WHITE PAPER
THE SIGNIFICANCE OF THE INTERTEK ETL SEMKO LABEL FOR THE CORROSION PERFORMANCE OF COATED RIGID METAL CONDUIT

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Robroy polyvinyl-chloride (PVC) externally coated rigid steel conduit has been successfully used to protect sensitive wire and cable systems in extremely corrosive environments for several decades. In 1987 Robroy Industries introduced an innovative product with an interior urethane coating to provide corrosion protection for the interior conduit surface. In 1989 the internal urethane coating was significantly improved with a re-formulated urethane.

Resulting from user concerns expressed about swelling and corrosion beneath the external PVC coatings, in 1993 Robroy initiated a development program to improve and confirm the external coating adhesion. This adhesion improvement program was completed in mid-1994. To confirm the improved performance of the external PVC coating, Professional Service Industries, Inc. (PSI) of Pittsburgh, PA, a recognized independent third party, was selected to witness and certify the test results. Certified hot water immersion and heat/humidity test results documenting the adhesion improvement were published and distributed in early 1995.

Since 1995 Robroy has continued to improve its coated conduit products and processes. In the interim Robroy has added the Perma-Cote and KorKap product lines to its coated conduit family. Robroy's innovations and developments were incorporated into the Perma-Cote and KorKap conduit products.

INTRODUCTION

In 2004 an independent third party, Intertek ETL SEMKO, was engaged to develop a Regulated and Quantitative Test protocol to confirm Adhesion Performance.

Coating adhesion is the key to exceptional corrosion resistance and coated conduit system performance. Once the external or internal coating bond is broken the moisture penetrates to the metal substrate and corrosion begins. For a time the corrosion remains hidden beneath the coating, but eventually a swelled area becomes visible. The rate of corrosion and the time until it is detected depend on the application environment. The situation is similar to the corrosion blisters that occur under painted surfaces such as an automobile finish.

To instill credibility and provide consistent test data, American Society for Testing and Materials (ASTM) Standards were selected. The adhesion performance test specification, PVC-001, utilized two accelerated test methods:

Immersion in Boiling Water according to the intent of ASTM D 870, Testing the Water Resistance of Coatings Using Water Immersion.

Exposure to heat and humidity according to the intent of ASTM D 1151, Test Method for Effect of Moisture and Temperature on Adhesive Bonds and ASTM D 4585, Testing Water Resistance of Coatings Using Controlled Condensation.

The adhesion was evaluated in accordance with the procedures outlined in Section 3.8, ADHESION, of NEMA Standards Publication No. RN 1, Polyvinyl-Chloride (PVC) Externally Galvanized Rigid Steel Conduit and Intermediate Metal Conduit. The testing began in December 2004 and ended in July 2005; specimens from four sources were tested.

The ASTM Standards do not specify quantitative performance or pass-fail criteria. Section 3.8 of NEMA RN 1 describes how to make the adhesion test; but has no associated performance requirement other than that the PVC tear before separation from the metal substrate. Performance requirements are not defined in existing standards even though the added cost of coated conduit for application in corrosive environments has been justified by widespread acceptance and application.

The lack of performance requirements for coated conduit has been recognized by Robroy and is gaining recognition by users. This fact is confirmed by recent discussions with consulting, specifying and maintenance engineers at paper plants, waste water treatment facilities, etc. Committees that develop conduit standards are also considering performance testing.

Heat and humidity testing were selected for several reasons:

a. Universally accepted in the coating industry as standard parameters to evaluate corrosion protection provided by a coating. Standard test procedures are documented and recognized.

b. Widely acknowledged as corrosion accelerating agents.

c. Typical conditions in coated conduit application environments.

d. Heat and humidity chambers are available as standard equipment for testing.

e. Provide a method, which combined with real time exposure, can be used to correlate laboratory and product life cycle in corrosive environments.

TEST REPORTS

Intertek ETL SEMKO presented the test results in the following reports (Copies of the respective reports are available by contacting the Robroy Conduit Division in Gilmer, Texas.):

Report Nos. 3069036-001 (January 26, 2005) & 3072346-001 (March 29, 2005) Exposure in Hot Water

These reports describe the results of the immersion in the hot ($95^0C \pm 5^0C = 203^0F \pm 9^0F$) water test as specified in the Robroy Test Specification "Environmental Exposure of PVC Coated Conduit Sections", 1st Edition, December 7, 2004. Intertek ETL SEMKO independently secured specimens from four suppliers for testing. Intertek ETL SEMKO received the specimens in good condition and the tests were conducted at the ETL facility in Cortland, New York.

The sample preparation, test schedule, test procedure and test results are provided in the respective report. Only summary test results are presented in the next section.

Report No. 3069034-001 (August 24, 2005) Exposure in Heat and Humidity

This test report describes the results of exposure in high temperature ($66^0C \pm 5^0C = 150^0F \pm 9^0F$) and 95% relative humidity as specified in the Robroy Test Specification "Environmental Exposure of PVC Coated Conduit Sections", 1st Edition, December 7, 2004. Intertek ETL SEMKO independently secured specimens from four suppliers for testing. Intertek ETL SEMKO received the specimens in good condition and the tests were conducted at their facility in Cortland, New York.

The sample preparation, test schedule, test procedure and test results are provided in the report. Only test results are presented in the next section of this white paper.

TEST RESULT PRESENTATION AND DISCUSSION

The PVC adhesion and corrosion protection afforded by the current Robroy coating process has significantly upgraded the performance as confirmed by the hot water and heat/humidity test results. Heat and humidity are recognized corrosion accelerators in corrosion engineering textbooks and published technical documents from organizations such as the National Association of Corrosion Engineers (NACE).

The data generated by these independent third party tests is the initial attempt to quantify the adhesion performance of coated conduit. In the past many tests have been cited and claims made about the adhesion on coated conduit. The claims are based on test results that include the measurement of coating thickness, coating checks on newly coated specimens, solvent resistance tests, etc. Assessing and comparing data from various tests is confusing, particularly when unique tests are cited.

The goal of these adhesion performance tests was to utilize performance tests that are:

1. Based on specifications defined by organizations such as ASTM so any third party can perform and consistently repeat the test.

2. Defined by conditions in the application environment such as heat and humidity that are recognized by corrosion experts as significant performance factors influencing coating adhesion.

3. Benchmarks to fairly and consistently compare quantitative performance and evaluate coating materials, methods and processes.

4. Extending the specifications to elevate performance rather than product characteristics in specifying coated conduit.

To meet these goals, promote the use of quantitative performance standards and provide a superior conduit system, Robroy is pleased to present this summary of the third party test results. Figure 1 provides a summary of the hot water test data.

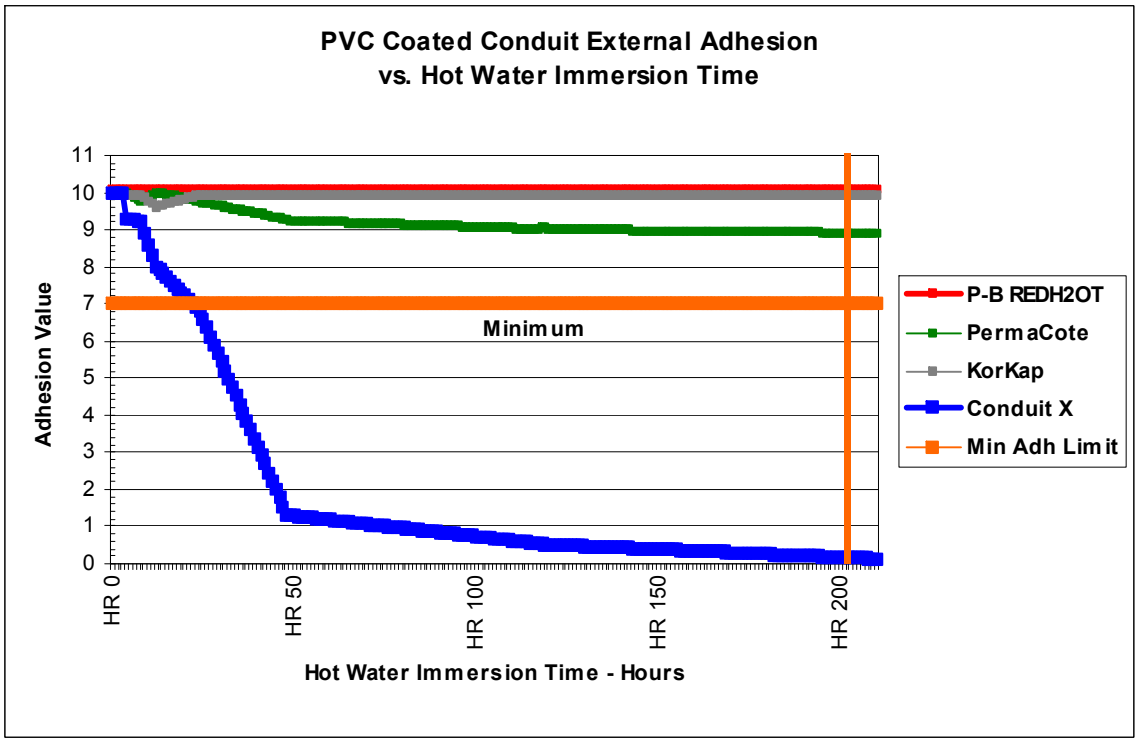

Figure 1. PVC Coating Hot Water Test Summary

To establish performance and safety margins for the coating technology, Robroy tested beyond the 200-hour Hot Water Immersion Time shown in Figure 1. Even after an extended exposure beyond 200 hours in boiling water, the Robroy PLASTI-BOND REDH$_2$OT, Perma-Cote and KorKap specimen adhesion still met the adhesion specifications. The tests were terminated by time constraints and economic considerations.

The Hot Water Immersion Test is used as an accelerated test to make a quantitative relative performance comparison of the coating material and application process. Few, if any, coated conduit systems are installed in boiling water; so it is necessary to make a quantitative comparison in conditions more like the application environment. Heat and humidity are conditions to which every coated conduit system is exposed; however, the deterioration of bonds at lower temperatures is a slower process compared to boiling water.

To evaluate coating adhesion in a more typical application environment, four sets of test specimens were exposed to 150^0 F and 95% relative humidity in a test cabinet for an extended time. These values were selected as the highest extremes of temperature and humidity that might occur in an outdoor application on a summer day in a tropical or semi-tropical area. Figure 2 provides a summary of the heat and humidity test data.

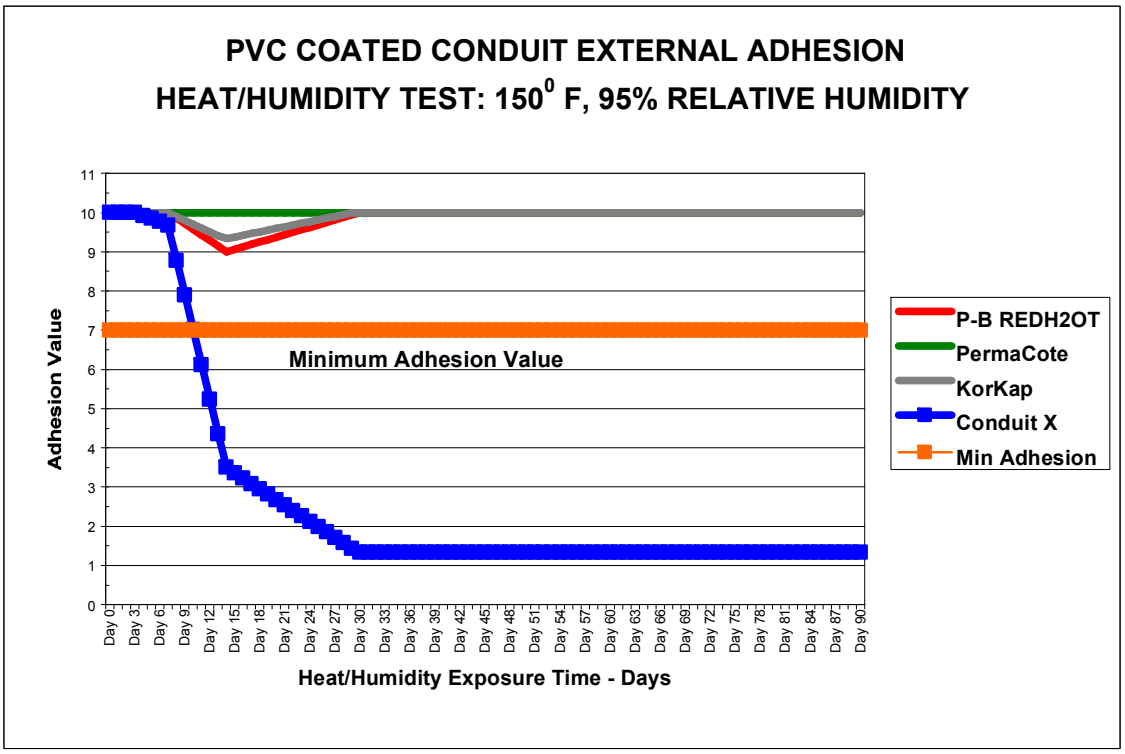

Figure 2. PVC Coating Heat/Humidity Test Summary

To establish performance and safety margins for the coating technology, Robroy tested beyond the 90-day Heat/Humidity Exposure Time shown in Figure 2. Even after an extended exposure in 150^0 F and 95% relative humidity, the PLASTI-BOND REDH$_2$OT, Perma-Cote and KorKap specimen adhesion still met the adhesion requirements. The tests were terminated by time constraints.

Figure 3 shows the conduit specimens as received and prepared for exposure in the Hot Water Immersion Test.

Figure 3. Conduit Specimens Prior to Exposure in the Hot Water Immersion Test.

Figure 4 shows the PVC adhesion test of a conduit test specimen according to procedures in Section 3.8 of NEMA RN 1. The cuts to make the adhesion test have already been completed and a PVC coating pull-tab has been created. The PVC coating is being pulled with pliers to determine if the coating will separate from the metal substrate or the PVC will break. Separation at the metal substrate is a failure.

The result of a successful PVC adhesion test appears at the end of the red arrow in **Figure 5**. The photograph in Figure 5 shows a Perma-Cote specimen being tested during the initial adhesion evaluation. The PVC coating appears in the cut area indicating that the PVC coating separated before the coating separated from the metal substrate.

Figure 6 shows a PVC coated conduit specimen where the coating adhesion has failed. This conduit sample was exposed for approximately two days in the Hot Water Immersion Test. Once the cuts are made, the PVC coating is easily removed by pulling the coating by hand. The PVC coating is torn to expose the galvanized steel conduit in the photograph.

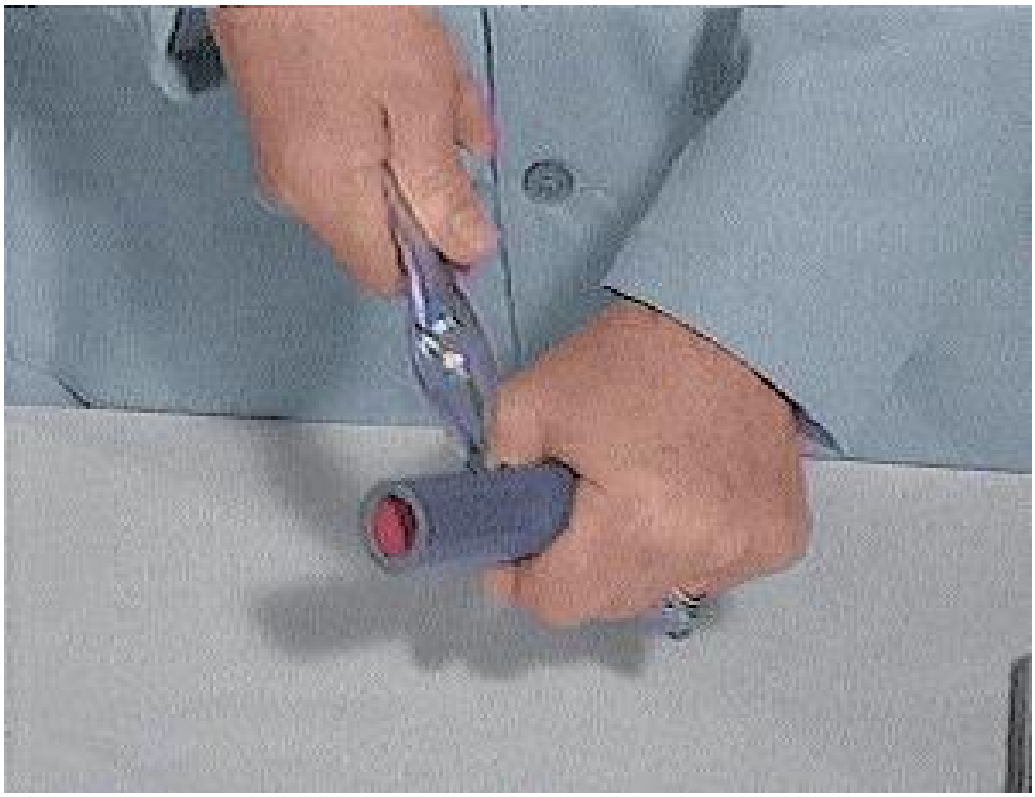

Figure 4. PVC Adhesion Test per NEMA RN 1, Section 3.8.

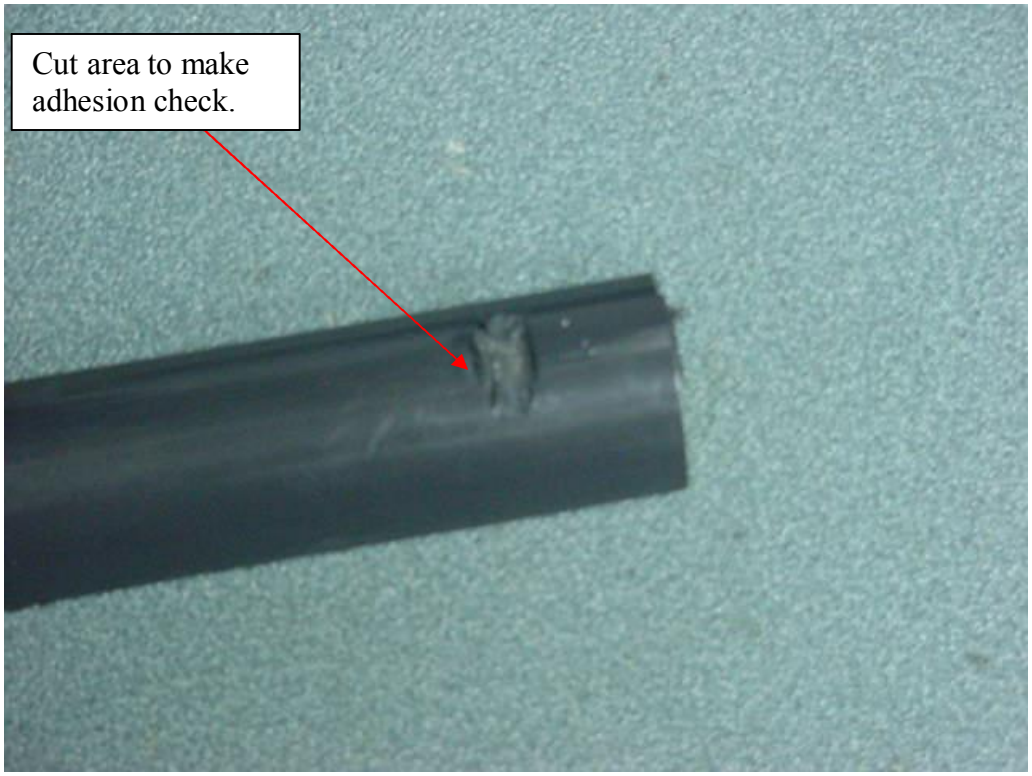

Figure 5. PVC Coated Conduit Specimen with Acceptable Adhesion.

Figure 6. PVC Coating Failure in Hot Water Immersion Test.

Fig 7. KorKap Conduit Specimen after 200+ Hours in the Hot Water Immersion Test.

Figure 7 provides a photograph of the KorKap conduit specimen after in excess of 200 hours exposure in the Hot Water Immersion Test. The cuts at the ends of the red arrows were completed to check PVC coating adhesion along the edge of the half section. This is a more severe test than specified in NEMA RN 1 because the cut edge of the test specimen is exposed in the hot water. Cuts along this edge directly expose the adhesive bond to the ingress of hot water that exacerbates adhesive bond failure. As shown in Figure 4, the tests specified in NEMA RN 1 are not performed on the edge of the test specimen that has been exposed to boiling water. The corrosive effects of the hot water are apparent from the "white" rust that appears on the galvanized conduit threads in the photograph.

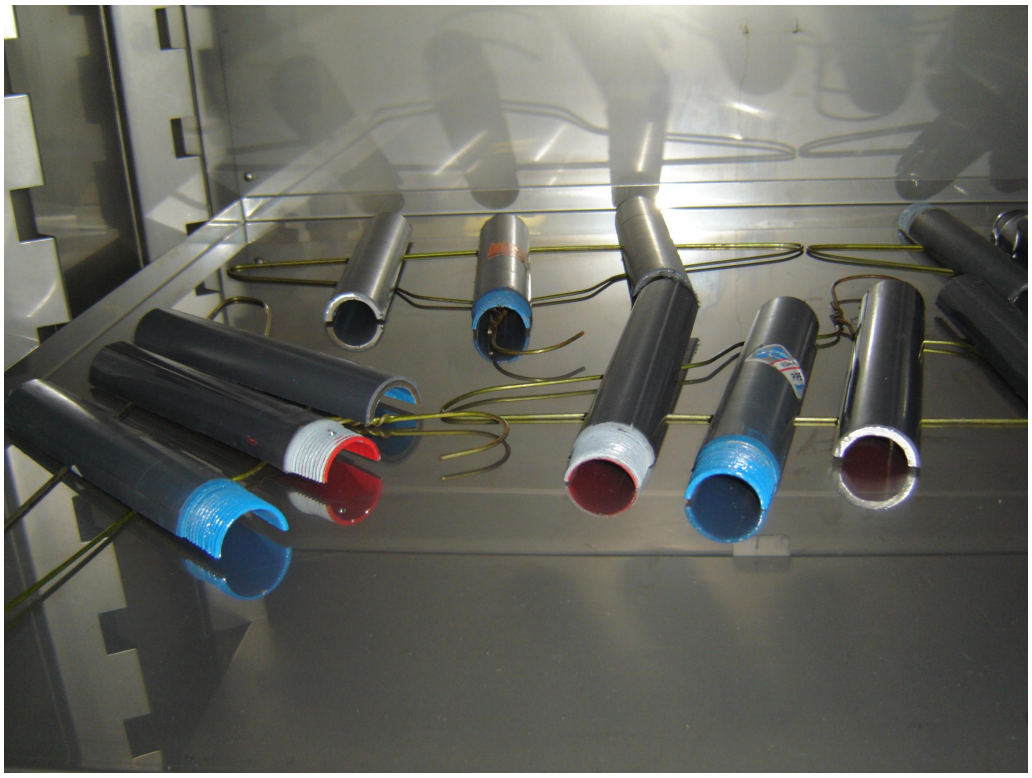

Figure 8. Conduit Specimens at the Beginning of the Heat/Humidity Exposure.

Figure 8 provides a photograph of the conduit test specimens at the beginning of the exposure to 150^0 F and 95% relative humidity.

Summary

The test results provided in this white paper provide a quantitative method to compare the relative performance of coated conduit systems in conditions typical of the corrosive application environment for coated conduit. The Hot Water Immersion Test can be used to evaluate the coated conduit adhesion quickly in ten days or less. The Heat and Humidity Test can be used to evaluate coated conduit adhesion in conditions more typical of the application environment, but it is a long-term test requiring several months. The results of both tests confirm significant differentiation in adhesion performance provided by the Robroy coating materials and processes.

It is one thing to successfully complete a one-time design test and confirm the adhesion of the PVC coatings; it is quite another to attain the consistency of process required to produce the same result on a continuing and consistent basis. As with any chemical process, control is extremely important to obtaining consistent coating adhesion. To insure the adhesion and confirm the process consistency, Robroy has retained Intertek ETL SEMKO to provide an ETL label and follow-up service. In June 2005, an Intertek ETL SEMKO representative completed an audit of the quality assurance procedures for the coating process and once each quarter the representative will randomly select specimens for exposure in a 200 hour Hot Water Immersion Test.

The Robroy Conduit Division welcomes input and comment from users and other interested parties regarding the desirability of performance testing and specifications, particularly with regard to incorporating such testing in coated conduit standards.

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