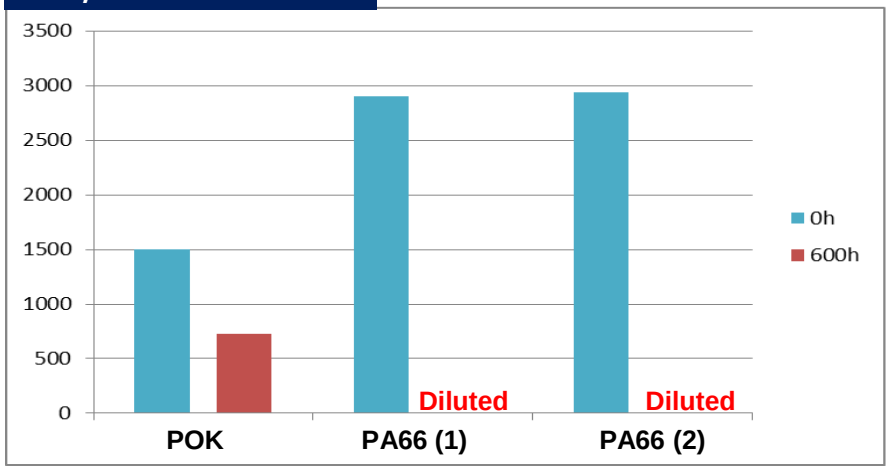
MPa, Tensile Strength



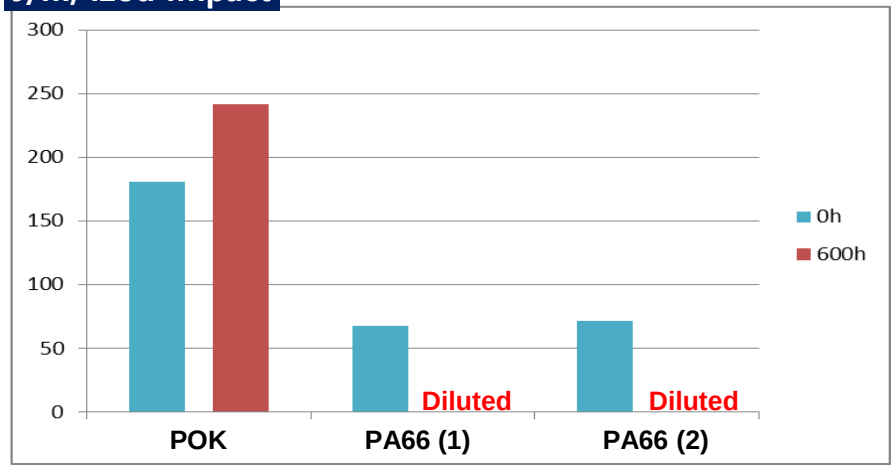
MPa, Flexural Strength



MPa, Flexural Modulus



J/m, Izod Impact



Outstanding Properties of chemicals at 80℃(50% $ZnCl_2$)

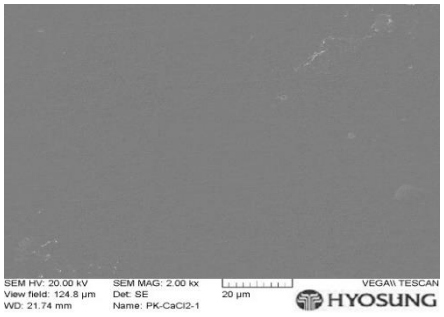
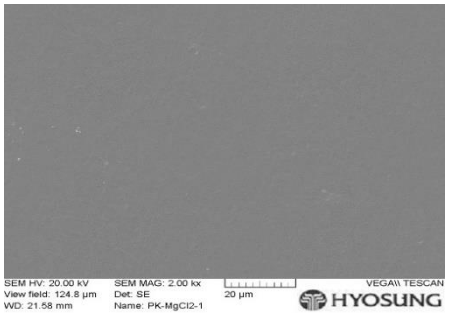
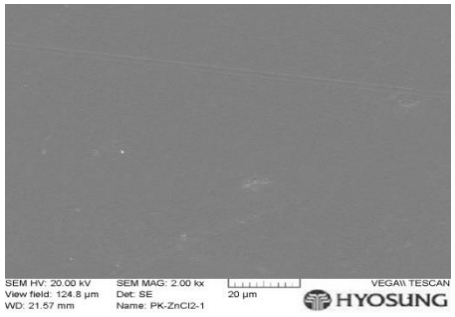
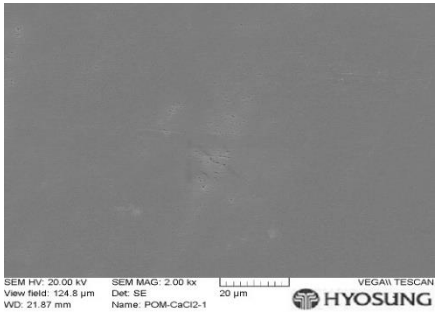
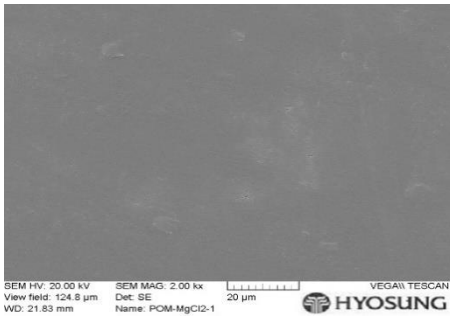
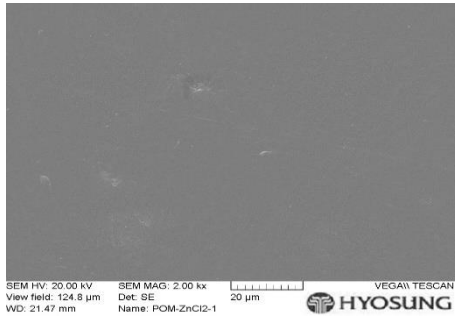
Confidential

Resistance to Chloride (Ford test method)

■ Chemical resistance test

- Grade : PK M630A
- Metal Chloride Solution : $CaCl_2$, $MgCl_2$, $ZnCl_2$ (50wt%)
- Immersed 96hrs at 23℃ → Dry for 24 hours at 40℃, Oven → Surface analysis by SEM

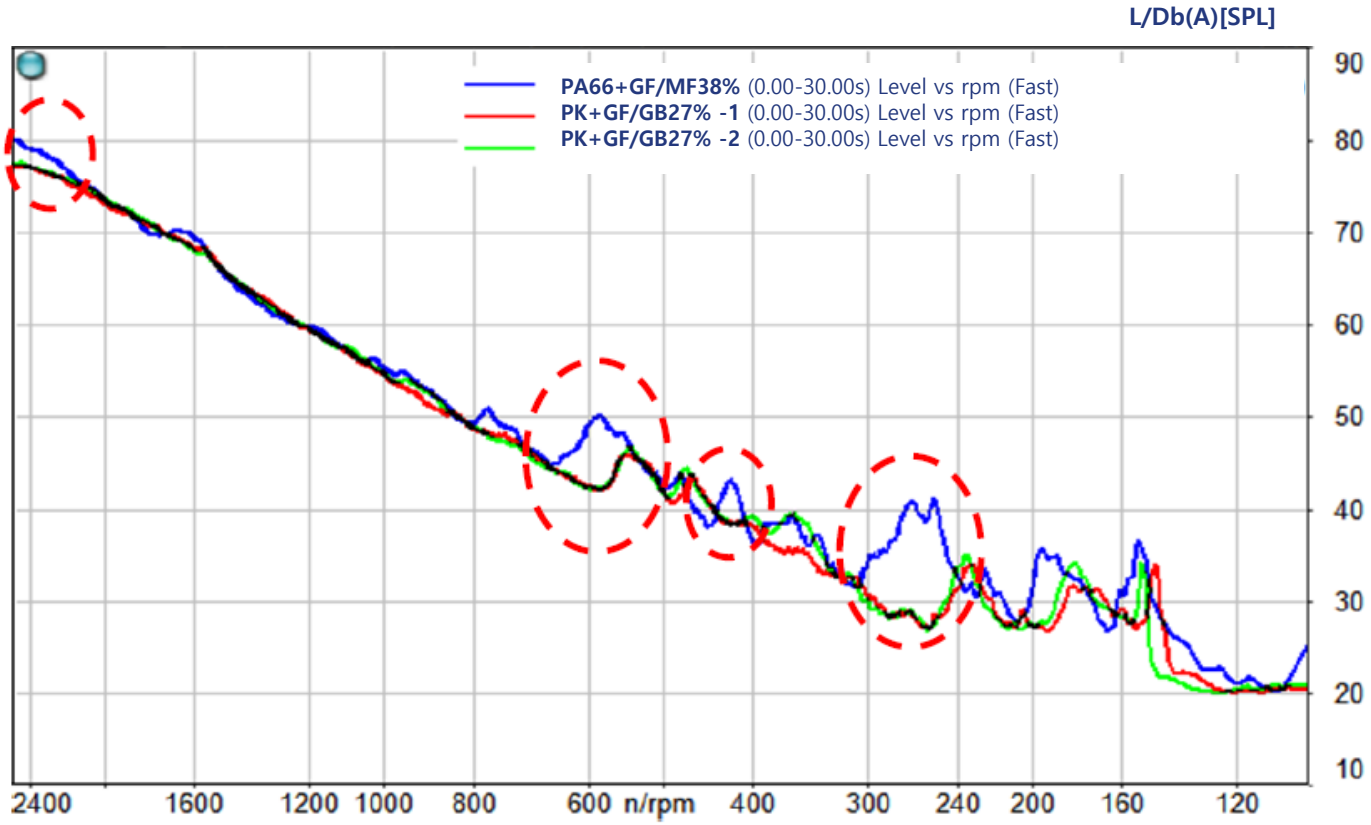
■ SEM Analysis (X2,000) : No crack on the surface

	CaCl2	MgCl2	ZnCl2
PK			
POM			

Confidential

2. NVH Test

- ***Engineering Specification of cooling fan***
  - Noise test



→ PK+GF shows low noise compare to PA66+GF/MF (5dB)

→ PK has a good damping effect which is caused by low Tg (~10 **℃**) at various RPM range

Confidential

3. Low Volatile Organic Compounds

HYOSUNG

SGS

Test Report No. F690101/LF-CTSAYAA16-17508 Issued Date: 2016. 03. 22 Page 2 of 3

Sample No. : AYAA16-17508.001
Sample Description : M330 pellet
Item No./Part No. : N/A
Materials : POLYKETONE

Sampling

Storage	**(23 ± 2) °C**
Sample Size	**5g**

VOC (Volatile Organic Compounds)

Tedlar bag size / Sampling Volume			**3L / 1L (N2)**		
Analysis Conditions			**65 °C , 2h**		
Analytes	**Test Method**	**Unit**	**MDL**	**Limit**	**Results**
Benzene	MS 300-55:2014, Tenax tube, GC/MS	μg/m³	10	30	N.D.
Toluene	MS 300-55:2014, Tenax tube, GC/MS	μg/m³	10	1 000	N.D.
Ethyl Benzene	MS 300-55:2014, Tenax tube, GC/MS	μg/m³	10	1 000	N.D.
Xylene	MS 300-55:2014, Tenax tube, GC/MS	μg/m³	20	870	N.D.
Styrene	MS 300-55:2014, Tenax tube, GC/MS	μg/m³	10	220	N.D.

Aldehyde

Tedlar bag size / Sampling Volume			**3 L / 1.5 L (N2)**		
Analysis Conditions			**65 °C , 2h**		
Analytes	**Test Method**	**Unit**	**MDL**	**Limit**	**Results**
Formaldehyde	MS 300-55:2014, DNPH Cartridge, HPLC	μg/m³	20	210	N.D.
Acetaldehyde	MS 300-55:2014, DNPH Cartridge, HPLC	μg/m³	20	50	N.D.
Acrolein (=Acrylaldehyde)	MS 300-55:2014, DNPH Cartridge, HPLC	μg/m³	20	50	N.D.

NOTE:
(1) MDL : Method Detection Limit
(2) N.D.: Not detected of below MDL
(3) MS 300-55: Hyundai-Kia motors Engineering Standard /VOC Emission test standard method
(4) * : The figure was expressed as a sign of inequality since the concentration was out of the calibration range in this experiment condition.
(5) Lab technician : Minsun Kim (VOCs), Jieun Lee (Aldehydes)
(6) Limit : refer to MS300-55 Table 2 Korea

Confidential

4. Wear resistance

SGS

Test Report **No. F690101/LF-CTSAYAA18-32469** Issued Date: 2018. 06. 20 Page 2 of 3

Sample No. : AYAA18-32469.001
Sample Description : POKETONE -M330A
Item / Part No. : M330A
Material : Poly ketone

Test Item	Test Method	Unit	Test Result	Remark
Wear Resistance	MS210-05:2017_4.8	Grade	5	-
			5	-
			5	-

<Note> Table 14 (Refer to MS210-05)

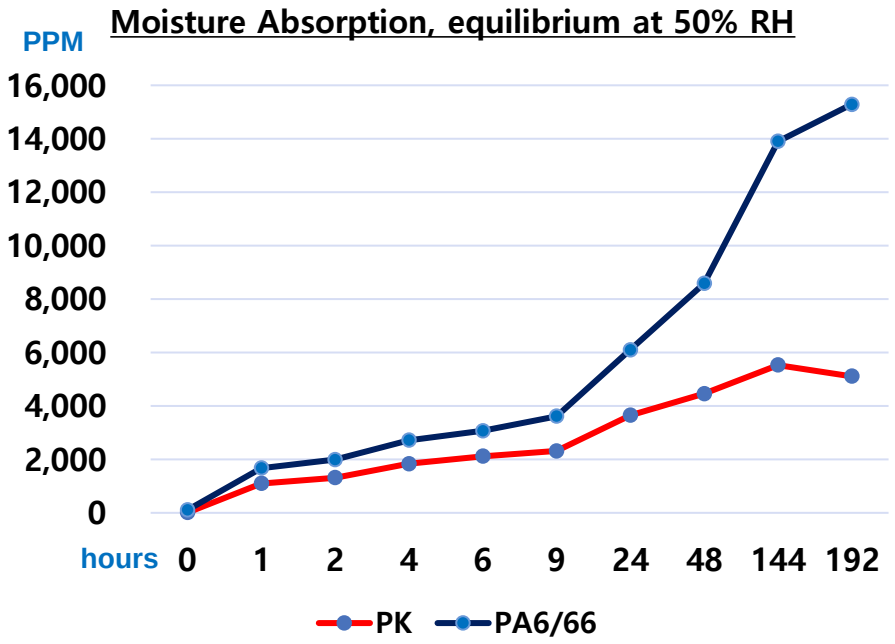
Grade	Appearance
5	Unnoticeable to the abrasion of surface
4	Slightly noticeable to the abrasion of surface
3	Somewhat noticeable to the abrasion of surface but not severe
2	Noticeable to the abrasion of surface
1	Excessively visible to the abrasion of surface

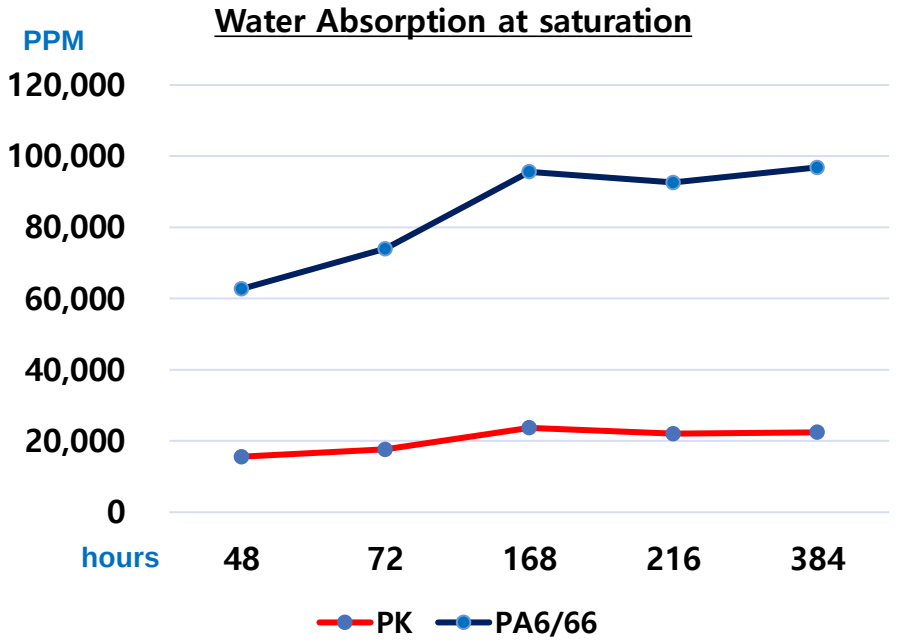
Test Item	Test Method	Test Result	
Scratch Resistance (Original)	MS210-05:2017_4.9.1 (Erichsen Method)	1	L -0.01
		2	L -0.07
		3	L -0.07
		Average	L -0.05

Confidential

5. Dimensional Stability

- Better dimensional stability compare to Polyamide





▶ POKETONE Base Resin

→ 0.5% Moisture Absorption @ 50% RH, 23℃ (vs 1.6% of PA6/66)

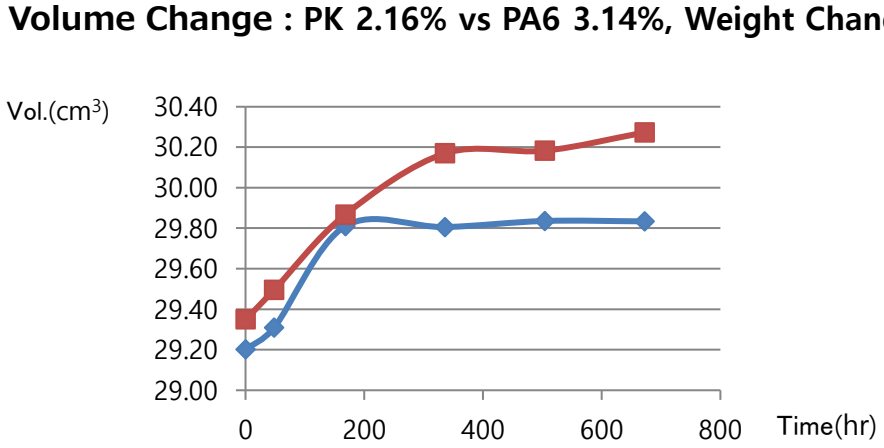
→ 2.0% Water Absorption @ Saturation, 23 ℃ (vs 10.0% of PA6/66)

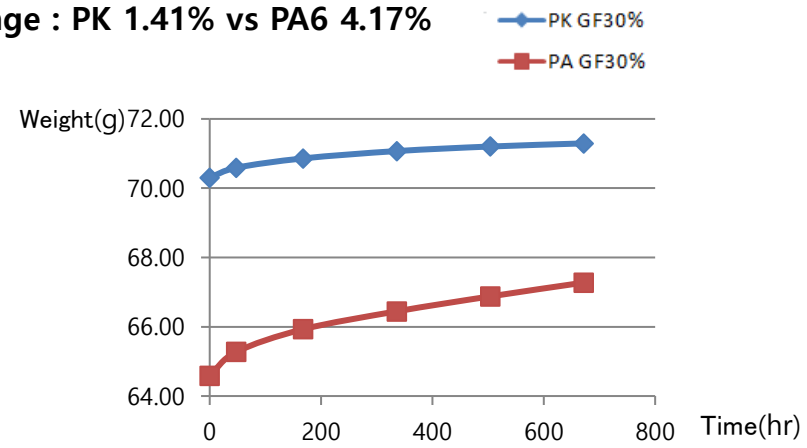
Confidential

Properties Retention after immersed water

*** Dimensional Change after immersed in water (23℃, 672hr)**

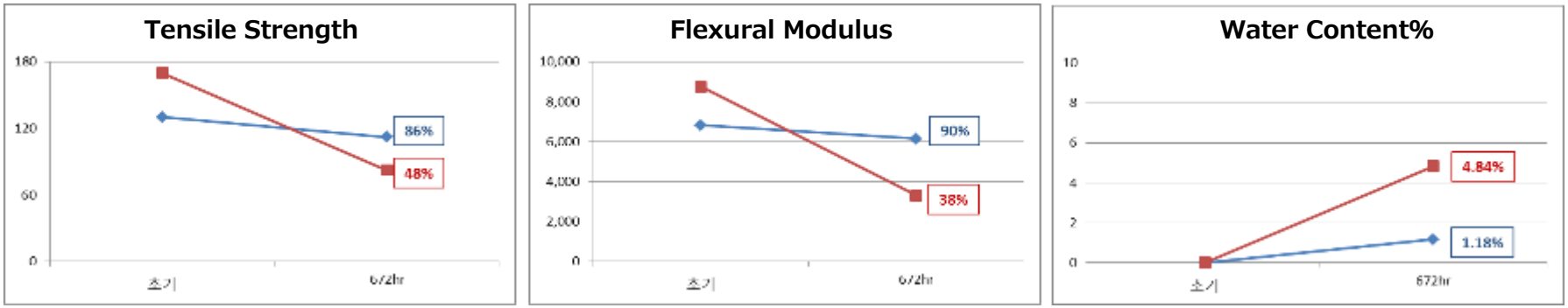
- Volume Change : PK 2.16% vs PA6 3.14%, Weight Change : PK 1.41% vs PA6 4.17%





*** Properties Retention Rate after immersed in Water (23℃, 672hr)**

- Tensile Strength: PK 86% vs PA 48%, Flexural Modulus: PK 90% vs PA 38%



Confidential

6. Impact Performance

HYOSUNG

POKETONE Characteristic – "High Impact Strength"

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

Items	Unit	PK**	PA6	PA66	PBT	POM
Density	g/cm^3	1.24	1.14	1.14	1.30	1.41
Melting Temperature	℃	222	220	260	220	160
Impact Strength	KJ/m^2	*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

** PK (POKETONE) : M330A Grade

Confidential

HYOSUNG

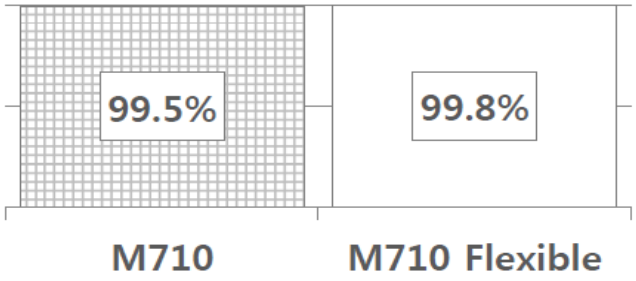
Fuel Barrier of Poketone and PA12,Teflon, EVOH

- Test Standard : SAE J2260 Permeability Test for Fuel Hose and Tubing
- Test Method: Measure weight change of fuel seal by tube [70days, 23℃]
- Fuel
  - ◎ **Fuel C** : Isooctane : Toluene = 50 : 50
  - ◎ **CM-15** : Fuel C : MeOH = 85 :15
  - ◎ **CE-10** : Fuel C : EtOH = 90 :10
- Materials
  - ◎ **PK Base** : M630, M620, M730, M710
  - ◎ **PK Flexible Grade**
  - ◎ **PA12**
  - ◎ **Teflon, EVOH**

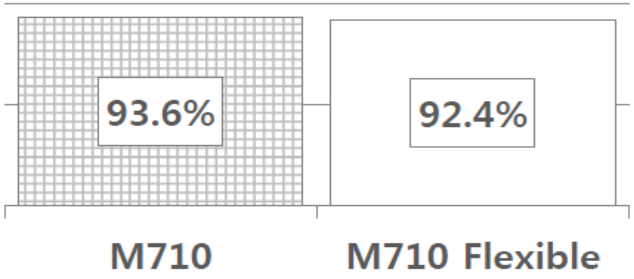
Confidential

■ PK Base vs Flexible – Weight Change %

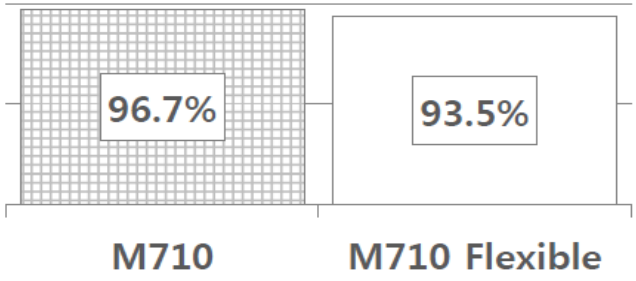
Fuel C



CM-15



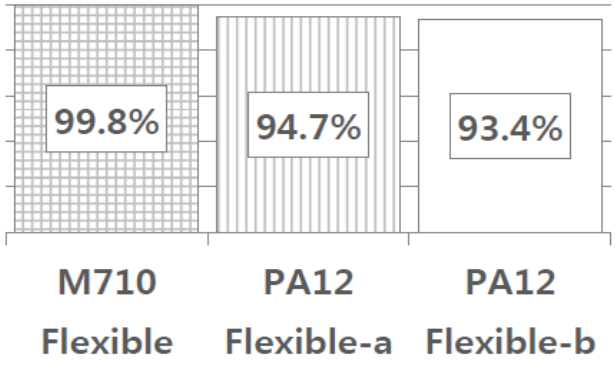
CE-10



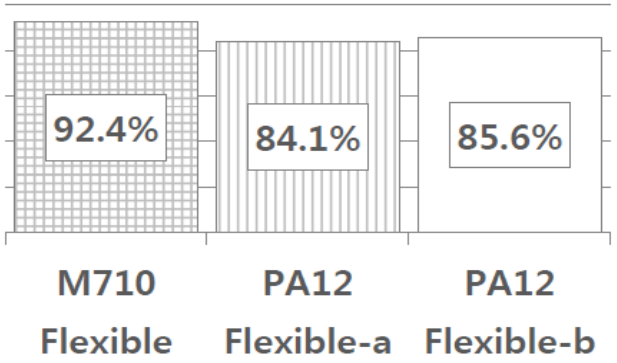
Confidential

■ PK vs PA12 – Weight Change %

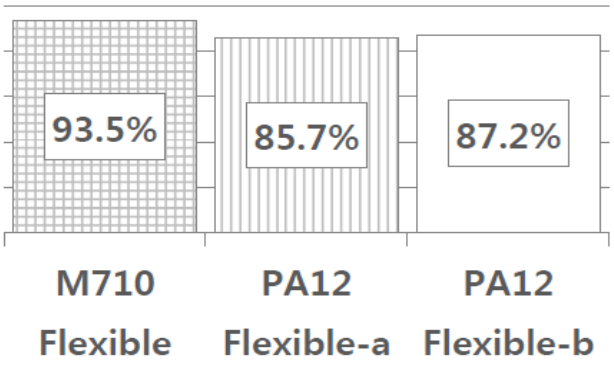
Fuel C



CM-15



CE-10

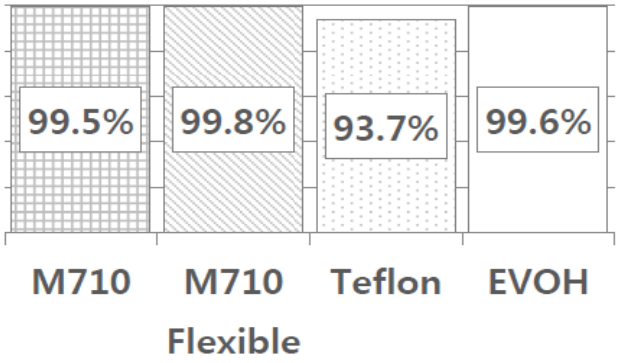


- **PK: M710 Flexible grade**
- **PA12-a: Flexible NY12(D**)**
- **PA12-b: Flexible NY12(U**)**

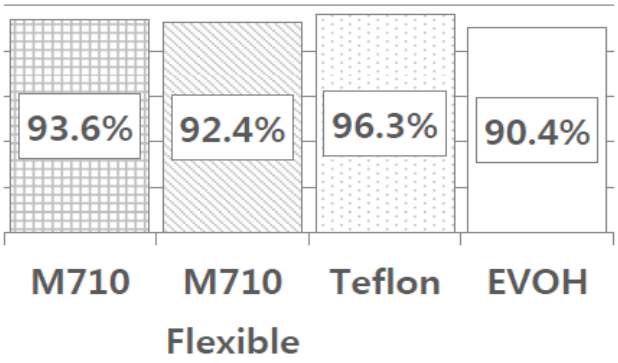
Confidential

■ PK vs Teflon vs EVOH – Weight Change %

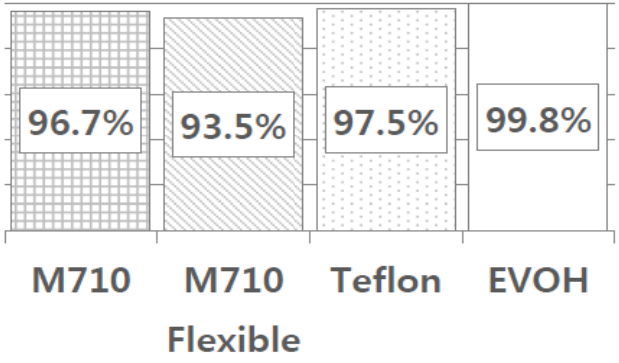
Fuel C



CM-15



CE-10



- **PK**: M710 Flexible grade
- **Teflon**: no info.
- **EVOH**: F171B(32mol%)

Confidential

PK Opportunities

HYOSUNG

Global Warming Potential

* PA6	6.70
* PA66	6.40
* PBT	4.88
* PC	3.40
* POM	3.20
* *PK	3.08 (KG CO_2 eq)

BIG 5 WEAKNESS

- High Price & Low HDT
- mPPO
- PA
- High Water Absorption
- PC
- PBT
- POM
- Weak Chemical Resistance
- Poor Hydrolytic Resistance
- Formaldehyde Emission

High HDT (1.82MPa/GF30%)
- PK GF 215
- mPPO GF 140℃

Competitive Price
- PK
- mPPO

Excellent Chemical Resistance
- PK ★★★★★
- PC ★

Excellent Hydrolytic Stability (85℃, 85% RH, 30days)
- PK 65MPa
- PBT 22MPa

High Impact Strength (kJ/m², Charpy)
- PK (M630) 15
- PBT 5.5

Formaldehyde Free (90℃, 24hr mg/L)
- PK 0.0
- POM 0.066

Low Density(g/cm³)
- PK 1.24
- POM 1.41

Dimensional Stability (Water Absorption, 23℃)
- PK 2.1%
- PA66 8.5%

Stable Price ('20 Oct~'22 Aug)

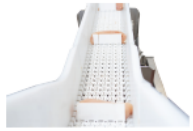

Water Purifier Tank


Pump Housing

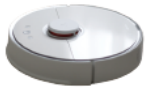

Electric Meter


Connector


Gear


Food Conveyor belt


Water Meter


Robot Vacuum Gear

Non Toxic High Efficiency

EARTH FRIENDLY

- Formaldehyde Free
- Phthalate Free
- Bisphenol A Free
- Acrylate Free
- Melamine Free
- Lead/Chrome Free

HYOSUNG
Poketone
▶ Contact: poketone@hyosung.com

Confidential