New Material Solutions for Engine Cooling and Other Demanding Under-the-Hood Environments

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*Modified to Include Product Trademarks, Grades for Clarifications
Topics

- What is a Polylphthalamide or “PPA”
- Properties Comparison Between “PPA” & “PA66”
- Applications Overview in:
  - Engine Cooling
  - Transmission
  - Engine Oil
  - Fuel
  - Air Induction
PPA (PolyPhthalamide) Family is a High Performance Engineering Polymer
PPA is Special Category of Polyamide (ASTM)

**ASTM D5336**:

- It is a Polyamide
- Use of Aromatic Acids: Terephthalic Acid or/and Isophthalic Acid
- Combination of the Two Ingredients Comprises at least 55 Molar Percent

Polyamide 66 (PA66)

“Aliphatic”

“Aromatic”

Terephthalic Acid

Isophthalic Acid

Adipic Acid
PPA is a Family of Resins: Product & Processing Performance Differs with the Polymer Chemistry

<table>
<thead>
<tr>
<th>Polymer Chemistry</th>
<th>Reference Here</th>
<th>Tg (C) by DMA</th>
<th>Tm (C) ISO 11357</th>
<th>DTUL@ 1.8MPa (C) ISO 75</th>
<th>%H20, 24Hrs ISO 62</th>
</tr>
</thead>
<tbody>
<tr>
<td>PA66 (Zytel®)</td>
<td>PA66</td>
<td>65</td>
<td>263</td>
<td>252</td>
<td>1.2%</td>
</tr>
<tr>
<td>PA6T/DT ** (Zytel® HTN51)</td>
<td>PPA 1</td>
<td>140</td>
<td>300</td>
<td>264</td>
<td>0.5%</td>
</tr>
<tr>
<td>PA6T/6I/66 (Competitive PPA)</td>
<td>PPA 2</td>
<td>125</td>
<td>312</td>
<td>278</td>
<td>0.5%</td>
</tr>
<tr>
<td>PA6T/66 (Zytel® HTN52)</td>
<td>PPA 3</td>
<td>90</td>
<td>310</td>
<td>285</td>
<td>0.5%</td>
</tr>
</tbody>
</table>

** “D” : 2-Methyl Pentamethylene Diamine
# PPA Resins Characteristics and Benefits to Your Automotive Applications

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Benefits</th>
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</thead>
<tbody>
<tr>
<td>1. Mechanical Properties Less Affected by Moisture</td>
<td>☑ Savings in weight, cost due to thinner walls</td>
</tr>
</tbody>
</table>
| 2. Mechanical Properties Retention due to Higher Glass Transition Temperatures, Long Term Heat Aging | ☑ Metal Replacement at Higher Temperatures, Savings in weight, cost due to thinner walls
                                                      | ☑ Higher service temperature, longer life                               |
| 4. Resistance to Automotive Chemicals and Environment  | ☑ Higher Temperature Under the hood Components, Longer Service Life      |
| 5. Creep Resistance at Higher Temperatures             | ☑ Dimensional Stability for Higher Load Metal Replacement Applications   |
PPA Has Long, Proven History of Delivering Cost-Effective Solutions under the Harsh & in Demanding Automotive Environment to our Customers Throughout the World
PPA Maintains Mechanical Properties under Humid Environment: but Moisture Effects PPAs Differently

Source: Suppliers’ Datasheets: PA66 (ISO527); PPA’s (ASTM D638), Tested @ 23oC

Zytel® HTN 51 Series: Least Impacted by Moisture

Zytel® HTN 51  Competitive PPA  Zytel® HTN 52
PPA Retains Rigidity Well at Higher Temperatures

**LEGEND**

- **PPA 1 - Zytel® HTN 51**
  - Series: Best Retention of Rigidity at High Temperature
- **PPA 3 - Zytel® HTN 52**
- **PA66 (33% glass)**
- **PPA 1- PA6T/DT (35% glass)**
- **PPA 3- PA6T/66 (35% glass)**
PPAs Provide Better Resistance to Hot Long Life Coolant than PA66; Performance Varies Depending on PPA Chemistry

Zytel® HTN 51 Series: Least Impacted by Exposure to Long Life Coolant

Zerex LLC G05, Full Immersion @ 130C, Properties Tested @ 23C

LEGEND

PPA 1 - Zytel® HTN 51
PPA 2 - Competitive PPA (PA6T/6I/66)
DuPont® Zytel® HTN 51 (PPA 1) Selected for the First Water Jacket Spacer for Open Deck Engines

- **Function** - Directs long-life coolant flow to transfer heat away from key areas of the combustion chamber, minimizing variations in cylinder wall temperatures.

- **Benefits** - Toyota engineers credit the improved cooling with increasing fuel economy by three-tenths of a mile per gallon, or 1 percent, while extending engine life.

- **Zytel® HTN** - Coolant Resistance; Rigidity & Strength; Dimensional Stability

*Winner of 2005 Society of Plastics Engineers Most Innovative Plastics - Powertrain Award*
PPA Delivers Performance/Benefits to Engine Cooling Applications

- Resistance to Hot Long Life Coolant
- Dimensionally Stable Due to Creep Resistance
- Low Creep to Maintain Sealing
- Cost & Weight Reduction vs Aluminum, PPS
- No Secondary Operations Like Deflashing With PPS
- Feasible Complex Shapes for Optimum Flow
- Smooth Surface Facilitates Flow
PPA Enables Parts Integration & Metal Replacement in Transmission Components

- Improved Resistance to ATF over PA66
- PPAs offer High Modulus & Strength – *But Performance Varies*
- Low Creep
- Low Coefficient Thermal Expansion

![Transmission coil](image)
PPA Delivers Performance to Engine Oil Components

- Strong & Rigid Parts at High Temperatures
- Tight Tolerance
- Low Creep to resist Leakage
- Longer Service Life: Improved Resistance to Hot Engine Oil over PA66
- Property Retention Varies Based on PPA Chemistry

Motorcycle Engine Cover
PPA = Cost Effective Fuel Component Solutions

- Chemical Resistance to Hot Motor Fuels
- Low Swell
- Low Permeability to Fuel
- Reduce cost, weight vs metal, PPS
- Superior Resistance to “Acid Wash” compared to POM
PPA - Low Creep Under Load at High Temperatures

Accelerated Flexural Creep by DMA;
Load of 28 MPa @ 150°C

LEGEND

PPA 1 - Zytel® HTN 51
PPA 2 – Competitive PPA (PA6T/6I/66)
PPA 3 - Zytel® HTN 52
PPA May be Used at Higher Temperatures Over Time

Zytel® HTN 51 Series Offers Best Heat Aging Protection

Tested at 23° C

AGING TIME, Hours

TENSILE STRENGTH, psi

AGED @ 175 °C

PPA 1 - PA6T/DT (35% glass)

PPA 2 - PA6T/6I/66 (33% glass)

PA66 (33% glass)

[Diagram showing tensile strength over aging time for PPA 1, PPA 2, and PA66]

LEGEND
PPA 1 - Zytel® HTN 51
PPA 2 - Competitive PPA (PA6T/6I/66)
PPA Cost-Effectively Replaces Metal

- High Temperature Modulus & Strength for Use Closer to Engine
- Improved Air Heat Aging Performance for Higher Temperature Use
- Low Coefficient Thermal Expansion for Dimensional Stability
- Low Creep at High Temperatures to Maintain Seal

Charge Air Cooler
Resonator
Heat Shield
PPA Delivers Cost Effective Solutions in Your Demanding Automotive Applications

For Engine Cooling, Transmission, Engine Oil, Air Induction, Fuel:

- High Temperature Capability
- Excellent Short & Long Term Mechanical Performance
- Stability of Performance Under Humid Environment
- Low Coefficient of Thermal Expansion for Metal Replacement
- Excellent Chemical Resistance to Automotive Fluids
- PPA is a Family of Resins: Properties vary because of Different Polymer Chemistry
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