Technical Data Sheet
Industrial adhesives

PR-2930 armor adhesive

Description
PR-2930 armor adhesive is a one-component thermosetting toughened epoxy adhesive paste. PR-2930 is the first adhesive formulated to meet all requirements for a Group I adhesive according to MIL-STD-3059: Acceptance Criteria for Adhesives for High-Loading Rate Applications.

Product features
- Exceptionally high combination of shear strength and shear strain (i.e. toughness)
- Meets MIL-STD-3059 criteria for Group I adhesive (see Appendix I)
- High peel and impact strengths
- Broad range of service temperatures
- Little-to-no volatiles during cure
- Broad range of cure times and temperatures
- Pumpable rheology with sag and wash-off resistance
- Ambient storage stability

Uncured properties

Color	Black
Consistency	Paste
% Solids	100%
Chemistry	Epoxy
Weight	9.8 lbs/gal
Viscosity @ 23 °C (73 °F) (Spindle 7, speed 20 RPM)	1,000,000 to 1,200,000 cP
Viscosity @ 23 °C (73 °F) (Spindle 7, speed 1 RPM)	2,550,000 to 2,750,000 cP

Storage
Adhesive may be stored at room temperature for at least 6 months without reduction in properties. Avoid prolonged or repeated exposure to temperatures > 50 °C (122 °F). Adhesive may be frozen to further prolong shelf life, avoid multiple cycles of freezing and thawing.

Surface preparation
Optimal adhesive performance is obtained with a thoroughly cleaned metal surface. The metal surface can optionally be grit blasted prior to cleaning. One exemplary immersion cleaning technique for optimal adhesive bonding to aluminum is recommended below:

The following immersion cleaning process is recommended for 2024-T3 aluminum:
1. Rinse surface with acetone
2. Immerse in deionized water for 2 minutes
3. Immerse for 2 minutes in 49 °C (120 °F) bath of ChemKleen 490MX at a concentration of 1.0 oz/gal in deionized water
4. Immerse in deionized water for 2 minutes
5. Dry under hot air or in a 60 °C (140 ° F) oven for 10 minutes
6. Bond within 4 hours of drying

Standard surface preparation techniques using a degreasing process followed by an acid etch are also sufficient to provide optimum adhesive performance. Surface preparation with silane coupling agents is recommended to be performed in conjunction with physical roughening of the surface through methods such as grit blasting; one such exemplary method is outlined in ARL-ADHES-QA-001.01 Rev. 2.2.

PR-2930 is also formulated to maintain the majority of its performance properties on slightly oiled surfaces, such as those coated with machining oils. However, excessive oil or other contamination is detrimental to adhesive performance and the above surface cleaning techniques are recommended when possible.

Adhesive application
Apply a layer of adhesive to one of the substrates to be bonded. Bond substrates and secure overlap area with clamps or clips during cure. The adhesive contains glass beads to maintain a bondline thickness of approximately 0.25 mm.

Prior to cure, it is important to clean any excess adhesive outside of the bonded area. Excess adhesive in the fillet region should either be completely removed or, more preferably, removed in a manner that leaves a small 45° adhesive fillet (Figure 1). Adhesive remaining in greater excess than a small fillet outside the bondline may reduce performance.

Figure 1. Side view of lap joint configuration with excess adhesive outside of overlap area cleaned as a 45° adhesive fillet.

***Note:** Clean any large volumes of PR-2930 outside of bonded areas prior to curing. Adhesive remaining at thicknesses greater than 5mm may cause excessive exotherm during cure, resulting in material degradation.

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Adhesive cure requirements

To cure, PR-2930 must be heated between 150 and 240 °C (240 and 464 °F) (Figure 2). Optimum cure is achieved between 160 and 180 °C (320 and 356 °F) in 10 to 30 minutes. It is recommended to use a thermocouple to monitor the temperature profile within each unique bond configuration to ensure that these minimum time and temperature requirements are achieved. Excessive time at temperatures >205 °C (401 °F) during cure should be avoided.

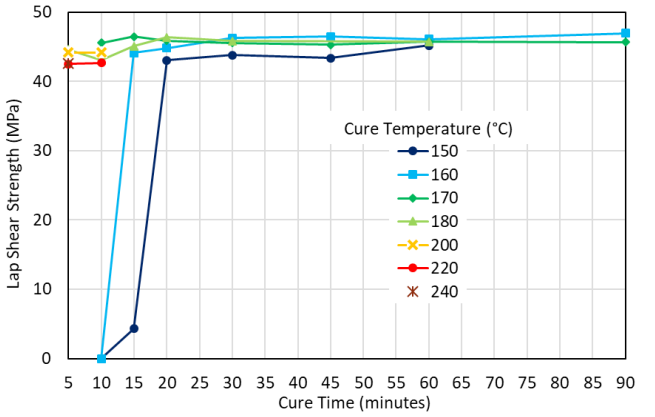


Figure 2. Range of cure times and temperatures that can be used to achieve optimum adhesive lap shear performance. All data collected using single lap joints prepared in the manner described below. Cure times and temperatures are that of the oven rather than that measured within the adhesive bondline.

Lap shear performance

Lap joint specimens were prepared on 1.6 mm thick 2024-T3 aluminum in accordance with ASTM D1002-10. Prior to bonding, the aluminum substrate was immersion cleaned with ChemKleen 490MX, as specified above, or grit blasted and treated with an epoxy silane solution, as specified in ARL-ADHES-QA-001.01 Rev. 2.2. Lap joints were cured at 170 °C (338 °F) for 20 minutes. The lap shear performance is detailed in the table below.

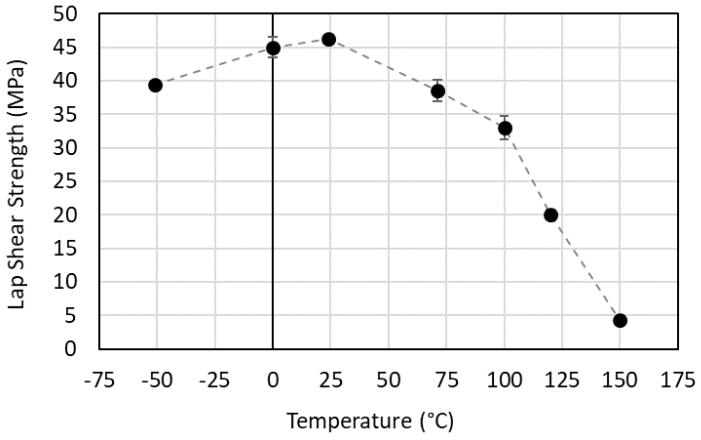
Lap joint specimens prepared in the same manner were also tested at elevated temperatures and after exposure to hot/wet environments (Table 1). These tests were performed in accordance with the Tier II testing dictated by MIL-STD-3059.

Table 1. Lap shear strength and displacement on 1.6 mm thick 2024-T3 aluminum. Adhesive performance was also tested at elevated temperatures and after hot/wet conditioning, in accordance with Tier I and Tier II testing of MIL-STD-3059.

Test temp.	Aluminum surface preparation	Environmental conditioning	Lap shear strength (MPa)	Displacement at failure (mm)
25 °C (77 °F)	Grit blast + epoxy silane	None	46.3 ± 0.6	6.2 ± 0.6
71 °C (160 ° F)	Grit blast + epoxy silane	None	38.6 ± 1.6	2.8 ± 0.4
25 °C (77 °F)	Grit blast + epoxy silane	60 °C (140 °F) hot room 14 days	46.9 ± 0.3	5.7 ± 0.1
25 °C (77 °F)	Grit blast + epoxy silane	63 °C (145 °F) water soak 14 days	38.4 ± 0.7	2.3 ± 0.1
25 °C (77 °F)	ChemKleen 490MX	None	44.3 ± 1.4	5.4 ± 0.9
71 °C (160 °F)	ChemKleen 490MX	None	38.2 ± 0.9	3.0 ± 0.2
25 °C (77 °F)	ChemKleen 490MX	60 °C (140 °F) hot room 14 days	44.6 ± 0.6	5.0 ± 0.4
25 °C (77 °F)	ChemKleen 490MX	63 °C (145 °F) after soak 14 days	25.9 ± 1.6	1.7 ± 0.2

The lap shear performance of PR-2930 over a broad temperature range is reported in Figure 3. Lap joint specimens were prepared in the same manner as above on 1.6 mm thick 2024-T3 aluminum. Prior to bonding, the aluminum substrate was grit blasted and treated with epoxy silane solution, as specified in ARL-ADHES-QA-001.01 Rev. 2.2. Lap joints were cured at 177 °C (351 °F) for 30 minutes. All lap joints were equilibrated at the specified test temperature for at least 30 minutes prior to testing.

Figure 3. Lap shear strength of PR-2930 tested at temperatures ranging from -50 to +150 °C (-58 to +302 °F).



Bulk shear properties

The bulk shear stress and shear strain of PR-2930 were measured using the Thick Adherend Shear Test, in accordance with ISO 11003-2. Stepped adherends were machined from 2024-T3 aluminum. Prior to bonding, the bond area was grit blasted with 54 grit aluminum oxide, rinsed with acetone, and treated with a solution of 3-glycidyloxypropyltrimethoxysilane (GPS) in ethanol as specified by ARL-ADHES-QA-001.01 Rev. 2.2. The overlap length (5 mm) and the bondline thickness (0.62 mm) were controlled by curing within a tooling fixture. To cure, the fixture was placed in a 190 °C (374 °F) oven for 75 minutes, at which point the oven heat was switched off and the fixture was allowed to cool within the oven. This resulted in PR-2930 being between 160 and 180 °C (320 and 356 °F) (the optimum cure temperature range) for a total of 40 minutes as measured by thermocouple.

Specimens were fitted with a D5656 averaging extensometer from Epsilon Technology Corporation and a pull rate of 0.5 mm/min was used. Intron and extensometer measurements were used to calculate the bulk material properties reported in Table 2.

Table 2. Bulk Shear Properties of PR-2930 Independent of Substrate Effects.

Bulk material property	Result
Maximum shear stress	56 ± 7 MPa
Maximum shear strain	62 ± 11 %
Strain energy density	27 ± 4 MPa

Crack propagation

Crack propagation specimens were prepared on 6022-T4 aluminum (3.175 mm thick), in accordance with ASTM D3762. Stainless-steel wedges (1" × 1", 0.25" tip) were manually driven into specimens. After 24 hours the initial crack position was recorded and specimens were placed into the conditions specified in Table 3.

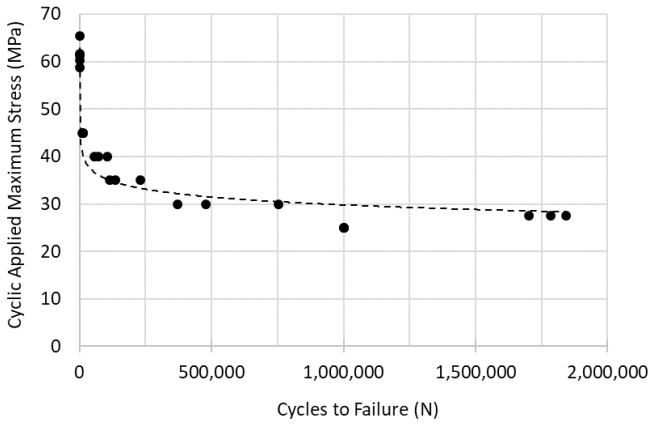
Table 3. Crack propagation under different environmental conditioning.

Surface preparation	Adhesive cure conditions	Environmental conditioning	Conditioning period	Crack propagation
ChemKleen 490MX immersion	180 °C (356 °F) 30 min	60 °C (140 °F) 100% R.H.	5 weeks	0.54 mm

Fatigue performance

Fatigue test specimens were prepared in accordance with ASTM D3166-99(2012) on 2024-T3 aluminum (4.8 mm thick). Prior to bonding, the aluminum surface was prepared with a combination of grit blasting and epoxy-silane treatment, as specified in ARL-ADHES-QA-001.01 Rev. 2.2. The lap was 9.5 mm and specimens were cured in a 180 °C (356 °F) oven for 30 minutes. Fatigue loading was performed on 100kN fatigue frame under ambient temperature 23 - 25 °C (73 - 77 °F) and humidity (24-52% RH) at a load ratio of 0.1 and a frequency of 20 Hz.

Figure 4. Fatigue performance of PR-2930 on 4.8 mm thick 2024-T3 aluminum. All failures were cohesive within the adhesive.



Performance on oiled substrate

The shear, impact, and peel properties on aluminum oiled with DRYCOTE® 290 and steel oiled with FERROCOTE® 61AUS are presented in Table 4. Lap joints were prepared at a 13 mm overlap length on substrate measuring 25.4 mm × 101.6 mm × the thickness specified in the table. Lap joints were tested at a gauge length of 101.6 mm and a pull rate of 13 mm/min. Impact specimens were prepared and tested via the symmetric wedge test, in accordance with ISO 11343. Metal-to-metal peel specimens were prepared with a 76.2 mm overlap in accordance with ASTM D1876. Peel tests were performed at a pull rate of 127 mm/min.

Table 4. Shear, Impact, and Peel properties of PR-2930 on Oiled Aluminum (5754 alloy, 1.6 mm thick, coated with *DRYCOTE*) and Oiled Steel (Cold Rolled Steel, 0.8 mm thick, coated with FERROCOTE®).

Test	Substrate	Cure 160 °C (320 °F) 20 min	Cure 205 °C (401 °F) 40 min
Lap shear	Oiled 5754 Aluminum	22.6 ± 0.2 MPa	21.5 ± 0.3 MPa
	Oiled Cold Rolled Steel	48.0 ± 0.2 MPa	46.7 ± 0.5 MPa
Wedge impact at 25 °C (77 °F)	Oiled 5754 Aluminum	35 ± 1 N/mm	34 ± 1 N/mm
	Oiled Cold Rolled Steel	33 ± 2 N/mm	33 ± 2 N/mm
Wedge impact at -40 °C (-40 °F)	Oiled 5754 Aluminum	15 ± 5 N/mm	14 ± 1 N/mm
	Oiled Cold Rolled Steel	9 ± 2 N/mm	8 ± 2 N/mm
T-Peel	Oiled 5754 Aluminum	16 ± 1 N/mm	TBD

Appendix I. MIL-STD-3059 testing

PR-2930 test results for Tiers I through III of MIL-STD-3059. PR-2930 was tested against Tiers I through III of MIL-STD-3059. All aluminum substrates were cleaned using the immersion cleaning procedure described above with ChemKleen 490MX. All specimens were cured in a 180 °C (356 °F) oven. Bondline temperatures were monitored to ensure that 160 °C (320 °F) was achieved for at least 20 minutes. The results are outlined in **Table 5**.

Table 5.
PR-2930 test results for Tiers 1 through III of MIL-STD-3059

MIL-STD-3059	Specification (Requirement)	Status
Tier I	Lap shear strength (>10 MPa)	**44 MPa**
	Lap shear displacement (>3.81 mm)	**5.14 mm**
Tier II	Strength after two weeks hot water immersion @ 63 °C (145 °F) (maintain 75% initial strength)	**78% initial strength**
	Strength @ 71 °C (160 °F) (maintain 50% initial strength)	**82% initial strength**
Tier III	Crack propagation after 5 weeks under static stress at 60 °C (140 °F) / 100% relative humidity (no crack propagation)	**No crack propagation**

Health precautions

This product is safe to use and apply when recommended precautions are followed. Before using this product, read and understand the Safety Data Sheet (SDS), which provides information on health, physical and environmental hazards, handling precautions and first aid recommendations. An SDS is available on request. Avoid overexposure. Obtain medical care in case of extreme overexposure.

For industrial use only. Keep away from children.

For emergency medical information call

1-800-228-5635.

Additional information can be found at:

www.ppgaerospace.com

For sales and ordering information call

1-800-AEROMIX (237-6649).

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