American Polywater's
Technical Talk
A Publication for Engineers Involved in Cable Installations

Lab Report

Subject: PowerPatch® Sealant Tests

Background and Purpose:

The PowerPatch® Paste Sealant is a two-part, rapid-cure, resin system which makes permanent field repairs in transformers, terminations, PILC cable and other oil-filled electrical systems. For a durable repair, the cured sealant must maintain a high level of adhesion and structural integrity in typical end-use environments. The two-part PowerPatch® Putty is included in the PowerPatch® system to temporarily stop an oil leak. Then the paste sealant is applied over the putty, and the paste serves as the long-term functional sealant in the system. For this reason, performance testing is done on the cured paste.

The tests presented below evaluate key properties for the PowerPatch® Sealant including adhesion, environmental resistance, physical integrity, dielectric strength, and application qualities.

1.0 Adhesion Tests:

1.1 Spot Adhesion Under Various Aging Conditions (ASTM D 3808, Qualitative Determination of Adhesion of Adhesives to Substrates by Spot Adhesion)

This is a simple qualitative test to screen the adhesion of the sealant to specific substrates. The substrates are representative of electrical equipment that might be repaired. The PowerPatch® Paste Sealant is applied to the substrate after the surface has been properly abraded and cleaned. The paste is applied at a thickness of 0.5 inch and an approximate diameter of two inches. Adhesion levels over time are subjectively evaluated by chipping and prying methods.

Adhesion to the Stainless Steel, Aluminum, Copper, Lead, Ceramic and Galvanized Steel substrates was evaluated in ambient air and immersed in oil and water at 50^o C (122^o F).

Result:

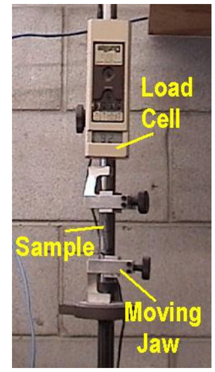
Materials	1 Week	1 Month
Ambient Control		
Stainless Steel	Excellent	Excellent
Aluminum	Excellent	Excellent
Copper	Excellent	Excellent
Lead	Excellent	Excellent
Ceramic	Excellent	Excellent
Galvanized Steel	Excellent	Excellent
Oil		
Stainless Steel	Excellent	Excellent
Aluminum	Excellent	Excellent
Copper	Excellent	Excellent
Lead	Excellent	Excellent
Galvanized Steel	Excellent	Excellent
Tap water		
Stainless Steel	Excellent	Excellent
Aluminum	Excellent	Excellent
Copper	Excellent	Excellent
Lead	Excellent	Excellent
Galvanized Steel	Excellent	Excellent

PowerPatch® shows excellent adhesion to these typical electrical substrates under difficult exposure conditions. The sealant could not be pried off with a screwdriver and had good strength and integrity.

1.2 180° Peel Test (Modification of ASTM C 794 Standard Test Method for Adhesion-in-Peel of Electrometric Joint Sealants)

In the 180° adhesion test, the peel strength and adhesion characteristics of PowerPatch® Sealant are measured. Peel strength indicates the difficulty of removing a patch, once the edge of the seal has released.

A one-inch by four-inch metal strip with a thickness of 0.063 inch is prepared. Oxides are removed from the strip by sanding with 80-grit Aluminum Oxide abrasive cloth. The strip is then cleaned with a TR-1™ Cleaning and Preparation Wipe. Masking tape is used to prevent adhesion and provide a gripping area over 1.5 inches of the strip. The PowerPatch® Sealant is applied to the strip and is reinforced by pressing in a one-inch by six-inch strip of 30-mesh 304 stainless steel woven cloth. The sealant is skimmed to a thickness of 0.125 inch, cured, and then aged according to the conditions listed below.



The strip is clamped into one end of a pulling device and the steel mesh is pulled in a 180° orientation to the substrate at a rate of two inches per minute. Pulling force readings are recorded every five seconds. The final pulling force is the <u>average</u> of all the readings. The results below are the average from two separate pulls. These values may vary with application technique and condition.

	Air Control Ambient Temperature		**Oil* Immersion 50° C**
	24 hours	**1 week**	**1 week**
	Results		
Materials	**lbs/inch (pli)**	**lbs/inch (pli)**	**lbs/inch (pli)**
Stainless	>100 Max	>100 Max	>100 Max
Aluminum	>100 Max	>100 Max	76
Copper	>100 Max	>100 Max	>100 Max
Lead	15.8	16.5	15.7
Galvanized Steel	>100 Max	>100 Max	>100 Max

* Oil used is Dussek PILC Dielectric Impregnating Oil (Polybutene).

1.3 90° Peel Test (Modification of ASTM C 794 Standard Test Method for Adhesion-in-Peel of Electrometric Joint Sealants)

The 90° peel test is similar to the 180° peel, but measures adhesion to substrates that are not stiff. Polyethylene and PVC cable jackets are removed from a power cable and nailed flat to a wood support surface. The plastic jacket is abraded with 80-grit aluminum oxide abrasive cloth and cleaned with a TR-1™ Cleaning and Preparation Wipe. Sealant is applied to the surface and reinforced with a one-inch by six-inch strip of 30-mesh 304 stainless steel woven cloth. The sides are carefully trimmed and the surface is skimmed to a depth of 0.125 inch. The

PowerPatch® Sealant is allowed to cure. The ceramic surface of an insulator was also prepared as described. Both air and oil immersion aging is done.

The substrate is secured and the cured sealant (steel mesh) is pulled away from the substrate at a 90° angle. The highest tension readings from three pulls are averaged and recorded. Results below are typical values and may vary with application technique and condition.

	Air Control, Ambient		**Oil* Immersion, 50° C**	
	72 hours	**1 week**	**72 hours**	**1 week**
Materials	**lbs/inch (pli)**	**lbs/inch (pli)**	**lbs/inch (pli)**	**lbs/inch (pli)**
Polyethylene	42.6	48.7	49.7	47.3
PVC	39.7	46.4	43.2	64.9
Ceramic	>100 Max	>100 Max	NA	NA

* Dussek PILC Dielectric Impregnating Fluid (POLYBUTENE)

When peel is possible, it is usually adhesive release at the substrate surface. Surface preparation is particularly critical for plastics like cable jacket. With good application technique, PowerPatch® Sealant has good adhesion to all materials tested. Oil immersion has a negligible effect on the peel adhesion of these surfaces.

1.4 Lap Shear Test (Modification of ASTM D 1002 Standard Test Method for Apparent Shear Strength of Single-Lap-Joint Adhesively Bonded Metal Specimens by Tension Loading)

The ASTM D 1002 test method usually measures the internal shear strength of adhesives. However, in the following modification, failure is typically adhesive release at the substrate rather than shear failure within the sealant. In other words, the shear strength of the PowerPatch® Sealant is typically greater than its adhesive strength.

A polyethylene (Union Carbide DFDC-5425) 0.125-inch thick platen sample is cut into one-inch by three-inch strips. Two strips are sanded with 80-grit abrasive and cleaned with the TR-1™ Cleaning and Preparation Wipe. The sealant is applied over ½-inch of the polyethylene strip to a thickness of ½-inch. The second strip is placed over the sealant and light pressure is applied. In other words, the two strips are glued together by a ½-inch by 1-inch area of sealant. The sample is cured and aged according to the listed condition. The pulling load when the two strips break apart is recorded. The results below are an average of three trials. Results may vary with application technique and condition.

Condition	**Result (lbs/inch)**
PowerPatch® Sealant, aged 24 hours	99.4
PowerPatch® Sealant, aged 1 week	114.3

This shear test is another way to evaluate adhesion to a polyethylene substrate. A platen of a known polyethylene formulation is used for consistency. The PowerPatch® Sealant shows consistently good adhesion to polyethylene.

2.0 Environmental Testing

2.1 Heat Freeze Cycle Testing

Performance of cured sealants can be affected by temperature extremes. It is important that the PowerPatch® seal adheres as the substrate expands and contracts with temperature extremes.

PowerPatch® is applied to a one-inch by four-inch sample as described in the 90° and 180° peel test methods. The samples are cured at room temperature for 7 days. The samples were then cycled from an air-circulating oven at 95° C to a freezer set at -30° C every two hours for 10 cycles. A 180° peel is performed.

Results:

Materials	Test Method	Result (lbs/inch)
Galvanized Steel	180° Peel	>100 Max
Aluminum	180° Peel	>100 Max
Ceramic	90° Peel	>100 Max
Copper	180° Peel	>100 Max
Stainless Steel	180° Peel	>100 Max
Lead	180° Peel	19.3

There are no signs of degradation of the PowerPatch® seals after 10 temperature cycles between 95° to -30° C.

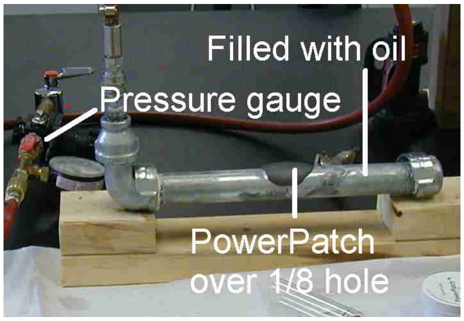
2.2 Weathering Testing

PowerPatch® was applied to lead, polyethylene and PVC jacketed cables using standard instructions. The surface was prepared by sanding and cleaning with TR cleaner wipes. PowerPatch® was cured for 1 hour, then placed on the roof of American Polywater's facility.

Temperatures ranged from -30° to 32° C. Conditions include rain, snow and sleet as well as exposure to sun and uv. After 5 years there has been no deterioration of PowerPatch® . It cannot be removed from the substrates by prying with a screwdriver. There is no visible sign of separation on any of the surfaces. The sealant has developed a slight green-grey discoloration on the surface (<1/16" thickness).

3.0 Physical Integrity Test

3.1 Oil pressure Test



The pressure test was developed to mimic actual field conditions. An oil-filled leak is repaired with oil actively seeping from leak and then tested under increased oil pressure.

A 1/8-inch hole is drilled into a 1-inch galvanized pipe. The pipe is then filled with oil (Dussek PILC Dielectric Impregnating Fluid (POLYBUTENE)). This creates a seeping leak. An approximate 1.5-inch circumference around the hole is prepared by abrading the surface with an 80-grit aluminum oxide abrasive cloth. The sanded area is then cleaned with a TR-1™ Cleaning and Preparation wipe and a temporary patch is immediately placed over the hole using a small amount of the PowerPatch® Putty (mixed). This putty patch is sized to cover about ½-inch around the drilled hole.

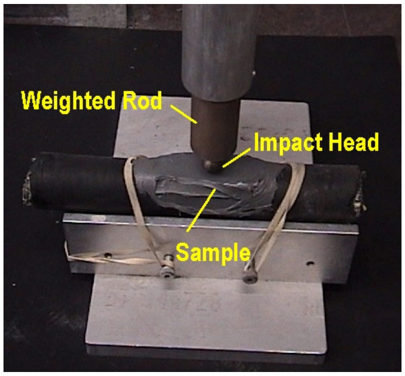
Once the putty has cured ands stopped the leak, a larger area over and around the putty patch is cleaned again with a TR-1™ wipe. The PowerPatch® Paste is mixed and applied over the PowerPatch® Putty extending onto the metal at least ½ inch beyond the cured putty. The paste is allowed to cure for 10 minutes and oil pressure is increased in the pipe. Oil pressure is set and held at 30 psi or 100 psi. The patch is checked for leaks using leak detection chalk.

Condition	Result after Aging	
Pressure (psi)	**1 week**	**1 month**
30	Good Seal	Good Seal
100	Good Seal	Good Seal

PowerPatch® has good adhesion after a short cure and can withstand oil pressures above those typical in most applications.

3.2 Impact Testing (Modification of ASTM G 14; Impact Resistance of Pipeline Coatings)

Impact testing is important for the PowerPatch® Sealant as an indicator of resistance to dropped tools and other unknown impacts.



In this test a 1/2-inch steel ball and rod with a weight of three pounds is dropped from varying heights to establish the impact resistance of the PowerPatch® seal. The test fixture is designed such that the steel ball and rod drops in a straight free fall through a drop tube. The PowerPatch® Sealant is applied according to instructions onto a cable. The patch is allowed to fully cure and harden for one week. The coated cable is clamped into an attached base that positions the cable exactly center to the falling weight. Impact resistance is determined as the amount of energy required to cause a crack in the sealant.

The calculation is as follows:

$$M = (h \times W)/ai$$

Where:

M	=	Impact strength [(g-cm)/mm^2 or (in-lbs)/in^2.]
h	=	Average height at which sealant failure occurs [in. or cm]
W	=	weight of steel ball and rod [lbs or g]
ai	=	area of impact, steel ball [in^2 or mm^2]

Results are an average of 20 trials. These results are typical values and may vary with application technique, condition, and age of seal.

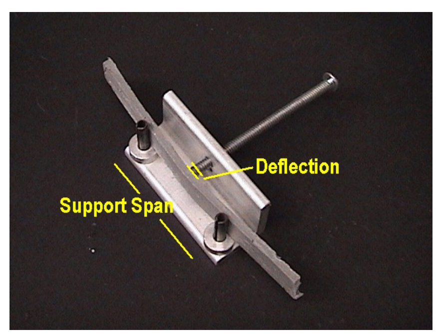
Materials Tested	Impact Strength (in-lbs/in^2)
PowerPatch® Sealant on 1¼-inch Lead Cable	817
PowerPatch® Sealant on 1½-inch Polyethylene Jacket	692
PowerPatch® Sealant on 1-inch Galvanized Pipe	1192

PowerPatch® Sealant has good ductility. In other words, it has both the flexibility and strength to withstand impact. It withstands impacts much greater than those typical of human foot traffic (35 in-lbs/in^2).

3.3 Flexural Strain Test (Modification of ASTM D 790 Flexural Properties of Unreinforced and Reinforced Plastics and Electrical Insulating Materials)

Flexibility of a sealant is an indication of how it will withstand vibrations and flexing abuse. The more flexible the sealant, the better able it is to withstand these vibrations and retain adhesion.

Two 5-inch X 1/2-inch X 1/8-inch platens are cured from the sealant. The platens are placed into a testing apparatus comprised of two fixed metal bolts with a 2-inch span and a moveable bolt in the middle. The middle bolt is turned at a constant clockwise pace until the sample has cracked or shattered. The length that the bolt has displaced is measured to determine the sample deflection. This number is then used in the following calculation to determine strain (flexibility) of the cured sealant.



Strain (flexibility), $r = 6dD/L^2$

Where:

D	= midspan deflection
r	= strain (inch/inch)
L	= support span (inches)
d	= depth of beam (inches)

Flexural Strain Test	Strain (r)
PowerPatch® Sealant, aged one week	39.1 X 10^{-3} in/in

A higher strain (r) before break indicates a higher flexibility. PowerPatch® shows fairly good flexibility. Such flexural strain can come from temperature expansion, bending, vibration, and other shocks to the cable surface.

4.0 Electrical Properties

4.1 Dielectric Strength Testing

The PowerPatch® Sealant was mixed at the proper ratio and 10 platen samples, 3" X 4" X ~0.09" were produced. Samples were sent to Doble Testing Company and dielectric strength was measured according to method ASTM D 149.

In this test, method A with 2000 Volts/Second rate of rise was used. Type 3 electrodes with a 0.25-inch diameter were used. Ten tests were performed in insulating oil to prevent discharges and flashovers.

Results are as follows:

Average Sample Thickness: 0.0916 inches

Average Breakdown Voltage: 43 kV

Dielectric Strength: 450 Volts/Mil

5.0 Application Properties

5.1 Oil Coat Test

PowerPatch® Sealant is intended to seal oil leaks. Such leaks leave oil contamination on the surface. This test measures adhesion to an oil-contaminated surface after cleaning with several different methods.

Copper, lead, and galvanized steel samples are soaked in oil (Dussek PILC Dielectric Impregnating Fluid (POLYBUTENE)) for 72 hours. The samples are removed and cleaned with one of the following; Type TR™ cleaner, Type HP™ cleaner, or a dry towel (polyester and cellulose blend). The PowerPatch® Sealant is then applied to the prepared surface. 72-hour adhesion values are obtained with a peel test.

		Dry Towel	TR™ Cleaner	HP™ Cleaner
Materials	**Test Method**	**lbs/inch**	**lbs/inch**	**lbs/inch**
Copper	180° Peel	>100 Max	>100 Max	>100 Max
Lead	180° Peel	9.3	19.8	19.4
Galvanized Steel	180° Peel	>100 Max	>100 Max	>100 Max

Cleaning and preparation of the surface is very important to the adhesion of any product. Best adhesion is obtained with a well cleaned surface. PowerPatch® Sealant has excellent adhesion to surfaces cleaned with specially formulated Polywater solvents. Cleaning with a dry towel leaves contamination that interferes with good adhesion to the surface.

5.2 Paint Adherence Test ASTM D3359 test method B Cross-cut tape test.

ASTM D3359 test method B cross-cut tape test was used to test paint adhesion to a cured PowerPatch® seal. A three-by-four-inch platen is prepared by mixing the PowerPatch® Sealant, applying it into a mold and curing for 15 and 30 minutes. The platen is then removed and paint is applied. In this test, G13606 Munsell Green Topcoat enamel paint from PPG Industries, Inc. and One-Blend™ Water-Reducible Alkyd Blend spray paint from Omni Pak (Sherwin Williams) were used. The painted surface is allowed to dry (cure) for 24 hours and the cross-cut tape test is run. The painted surface is hatched with 11 parallel razor cuts set at 1.5 mm distance. The cuts are ¾-inch in length and two sets of cuts are made in a perpendicular manner. A pressure sensitive tape is placed over the grid and smoothed into place with a finger. The tape is removed at a 90° angle within one to two minutes. Percentage of paint removed is reported.

PowerPatch® Cure time	Topcoat Results
15 minutes	0% Paint Removed
30 minutes	0% Paint Removed
	One-Blend™ Results
15 minutes	0% Paint Removed
30 minutes	0% Paint Removed

Paint has excellent adhesion to PowerPatch® Sealant and may be applied within 15 minutes of application.

5.3 Vertical Sag Test

The PowerPatch® Paste must be able to cling to vertical surfaces and other difficult angles, common in field repairs. As it cures, the paste must remain as it is applied: centered over the leak and at the proper thickness.

In this test, the PowerPatch® Paste is mixed and spread into a 3-inch by 1.75-inch by 0.25-inch platen form in a controlled temperature environment. One minute or two and a half minutes after starting the mixing of the paste, the platen is turned on end (at a 90° angle). Cure time is measured as the time at which the PowerPatch® Sealant becomes hard to the touch and cannot be indented with light finger pressure. The center of mass is determined by finding the balance point. The distance between the center of the platen and the center of mass is measured to determine the sag or flow of the paste as it cured.

Time platen is placed at 90° angle	Cure Time	Temperature	Displacement from center
2.5 minutes	10 minutes	60° F	0 inches
2.5 minutes	6 minutes	75° F	1/16 inch
1 minute	3 minutes	95° F	3/32 inch
1 minute	2.5 minutes	110° F	3/16 inch

The uncured PowerPatch® Paste has good cling and low flow at all temperatures.

Summary:

Adequate surface preparation is critical for optimal adhesion and performance of the PowerPatch® Sealant. All laboratory testing is done with careful preparation techniques. These laboratory test results combined with numerous field seals on transformers, terminations, PILC cables and other oil-filled systems to indicate that the PowerPatch® Sealant product has adequate adhesion, physical integrity, and resistance to the end-use environment to make a long-lasting permanent seal. It is recommended that specific testing be done on special or non-standard substrates, or with any unique environmental exposure.

Topic Related Links

- PowerPatch® Flyer
- PowerPatch Technical Data Sheet
- Slide Show Featuring PowerPatch® Repair System
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