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BonDuit™ Conduit Adhesive

Bonds to Polyethylene, PVC, Steel, Fiberglass and Aluminum

LABORATORY REPORT

Date: January 15, 2004

Subject: BonDuit™ Conduit Adhesive Tests

Background and Purpose:

The BonDuit™ Conduit Adhesive is a two-part, rapid-cure, resin system designed to bond polyethylene or fiberglass conduit to PVC or metal connectors. For a durable long lasting, strong bond, the cured sealant must maintain a high level of adhesion and structural integrity in typical end-use environments over time.

The tests presented below evaluate key properties of BonDuit™ Conduit Adhesive including adhesion, environmental resistance, physical integrity, dielectric strength, and application qualities.

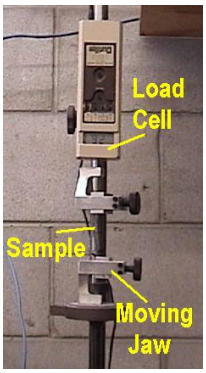
Test Section Description

1.0 Adhesion Tests:

1.1 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 measures the internal shear strength of adhesives. The shear strength adhesion characteristics of BonDuit™ Adhesion were measured on different substrates. Shear strength is the force needed to pull apart the bond of overlapping substrates. This can be compared to the tensile strength of a coupling. The adhesion force is dependent on total area of bond.

0.4-inch by 6-inch strips were obtained from the following materials: Blue Diamond schedule 40 polyethylene innerduct (1.25 inch), fiberglass conduit (2 inch), galvanized steel plate, aluminum plate and schedule 40 PVC connector (1 ¼-inch). All surfaces were sanded with 80 grit aluminum abrasive cloth and cleaned with a TR-1™ Cleaning Wipe to remove contaminates. A ¼-inch bead of BonDuit™ Conduit Adhesive was applied to the edge of the polyethylene or fiberglass strip. The second strip is slid over the bonding surface as if it were being placed into a connector. Any excess adhesive is trimmed from the edges of the bonded strips and the joint is aged according to the conditions listed below.



For the adhesive shear test, the strip is clamped into a pulling device and pulled apart at a rate of two inches per minute. Pulling force readings are the maximum force before breaking. The value shown is the average of three pulls. These values may vary with application technique, field conditions and the actual material.

	Aging Condition				
	Air Control Ambient Temperature				50° C Water Immersion
Materials	**1 hours**	**24 hours**	**1 week**	**1 month**	**1 week**
HDPE to PVC	242 lbs/in^2	277 lbs/in^2	276 lbs/in^2	343 lbs/in^2	312.6 lbs/in^2
HDPE to Steel	298 lbs/in^2	557 lbs/in^2	613 lbs/in^2	571 lbs/in^2	488 lbs/in^2
HDPE to Aluminum	254 lbs/in^2	332 lbs/in^2	391 lbs/in^2	395 lbs/in^2	441.6 lbs/in^2
HDPE to Fiberglass	181 lbs/in^2	189 lbs/in^2	239 lbs/in^2		
Fiberglass to Steel	294 lbs/in^2	528 lbs/in^2	600+ lbs/in^2		
Fiberglass to PVC	201 lbs/in^2	119 lbs/in^2	141 lbs/in^2		

Peak adhesion was reached after 7 days of cure. The PVC strip routinely broke during testing indicating that the bond was stronger than the PVC itself.

1.2 Pipe Adhesion Test

This test mimics the real world tensile strength of the connector and innerduct.

A 1 ¼-inch PVC connector (with 1-inch of insert) was bonded to a 1 ¼-inch HDPE innerduct. The interior bonding surface of the PVC connector and the exterior of the HDPE innerduct were sanded with 80-grit abrasive cloth and then cleaned with the TR™ Cleaning Wipe before bonding.

After the surface was prepared, the BonDuit™ Conduit Adhesive was applied as a ¼ inch bead line along the outside edge of the HDPE innerduct. The connector was twisted on, spreading a thin layer of adhesive throughout the connection. The BonDuit™ Conduit Adhesive is cured and aged according to the listed condition. The innerduct was attached to a stationary fitting and the connector was attached to a load cell with winch attachment. The maximum pulling force was recorded. The results below are an average of three trials.

	24 hours		7 days	
Material	**Total Lbs**	**Lbs per Inch^2**	**Total Lbs**	**Lbs per Inch^2**
PVC/HDPE	801	204	1000+ *	255

* The load cell used in this testing is limited to 1,000 lbs.

Results may vary with application technique and condition. The results from this test are comparable to the lap shear testing reported in Section 1.1. The BonDuit™ Conduit Adhesive shows consistently good adhesion to polyethylene and PVC.

2.0 Environmental Testing

2.1 Heat Freeze Cycling Testing

The cured BonDuit™ Conduit Adhesive bond should withstand temperature extremes. Temperature cycling measures adhesion under this type of environmental condition. This is a measurement of the substrate adhesion during the expansion and contraction of materials under different temperature extremes.

BonDuit™ Conduit Adhesive is applied to a 0.4-inch by 6-inch polyethylene strip and a 0.4-inch by 1.25-inch insert PVC connector. The bond was prepared as described in the lap shear test method. The samples were cured at room temperature for 1 hour. The samples were aged in an air circulating oven at 50° C and a freezer set at -15° C for a minimum of four hours. The samples were aged for 10 cycles over 1 month. The lap shear adhesion test was then performed.

Results:

Materials Bonded	Adhesion Strength
PVC to HDPE	295 lbs/inch^2

These results compare favorably to the lab shear adhesion results with ambient air and water immersion aging testing. There were no signs of degradation of the BonDuit™ Conduit Adhesive after 10 temperature cycles between 50^o to -15^o C.

2.2 Weathering Testing

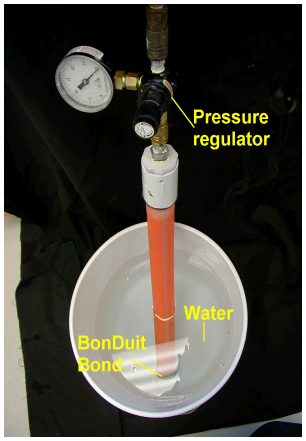
BonDuit™ Conduit Adhesive was applied to polyethylene and PVC connector using standard instructions. The surface was prepared by sanding and cleaning with TR™ Cleaner Wipes. BonDuit™ Conduit Adhesive was cured for 1 hour then placed on the roof of American Polywater.

Temperatures ranged from -10° to 80° F. Conditions include rain, snow and sleet as well as exposure to sun and UV. After 3 month there has been no deterioration of BonDuit™ Conduit Adhesive. The bond can not be broken by prying with a screwdriver. There is no visible sign of separation on any of the surfaces. BonDuit™ Conduit Adhesive has a slight green-grey discoloration on the surface (<1/32" thickness).

3.0 Physical Integrity Test

3.1 Air Pressure Test

The pressure test was developed to mimic actual field conditions to make sure water could not enter the conduit and that the bond was air tight. A PVC cap was attached to both ends 2 foot length of 1 ¼-inch HDPE conduit using standard instruction methods. The polyethylene conduit and PVC caps were sanded with the 80 grit sanding cloth and then cleaned with a TR™ Cleaner Wipe. A ¼ inch bead line of BonDuit™ Conduit Adhesive was placed on the end of the Polyethylene conduit. The PVC caps were then twisted onto the conduit. Two samples were prepared. In the first samples, the BonDuit™ Conduit Adhesive was cured for 1 hour and in the second samples, the BonDuit™ Conduit Adhesive was cured for 24 hours. The conduit was immersed into a 5 gallon pail filled with water and pressurized to 30 and 100 psi respectively.

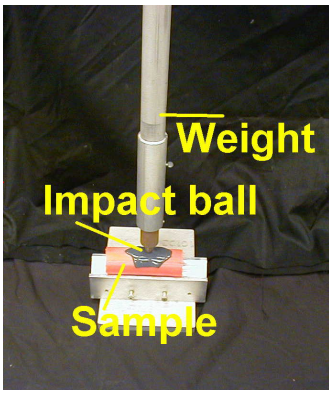


The caps were checked for leaks over time.

Condition	Result after Aging			
Pressure (psi)	**1 week**	**1 month**	**3 months**	**6 months**
30 - 1 hour cure	Pass	Pass	Pass	Pass
100 - 24 hour cure	Pass	Pass	Pass	Pass

BonDuit™ Conduit Adhesive has good adhesion after a short cure and is airtight up to 100 psi air pressure.

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



Impact testing is important for the BonDuit™ Conduit Adhesive as it indicates a resistance to dropped tools and other unknown, sharp impacts to the joint.

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 BonDuit™ Conduit seal. The test fixture is designed such that the steel ball and rod drops in a straight free fall through a drop tube. The BonDuit™ Conduit Adhesive is applied according to instructions and with proper surface preparation. The BonDuit™ Conduit Adhesive was applied to a 2 by 2 inch area approximately ⅛-inch thick. The patch is allowed to cure and harden for 1 week. The coated substrate is clamped into an attached base that positions the cured adhesive exactly center to the falling weight. Impact resistance is determined as the amount of energy required to cause a crack in the adhesive seal.

The calculation is as follows:

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

Where:

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

Results are an average of 3 trials. These results are typical values and may vary with application technique, condition, and age of adhesive seal.

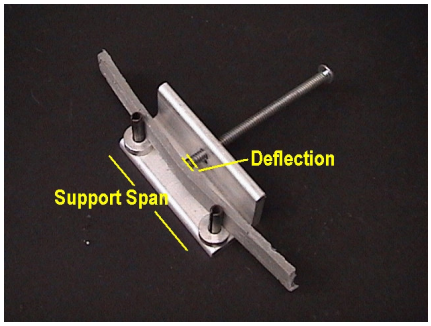
Materials Description	Impact Strength (in-lbs/in^2)
1 ¼ inch Polyethylene conduit	308
1 ¼ inch PVC connector	474
1 inch Steel conduit	282
2 inch Fiberglass conduit	474

BonDuit™ Conduit Adhesive 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 an adhesive is a good 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 made from each sealant. The platens are placed into a testing apparatus comprised of two fixed metal bolts with a 3-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 is inserted into the platen is measured to determine the 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)
BonDuit™ Conduit Adhesive, aged one week	2.34%

A higher strain (r) before breaking indicates a higher flexibility. BonDuit™ Conduit Adhesive has 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 BonDuit™ Conduit Adhesive was mixed at the proper ratio and 10 platen samples, 3”X4”X~.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 Surface Preparation Test

BonDuit™ Conduit Adhesive is intended to adhere to polyethylene innerduct and a PVC connector. The connectors and innerduct needs some preparation for the best bond. This test measures the adhesion of a PVC connector to polyethylene using several different methods to prepare the surfaces.

The BonDuit™ Conduit Adhesive is applied to the prepared surface according to the instructions with the following variations in preparation: a) the surface is not cleaned or modified in any way, b) the surface is sanded with 80 grit sanding cloth, c) the surface is not sanded but is cleaned with the TR Cleaner and d) the surface is both sanded with the 80 grit and fully cleaned with the TR Cleaner as recommended. The materials in this test were relatively new and do not contain a coating of dust or grime as may be found in true field conditions.

The bonded samples were allowed to cure for 7 days and then tested according to the lap shear test method found in section 1.1.

Material Description	Lap Shear Adhesive Strength, lbs/inch2			
	No Preparation	Sanding	TR™ Cleaner	Sanding & TR™ Cleaner
PVC to HDPE	56.6	235.2	77.2	275.8

Cleaning and preparing of the surface is key to the adhesion of the BonDuit product. Best adhesion is obtained with a well sanded and TR™ Cleaner Wipe surface. BonDuit™ Conduit Adhesive has excellent adhesion to surfaces cleaned with specially formulated Polywater solvents TR™. Proper abrasion is very important, but sanding alone may leave contamination that interferes with adhesion to the surface.

Summary:

Adequate surface preparation is critical to optimize adhesion and performance of the BonDuit™ Conduit Adhesive. All laboratory testing was done with proper preparation techniques. These laboratory test results combined with numerous field test adhering Polyethylene conduits to different connectors confirm that the BonDuit™ Conduit Adhesive product has adequate adhesion, physical integrity, and resistance to the natural environment to make a tough, long-lasting, water-tight conduit joint. It is recommended that specific testing be done on special or non-standard substrates, or with any unique environmental exposure.