Polypropylene (PP) Fitting Report:  
Fitness For Use of PP Bodied  
Mechanical Fittings  
For Liquid Propane Applications  

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Prepared For:  
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Fitness For Use of PP Bodied Mechanical Fittings 
For Liquid Propane Applications

I. Executive Summary

Valencia Pipe Company (VPC) plans to market mechanical fittings made with a polypropylene (PP) body for use with polyethylene (PE) pipe and tubing used in liquid propane applications. These fittings are manufactured by Philmac Pty Ltd in Australia. These PP mechanical fittings and the joints between these mechanical fittings and PE pipe meet the Category 1 requirements of NFPA 58-2008 Section 5.9.5 and ASTM D2513-06. These PP mechanical fittings also meet all of the requirements of NFPA 58 Section 5.9.5 (D), including sections (1) to (3). In addition, the elevated temperature sustained pressure test results show that these mechanical fitting joints have a service life of over 100 years at a hoop stress several times the normal operating pressure (stress). Based on the design of these mechanical fittings and the results of laboratory testing, these PP mechanical fittings are “fit for use” in LP applications in accordance with NFPA 58.

II. Background

Valencia Pipe Company (VPC), headquartered in Valencia, CA, desires to market mechanical fittings made with a polypropylene (PP) body for use in liquid propane (LP) applications. These PP mechanical fittings would be joined to polyethylene (PE) pipe, which is commonly used for LP applications. To assure Fitness For Use in this application and to assure that these PP mechanical fittings meet all the requirements for LP applications, VPC sought the assistance of Dr. Gene Palermo, president of Palermo Plastics Pipe Consulting. Dr. Palermo’s qualifications are summarized in Section VII of this Report.

III. NFPA 58

The key standard that needs to be investigated for plastic piping components used in LP applications is National Fire Protection Association (NFPA) 58, “Liquefied Petroleum Gas Code”. In accordance with Section 5.11.3, NFPA 58-2008 allows the use of various types of metal and plastic materials for pipe and tubing, including PE, which shall be made in accordance with ASTM D2513-06. Section 5.9.5 provides the requirements for fittings to be used with PE pipe and tubing. Section 5.9.5 states that a
suitable joining method for PE pipe and tubing is mechanical fittings. The key section in NFPA that applies to the question at hand is Section 5.9.5 (D), which states:

(D)* Mechanical fittings shall comply with Category 1 of ASTM D 2513, Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings, and the following:
(1) Mechanical joints shall be tested and recommended by the manufacturer for use with polyethylene pipe and tubing.
(2) Compression-type mechanical fittings shall include a rigid internal tubular stiffener, other than a split tubular stiffener, to support the pipe.
(3) Gasket material in the fitting shall be resistant to the action of LP-Gas and shall be compatible with the polyamide or polyethylene pipe material.

Thus, NFPA requires that a mechanical fitting shall be tested to demonstrate it is a Category 1, it shall include a stiffener, and the material shall be compatible with PE pipe. The requirements for a Category 1 mechanical fitting are specified in ASTM D2513.

IV. ASTM D2513

ASTM D2513-06 “Standard Specification for Thermoplastic Gas Pressure Pipe, Tubing and Fittings” specifies the following requirements for mechanical fittings in Section 5.9. The definition and test requirements for a Category 1 mechanical fitting are in Section 6.10.

5. Requirements
5.9 Joints:
5.9.3 Mechanical—Mechanical fittings shall be installed in accordance with the user's written procedures and the fitting manufacturer's installation instructions. The joint shall be tested in accordance with the specific design category as outlined in 6.10.

6. Test Methods
6.10 Categorization of Mechanical Joints—The following test methods provide a uniform procedure for qualification or categorization of mechanical joints using short term pullout resistance tests and burst tests. The mechanical joint categories and test methods are as follows:
6.10.1 Category 1—A mechanical joint design that provides a seal plus a resistance to a force on the pipe end equal to or greater than that which will cause a permanent deformation of the pipe.
6.10.1.1 The apparatus and report shall be as specified in Test Method D638. The test shall be conducted at ambient temperatures, that is, 67 ± 10°F (19.4 ± 5.6°C). The speed of the testing shall be 0.2 in. (5 mm)/min ±25 %. Five specimens shall be prepared following the manufacturer’s published installation instructions. Length of the specimens shall be such that the unreinforced distance between the grip of the
apparatus and the end of the stiffener is at least five times the nominal outside
diameter of the pipe size being tested. Apply a load until permanent deformation
(yield) occurs in the unreinforced area of the piping.
6.10.1.2 Results obtained from the above method pertain only to the specific outside
diameter, wall thickness, and compound of the piping used in the test and specific
fitting design tested.

It is clear from these ASTM D2513 requirements that a Category 1 mechanical fitting
must provide not only a seal to prevent the internal fluid from escaping, but also a pull-
out resistance to prevent the PE pipe or tubing from pulling out of the mechanical fitting
in service. A long-term seal is generally demonstrated by an elevated temperature
sustained pressure test of the mechanical joint after proper assembly. As for the pull-
out resistance, ASTM D2513 specifies a pull test in accordance with ASTM D638. This
pull test must result in the PE pipe or tubing necking down or deforming, which
demonstrates that the pull-out resistance is greater than the strength of the PE pipe
material.

V. PP Fitting Test Data

QAI Laboratories in Tulsa, OK was selected to conduct a test program for PP
mechanical fittings, which were manufactured by Philmac Pty Ltd in Australia. QAI
Laboratories joined these PP mechanical fittings to 2” IPS PE pipe and ½” IPS PE pipe,
per the manufacturer’s installation instructions. For each pipe size, three types of
fittings were tested – coupler, elbow and tee. All laboratory testing was conducted in
accordance with ASTM F1924, “Standard Specification for Plastic Mechanical Fittings
for Use on Outside Diameter Controlled Polyethylene Gas Distribution Pipe and
Tubing”. Specifically, these tests were:

- Section 7.2 “Elevated Temperature Sustained Pressure Test”
- Section 7.3 “Tensile Strength Test”
- Section 7.4 “Temperature Cycling Test”
- Section 7.5 “Constant Tensile Load Joint Test”

A. Elevated Temperature Sustained Pressure Test

QAI assembled six mechanical joints for each size and type of mechanical fitting per the
manufacturer’s instructions. Each assembly was tested at a hoop stress of 580 psi (4.0
MPa) at a temperature of 80°C (176°F) for a time of 1000 hours as required by ASTM
F1924. None of the assemblies failed this long-term elevated temperature sustained
pressure test.

As I stated previously, this test method is the most common test method used in the
plastic piping industry to assess long-term performance and leak-tightness or “seal” of
PE components. Using the industry-accepted Bidirectional Shift Factors, the test
condition of 80°C/580 psi/1000 hours can be shifted to the in-service condition of
15°C/1233 psi/136 years – See Appendix A. This means that these PP mechanical fittings when properly joined to PE pipe will provide a “seal” for more than 136 years, at an average annual ground temperature of 15°C (60°F) at a hoop stress of 1233 psi (247 psig for SDR 11 pipe), which is several times higher than the normal operating pressure for these assemblies in LP applications.

Certainly, the long-term performance and ability to provide a “seal” has been adequately demonstrated for these PP mechanical fittings joined to PE pipe.

B. Tensile Strength Test

QAI assembled six mechanical joints for each size and type of mechanical fitting per the manufacturer’s instructions. Each assembly was tested in accordance with ASTM D638 at a speed of 0.2 inches/minute. The required minimum elongation in the pipe outside the joint assembly is 25%. All specimens were pulled until an elongation of 50% was achieved. None of the assemblies failed this pull-out resistance test.

This pull-out resistance test is the second requirement to demonstrate a category 1 type of mechanical fitting – one that has both long-term seal and pull-out resistance. Thus, these PP mechanical fittings produced by Philmac Pty Ltd in Australia meet the ASTM D2513 requirements for a category 1 mechanical fitting.

C. Temperature Cycling Test

QAI assembled six mechanical joints for each size and type of mechanical fitting per the manufacturer’s instructions. Although not a requirement of NFPA 58 for mechanical fittings, and not a requirement of ASTM D2513 for a category 1 mechanical fitting, QAI Laboratories was also asked to conduct a temperature cycling test in accordance with ASTM F1924. This is another sustained pressure test that introduces cycling of the temperature between -20°F and 140°F. This is a particularly aggressive test for mechanical fittings as it tests the ability of the gasket material to maintain a pressure seal at extreme temperature conditions. No failures were observed during this test.

D. Constant Tensile Load Joint Test

QAI assembled one mechanical joint for each size and type of mechanical fitting per the manufacturer’s instructions. Although not a requirement of NFPA 58 for mechanical fittings, and not a requirement of ASTM D2513 for a category 1 mechanical fitting, QAI Laboratories was also asked to conduct a constant tensile load joint test in accordance with ASTM F1924. This test simultaneously measures the ability of the mechanical fitting joint to maintain a seal while under a constant pressure, and to demonstrate resistance to pull out during the duration of the test. Again, no failures were observed during this test.
VI. Fitness For Use

The mechanical fittings produced by Philmac Pty Ltd in Australia using a polypropylene body are being questioned as to whether or not they are “fit for use” to be joined to PE pipe used in an LP application. As we have shown in this report, the PP mechanical fitting and the joints between these mechanical fittings and PE pipe meet the Category 1 requirements of NFPA 58-2008 Section 5.9.5 and ASTM D2513-06. As shown in Appendix B, these PP mechanical fittings use a rigid insert stiffener. The nitrile gasket material is known to perform well in LP applications. Thus, these PP mechanical fittings meet all of the requirements of NFPA 58 Section 5.9.5, including sections (1) to (3). The elevated temperature sustained pressure test results show these mechanical fitting joints have a service life of over 100 years at a hoop stress several times the normal operating pressure (stress). Based on the design of these mechanical fittings and the results of the laboratory testing, my professional opinion as a consultant for the plastic piping industry with over 40 years of experience is that these PP mechanical fittings are “fit for use” in LP applications in accordance with NFPA 58.

VII. Dr. Gene Palermo Qualification and Certification

I am a professional polymer chemist, and have worked in the plastic pipe industry for over 40 years. My experience in the industry is broad, covering manufacturing, formulation, testing, standards, technical and regulatory approvals, and marketing new plastic piping materials. I hold a Bachelor of Science degree in Chemistry, which I obtained from St. Thomas College in St. Paul, Minnesota in 1969. I also have a PhD in Analytical Chemistry from Michigan State University, which I received in 1973.

My work in the polymer industry started immediately upon graduation, when I started working at the DuPont Company at their Experimental Station Laboratory in Wilmington, Delaware. I worked for DuPont for the next twenty-two years, in various roles:
(a) From 1973-1974, I worked at DuPont in their Analytical and Physical Measurements group. I was involved in analytical measurements, testing, and characterization of polymers and other chemical compounds using thermal analysis methods and infrared (IR) spectroscopy.
(b) From 1974-1975, I worked for DuPont’s Marketing group in the Plastics Department, researching and finding new markets for powdered polymers and nylon blends.
(c) From 1976-1995, I worked in the polyethylene gas pipe business at DuPont, focusing on pipe and fittings made for natural gas distribution. They were marketed under the trade name “Aldyl A”. DuPont sold the Aldyl business to a joint venture between Uponor and Neste in 1990. My experience at DuPont and Uponor/Neste during this time encompassed virtually all aspects of pipe manufacture, testing, marketing and sales, including formulation, extrusion, pressure rating, failures analyses and other analytical testing, and customer presentations.
In 1995, I was hired as a Marketing Specialist by a company called Elf AtoChem, which was a large plastic resin manufacturer. While at Elf AtoChem, I developed the first use of polyamide pipe 11 (PA-11) for high pressure gas distribution pipe and fittings in North America.

In 1996, I was recruited by the Plastics Pipe Institute (PPI), which is the largest trade organization in North America relating to plastic pipes. I was hired as the Technical Director of PPI. PPI was formed in the 1960s, and works in association with manufacturers, trades, and regulatory authorities to gather information on, set standards for, and approve plastic pipes for use in North America. As will be explained further below, virtually every manufacturer who seeks to obtain regulatory approval for their product in North America applies to PPI in order to seek listings and technical certifications for their products. In my role as Technical Director at the Plastics Pipe Institute, I worked to develop the standards and pressure rating methods of plastic pipe and piping systems. During this time, I also worked with many standards organizations to develop testing and certification standards for pipes, working with groups such as the American Society for Testing and Materials (ASTM), the Canadian Standards Association (CSA), and the International Standards Organization (ISO). Through this work, I gained further significant and detailed expertise on plastic pipes and fittings developed and sold around the world, including pipes for water and gas distribution, and cross-linked polyethylene (PEX) pipe.

In 2004, I became an independent consultant in the plastics pipe industry, forming a company called Palermo Plastics Pipe (P³ or P Cubed) Consulting. Since 2004, I have continued working with the ASTM, CSA and ISO standards organizations to develop new standards and testing methods for plastic pipes and fittings. I regularly give technical presentations at customer locations or at industry meetings to promote new plastic piping materials. I have also worked as an expert witness on litigation cases involving plastic pipes and fittings, primarily product liability cases in which piping failures occurred.

I have received several awards in association with my work in the plastic pipe industry. For example, I have received two Awards of Appreciation, a Special Service Award, the Paul Finn Memorial Award, the Rinehart Kuhlmann Award, and the Award of Merit (highest award given) from ASTM for my service and contributions to the plastic pipe standards. I also received several awards from the American Gas Association for my contributions to the industry, including the Platinum Award of Merit, which is the highest award given by this association.

Details of my educational and professional background are found in my website – www.plasticspipe.com.

### Appendix A

**Bidirectional Shift Factors**

<table>
<thead>
<tr>
<th>Reference Conditions</th>
<th>Shifted Conditions</th>
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<tbody>
<tr>
<td>Temperature (Tr)</td>
<td>Temperature (T)</td>
</tr>
<tr>
<td>= C</td>
<td>= C</td>
</tr>
<tr>
<td></td>
<td>80 C</td>
</tr>
<tr>
<td>Stress (Sr) = psi</td>
<td>Stress = S</td>
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<tr>
<td></td>
<td>580</td>
</tr>
<tr>
<td>Failure time (tr)=</td>
<td>Failure time = t</td>
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<tr>
<td>hours</td>
<td></td>
</tr>
<tr>
<td>1,000</td>
<td></td>
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\[
\begin{align*}
\text{at} &= \exp(-0.109(T-Tr)) \\
\text{bt} &= \exp(0.0116(T-Tr)) \\
\text{at} &= 1193.923235 \\
\text{bt} &= 0.47048086 \\
\text{Sr} &= S \times \text{bt} \\
\text{tr} &= \frac{t}{\text{at}} \\
\text{S} &= \frac{\text{Sr}}{\text{bt}} \\
\text{t} &= 1193923 \text{ hours} \\
\text{S} &= 1233 \text{ psi} \\
8.5 \text{ MPa} & \quad \text{for} \quad 247 \text{ psig} \\
136 \text{ years} & \quad \text{for} \quad \text{SDR 11 pipe}
\end{align*}
\]
Appendix B

<table>
<thead>
<tr>
<th>Part No.</th>
<th>Size (IPS)</th>
<th>SDR</th>
<th>Length</th>
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<td>11</td>
<td>100'</td>
</tr>
<tr>
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Check homeflexunderground.com for up-to-date product listings.

2.2 Fittings

Application Information
Gas compression fittings for use in Natural Gas and Liquefied Petroleum (LP) Gas applications with Polyethylene (PE) gas pipelines.

Technical Data

<table>
<thead>
<tr>
<th>Materials</th>
<th>Pressure Ratings</th>
<th>Temperature Ratings</th>
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<tbody>
<tr>
<td>Nut and Main Body: Polypropylene (PP)</td>
<td>125 PSIG</td>
<td>Operating Temperature Range: -20°F - 180°F</td>
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<tr>
<td>Spacer: Nylon</td>
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<td></td>
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<tr>
<td>O-Ring: Nitrile</td>
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<td></td>
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<tr>
<td>Grip Ring &amp; Stiffener: Acetal</td>
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Codes
NFPA 54/ANSI Z223.1
International Fuel Gas Code
Uniform Plumbing Code

Part Number Listing

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<tr>
<th>Part No.</th>
<th>Description</th>
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<tr>
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<tr>
<td>18-429-101</td>
<td>½” CTS x ½” IPS Coupling Fitting</td>
<td>9.3</td>
</tr>
<tr>
<td>18-429-007</td>
<td>¾” x ¾” Coupling Fitting</td>
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</tr>
<tr>
<td>18-429-010</td>
<td>1” x 1” Coupling Fitting</td>
<td>11</td>
</tr>
</tbody>
</table>