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RAPID REPAIR OF CB HARDENED SYSTEMS

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Final Report
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14. ABSTRACT
POLYMERight has developed and tested an adhesive system for field repair kits for collective protection shelters. This system can eliminate vulnerability of personnel created when CB protective shelters are breached. The adhesive chemistry utilized can quickly, easily and dependably bond the like and unlike substrates together, including Kevlar, polyfluorinated materials, polyolefins, PVC and other materials associated with collective protection systems. It was tested on various combinations of CB hardened surfaces, and provided consistent bonding strength of underlying substrates. Bonding strength was practically independent of outside temperature, humidity and other environmental conditions. The adhesive system comprises a primer for cyanoacrylate adhesives developed by POLYMERight and a commercial adhesive. The primer allows strong, practically instant bonding of all tested materials, including PTFE (Teflon®) and PVDF (polyvinylidene fluoride) with minimal surface preparation. It diminishes dependence of the bond of such adhesives on atmospheric moisture, improves bonding strength at below-freezing temperatures by 300%, increases stability of open-to-air primed surfaces and retention of the bonding strength in warm water. Additionally, POLYMERight has developed an easily implementable adhesive application technique that allows patching tents and other shelters without exposing personnel to hazardous conditions outside the shelter.

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PREFACE

Experimental work described in this report was conducted in the POLYMERight, Inc., facility in Fremont, California, as a Phase I feasibility study, "Rapid Repair of CB Hardened Systems."

It documents significant results and major accomplishments for work performed between October 2003 and March 2004. This project was funded by the DoD, through the Air Force CBD, under the Small Business Innovation Research program, Contract No. F08637-03-C-6019.

The authors acknowledge the valuable contributions of our Technical Point of Contact (TPOC), Lt. David McGraw at AFRL/MLQF, Tyndall AFB, FL.

A helpful and enlightening discussion with the Air Force personnel and contractors that occurred during the presentation of the results of this research at AFRL facilities at Tyndall AFB, Florida, in March, 2004, has provided us with helpful leads in identifying the means to continue this project towards successful commercialization. We are very grateful to Dr. Randall W. Brown, Dr. Joe Wander, George C. Laventure, Captain Jeffery R. Owens, and everybody else present at this meeting.

EXECUTIVE SUMMARY

A. OBJECTIVE

The main objection of this project is to develop repair kits that will allow field personnel to repair and patch breached CB shelters at forward deployment locations quickly, effectively and durably. In order to achieve this objection it was necessary to develop generic adhesion chemistry capable of dependently binding polymeric materials associated with CB hardened structures together, and to choose or create all the supporting devices, tools and dispensing equipment that will allow fool-proof implementation of this chemistry under field conditions by inexperienced personnel. The most difficult technical problem in this complicated task was to develop an adhesive system capable of binding polyfluorinated plastics that cover the surfaces of CB shelter materials. In the course of Phase I of the project the goal was to demonstrate soundness and proof of concept of adhesion chemistry. This goal was successfully met.

B. BACKGROUND

Current chemical and biological collective protection shelters are expensive and difficult to assemble, limiting the number of fielded CB collective protection systems at forward locations. Due to this limitation, the current state of affairs does not allow extra capacity for the field-deployed shelters. If the existing shelters are breached, either by accident or by design, they can't provide the required protection from CBW agents. As the number of shelters, and their capacity is limited, without the means to quickly and effectively repair the breached shelters, the risk and vulnerability of the forward field-deployed personnel is increased to the unacceptable levels.

Cyanoacrylate adhesives are the most universal one-part adhesives currently on the market. They cure very quickly on contact with mated surfaces through a reaction with surface moisture. The most widely known cyanoacrylates are "Super Glue" and "Crazy Glue". Cyanoacrylate adhesive formulations are based on cyanoacrylate esters, of which methyl and ethyl cyanoacrylates are the most common. The main limitation of cyanoacrylates is weak bond to low surface energy plastics, including polypropylene, polyethylene, polyvinylidene fluoride (PVDF) and polytetrafluoroethylene (PTFE, or TEFLON®), i.e. materials associated with CB shelter constructions.

However, a combination of POLYMERight's proprietary S-Primer with a properly chosen cyanoacrylate adhesive has demonstrated ability to meet the project targets.

C. SCOPE

This report summarizes the results of a six month Phase I SBIR project to develop generic adhesion chemistry that would allow rapid repair of CB-hardened systems.

D. METHODOLOGY

The PTFE-coated Kevlar fabric, which is used for the outer shell of collective CBD shelters, was supplied to POLYMERight by the TPOC. This material, as most difficult to bond, was used for screening of the adhesive systems. It was experimentally proven that if an adhesive system bonds it up to the limit of its cohesive strength, it can also be used to bond all other materials associated with the construction of collective CBD shelters.

The PTFE-coated fabric was cut in 1" wide strips. Primer was applied on the surface of two strips with a brush. It was allowed to flash off, and 1-3 drops of adhesive were put on one of the strips. Adhesive was spread across the surface that needed to be bonded by rubbing one strip of fabric against another. The bonded strips were under light pressure (1-3 psi) for 1-15 minutes.

Testing specimens were prepared according to ASTM D1002 and ASTM D5868 for overlap shear tests, and ASTM D1876 for T-peel tests. The bonding strength was evaluated according to these ASTM testing procedures on a Tensile Tester SSTM-5K with a 1000 lb load cell, manufactured by United Testing Systems, Inc.

E. TEST DESCRIPTION

Eight formulations of POLYMERight's S-Primer were prepared and tested in a combination with a wide array of cyanoacrylate adhesives for their ability to bond the CBD Shelter material provided by the US Air Force. These formulations varied by the concentrations and ratios of the two key components, and by the type of solvent (hexane vs. heptane). The range of primers was eventually narrowed to two formulations that have shown consistently higher lap shear bonding strength.

Simultaneously with the evaluation of primers, different classes of cyanoacrylate adhesives were evaluated for their ability to bond the CBD shelter material. It was discovered that the capacity of various adhesives to bond PTFE-covered Kevlar is significantly different. After an extensive testing and screening, the selection of the type of cyanoacrylate adhesive was narrowed to low viscosity ethyl cyanoacrylate-based formulations with low concentrations of polymethyl methacrylate. Several such adhesives have shown bonding strength sufficient to satisfy the requirements of this solicitation, but only one has shown absolutely consistent results.

After the adhesive system was chosen, the bonding of specimens was conducted under a wide range of environmental conditions, and the bonding strength was evaluated as the function of time after bonding, temperature and humidity.

F. RESULTS

The POLYMERight 9-5-4 S-primer in the combination with Apollo 2008 adhesive (produced by Cyberbond, LLC , allowed to consistently bond the CBD shelter material. Every single lap shear test, when the overlap of two pieces of material exceeded ½", resulted in the substrate failure.

The ultimate bonding strength (achieved 24 hours after bonding) was not dependent on the relative humidity or temperature at the time of bonding. These parameters varied between 15% and 95% relative humidity and 35°F and 85°F. The adhesive system develops green strength after 8-10 seconds.

G. CONCLUSIONS

The work conducted has proved beyond a reasonable doubt that the chosen adhesive system can satisfy all the requirements of the solicitation and serve as a basis for development of a shelter repair kit that could allow field personnel to repair and patch breached CB shelters at forward deployment locations quickly, effectively and durably.

A major cyanoacrylate producing and distributing company, Cyberbond LLC, located in Batavia, IL, is interested in this development, and can assure its commercial accessibility of this development to CBD and to wider military and civilian applications. A letter from Cyberbond to this effect is attached to the report in Addendum 1.

H. RECOMMENDATIONS

This development must be converted into a commercial patching/repair kit for CBD shelters that will serve the needs of the Air Force CBD and other military and civilian organizations interested in this development. It will be very useful to further test the bonded specimens of shelter materials and patched shelters under both laboratory and field conditions. They should pass through accelerated testing that mimics typical harsh environmental conditions encountered in the field. Producibility, cost effectiveness, field serviceability and ease of application of the repair kits should be demonstrated.

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Work Summary

For this project POLYMERight proposed to develop generic adhesion chemistry capable of binding a variety of synthetic polymer surfaces, including polyfluorinated synthetic materials, for use to repair and couple CB hardened surfaces and structures. The work on this project started with the adhesive system already developed by the company and modifying this system to allow it to satisfactorily meet all requirements of this solicitation.

The scientific merit and feasibility of such adhesive systems was clearly demonstrated during the implementation of Phase I of this proposal. This work resulted in the creation a primer/adhesive systems, that had clearly demonstrated the feasibility of producing field repair kits for repair of CB-hardened structures with distinct advantages over currently used state-of-the-art materials.

POLYMERight's goals for the Phase I of this project included:

- Creating an innovative adhesive system and treatment design for easily patching CB hardened plastics and fabrics, coated with polyfluorinated materials, and providing proof of concept for the chemistry involved.
- Testing the developed adhesive system for bonding CB hardened surfaces at a reasonable range of temperatures and humidities, to qualify the adhesive system for the Phase II testing.

1.2 Project Status

POLYMERight has met these goals by developing a technology that allows many commercial cyanoacrylate adhesives to bond multiple types of like and unlike synthetic substrates, including such low surface energy substrates as Teflon®, other polyfluorinated materials, polyolefins, Kevlar®, and other materials associated with collective protection systems.

This technology is realized by a POLYMERight's proprietary primer, which is applied to the surface of substrates prior to the adhesive, enabling cyanoacrylate adhesives to bond to such substrates. This primer/adhesive system provides an expedient repair mechanism to mitigate loss of integrity of collective protection against the action of CBW agents. The system is user friendly and easily applied under field conditions. It can be used across a wide range of temperatures and humidities, and binds PTFE-coated materials with sufficient durability and with strength equal to or greater than that holding the PTFE coating to the Kevlar® weave.

During Phase I of the project we have not only demonstrated soundness of treatment design and proof of concept of adhesion chemistry, as specified by the grant solicitation, but also developed concepts that allow easier implementation of repairs and minimize exposure of the sheltered personnel to the CBW agents in the course of repairs.

Therefore, POLYMERight has not only created, identified and demonstrated an adhesive system suitable for further development and refinement in Phase II, but also has conducted a significant amount of work beyond the tasks outlined in the Phase I Work Plan. All this work was done in the course of six months, instead of nine months allowed by the project. We hope that this approach will allow us to successfully fulfill the tasks outlined in Phase II of the project, and create repair kits for the CBD shelters in similar speedy and efficient manner.

2. BACKGROUND AND TECHNICAL APPROACH

Current chemical and biological collective protection shelters are expensive and difficult to assemble, limiting the number of fielded CB collective protection systems at forward locations. Due to this limitation, the current state of affairs does not allow extra capacity for the field-deployed shelters. If an existing shelter is breached, either by accident or by design, it can't providecompetent protection from CBW agents. As the number of shelters—and their capacity—is limited, lacking the means to quickly and effectively repair a breached shelter, the risk and vulnerability of the forward field-deployed personnel is unacceptably high.

Typical CB collective shelters are hermetically sealable tents made from extremely strong Kevlar® fabric covered on both sides with impermeable PTFE-based coating.

PTFE (polytetrafluoroethylene), due to its excellent impermeability, weatherability and moisture and chemical resistance, is an ideal material to cover chemical and biological shelters. However, PTFE has extremely low surface energy. The positive effect of this property is that it has the lowest coefficient of friction of all solid materials, and is very difficult to moisten (contact angle with water = 126°).

The negative effect of the same property is that other materials show little or no adhesion to PTFE. Therefore it is extremely difficult to adhesively bond PTFE to itself and to other materials[1]. To bond PTFE, it is typically necessary either to heat it to over 300°C, to treat its surface with plasma, or to etch it with extremely aggressive chemicals for prolonged periods of time. Needless to say, these joining methods cannot be effectively used under field conditions.

Shelters can be breached both accidentally and intentionally, *e.g.*, when piping or communication and electrical cables need to be brought inside the tent at a location that does not have a prepared hermetical connector. Naturally, for the tent to fulfill its function, it must be repaired and sealed.

The final objective of this project was to develop repair kits that will allow field personnel to quickly, effectively, and durably repair and patch breached CB shelters at forward deployment locations. Evidently, due to the inherent properties of the CB shelter materials, this called for the development of a new adhesive chemistry that would overcome the difficulties outlined above.

Since its formation in 1998, POLYMERight has worked extensively on the problem of bonding low-surface-energy materials. We have developed and successfully commercialized several adhesives with unique combinations of properties previously unachievable in one adhesive material. The most widely commercialized POLYMERight adhesive bonds various materials (including many plastics, PVC, metals, wood, concrete, etc.) under water, or at low ambient temperatures, and under other harsh environmental conditions. After curing, it provides a permanently flexible, chemically resistant, very strong and stable bond. When Pacer Technology, an adhesive marketing company, introduced this product under the brand name Anchor Tite® during the 2002 Annual Hardware Exhibition in Chicago, it was awarded the "Product of the Year" title by *Popular Mechanics* magazine.
Among the products developed by the company in this period, is a primer, which allows many conventional cyanoacrylate adhesives to strongly glue, without any surface preparation, such difficult-to-bond substrates as polyethylene, polypropylene, other plastics and various polyfluorinated materials associated with collective protection systems at a wide range of temperatures (including below 32°F) and humidities.

Cyanoacrylate adhesives are the most universal one-part adhesives currently on the market. They cure very quickly on contact with mated surfaces through a reaction with surface moisture. The most widely known cyanoacrylates are "Super Glue" and "Crazy Glue." Cyanoacrylate adhesive formulations are based on cyanoacrylate esters, of which methyl and ethyl cyanoacrylate are the commonest.

The bonding capability of cyanoacrylates is based on cyanoacrylic esters undergoing anionic polymerization in the presence of a weak base, such as water. These adhesives are stabilized through the addition of a weak acid. When the adhesive contacts a surface, the water present on the surface neutralizes the acidic stabilizer in the adhesive, resulting in the rapid polymerization of the cyanoacrylate and formation of a rigid and strong thermoplastic adhesive layer with excellent adhesion to many substrates.

Advantages of standard cyanoacrylate adhesives include

- Ability to bond many plastics and rubbers to themselves or to other substrates
- Rapid room-temperature cure
- One-part system
- Solvent free
- Excellent bond strength in shear mode
- Excellent adhesion to many substrates
- Long pot life
- Easy and fool-proof application technology
- Wide range of viscosities available

Limitations of cyanoacrylates include

- Weak bond to low-surface-energy plastics, including polypropylene, polyethylene, poly(vinylidene fluoride) (PVDF) and polytetrafluoroethylene (PTFE, or TEFLON®)
- Poor peel strength (T-peel: 3 lb/in—typical[2])

1 http://www.elring-kunststoff.de/Pages/e_werkst_elring_ptfe.html
2 http://www.specialchem4adhesives.com/resources/adhesionguide/index.aspx?id=adhesivechemistry

- Vulnerability to moisture
- Relatively weak initial grip. Cyanoacrylate adhesives with existing commercial primers reach only 30% of their full strength after 15 minutes, and full strength after 24 hours
- Poor impact resistance
- Low tack: to achieve sufficient bonding strength, cyanoacrylates require both substrates to be firmly pressed against one another for a time sufficient to develop some green strength
- Inability to bond materials at low temperatures
- Limited gap cure, bad sealant properties, requirement for precise mating of bonded surfaces
- Limited resistance to polar solvents
- Low temperature resistance (service temperature: -55°C to 79°C max)
- Bonds skin rapidly
- May stress crack some plastics

The existing commercial primers, such as Loctite 770 Prism®, Henkel's Sicomet® Power Primer, or Cyberbond's Apollo® Boost 6010, successfully overcome some of these limitations, but still cannot qualify cyanoacrylates to be used for the CB shelter repair applications. On the other hand, a combination of POLYMERight's S-Primer with a properly chosen cyanoacrylate adhesive showed great potential to fulfill the requirements outlined in the grant solicitation.

In the course of Phase I work, POLYMERight managed either to overcome many traditional weaknesses of cyanoacrylate adhesives, or to find a solution that would bypass these weaknesses, and permit using cyanoacrylate-based adhesive system in a CB shelter repair project without sacrificing integrity of the repairs.

3. TECHNICAL OBJECTIVES

3.1 Phase I Technical Objectives

The main objective of this project was to develop repair kits that will allow field personnel to repair and patch breached CB shelters at forward-deployed locations quickly, effectively and durably. To achieve this objection it was necessary to develop generic adhesion chemistry capable of dependently binding polymeric materials associated with CB-hardened structures together, and to choose or create all the supporting devices, tools and dispensing equipment that will allow fool-proof implementation of this chemistry by inexperienced personnel under field conditions. The most difficult technical problem in this complicated task is to develop an adhesive system capable of binding polyfluorinated plastics that cover the surfaces of CB shelter materials.

The adhesive system developed for this project must

- Be user friendly, *i.e.*, easily applied by inexperienced personnel in forward fielded locations,
- Be usable across a wide range of temperatures and humidities,
- Have equal or greater strength than the matrices to which it binds, and

• Have durability characteristics equivalent to those of the matrices it binds.

In the course of Phase I of the project the goal was to demonstrate soundness and proof of concept of adhesion chemistry. This goal was successfully met.

3.2 Future Objectives

If POLYMERight is granted funds for Phase II of the project, we plan to demonstrate strength and durability of treated bonded materials over time and to demonstrate ability to bond a variety of different matrices with minimal application and cure time. In conjunction with a major cyanoacrylate-producing and distributing company we also plan to assemble a CB shelter patching kit that will contain all the necessary chemicals and gadgets to allow quick and effective repair of breached CB shelters by inexperienced personnel under field conditions.

If POLYMERight identifies funds for Phase III of the project, we plan to demonstrate the ease of practical field application of the developed CB shelter repair kits, and to commercialize them, making them available for procurement by DoD. We will concurrently pursue other military and civilian applications that can utilize the same development. Examples of such applications are miniature kits to repair individual personnel protective gear and industrial operations in which quick and dependable joining of Teflon® and other PTFE-based materials is of interest.

4. EXPERIMENTAL RESULTS

The Phase I Plan prepared by POLYMERight in its grant proposal included the following tasks:

Task 1. Set up all testing equipment and obtain raw materials necessary for work—including swatch samples of the actual shelter materials—and write protocols for future tests.

Task 2. Screen combinations of the POLYMERight primer with ready commercial cyanoacrylate adhesive formulations recommended by different cyanoacrylate-producing companies to find the most promising adhesive systems to bond CB hardened materials. Test both lap shear and peel strength of bonding. Analyze the results and choose 3–4 candidate adhesive systems for further evaluation and possible improvement.

Task 3. Test the chosen adhesive systems for their bonding strength under a wide variety of application conditions, including temperatures between –5°C and +40°C and humidity between 10 and 100%. Analyze the results to discern trends in properties vs. composition, and choose the best adhesive system for further testing during Phase II.

Task 4. Summarize the development and preparing a report for the Chemical/Biological Defense program (through the Air Force)

The work performed, and its results are summarized below.

4.1 Preparation for Work

This portion of the project was implemented during October 2003. We contacted major producers and distributors of cyanoacrylate adhesives: Pacer Technologies, Henkel (Loctite), Cyberbond, and Master Bond. Emphasis was placed on obtaining samples of different classes of adhesives, to select down to the types of cyanoacrylates that work best with the PTFE-coated Kevlar material used for the CBD shelters (supplied to POLYMERight by the project TPOC, Lt. David McGraw).

4.2 Screening Primers and Adhesives

In November and December, 2003, eight formulations of POLYMERight's S-Primer (which has been proven to enable cyanoacrylate adhesives to bond Teflon®) were prepared and tested in a combination with a wide array of cyanoacrylate adhesives for their ability to bond the CBD shelter material provided by the US Air Force. These formulations varied by the concentrations and ratios of the two key components, and by the type of solvent (hexane vs. heptane).

After a significant amount of testing, the range of primers was narrowed to two heptane-based formulations, coded 9-5-3 and 9-5-4. These primers have shown consistently higher lap shear bonding strength than other materials.

Simultaneously with the evaluation of primers, we evaluated different classes of cyanoacrylate adhesives for their ability to bond the CBD shelter material.

We discovered that the capacity of various adhesives to bond PTFE-covered Kevlar is significantly different. For example, none of cyanoacrylate adhesives supplied by Pacer Technologies (Super Glue Company), which originally was counted on to be a manufacturer and distributor of the CBD Shelter Patching Kits, have demonstrated the ability to bond the CBD shelter material with sufficient strength. Similarly, none of the cyanoacrylate gels could bond this material in such a way that after the separation we could observe the failure of substrates.

The adhesives based on methyl cyanoacrylates were discarded as candidates due to their extremely sharp, pungent and unpleasant odor. The adhesives that contained more than 10% of poly(methyl methacrylate) did not show sufficient bonding strength.

After extensive testing and screening, we narrowed down our selection of the type of cyanoacrylate adhesive to low-viscosity ethyl cyanoacrylate-based formulations containing low concentrations of poly(methyl methacrylate). Several such adhesives have shown bonding strength sufficient to satisfy the requirements of this solicitation, but only one has shown absolutely consistent results.

The POLYMERight 9-5-4 S-primer in combination with Apollo 2008 adhesive (produced by Cyberbond, LLC[3], allowed us to consistently form bonds to the CBD shelter material. When the overlap of two pieces of material exceeded ½ inch, every single lap shear test resulted in the substrate failure.

The ultimate bonding strength (achieved 24 hours after bonding) was not dependent on the relative humidity or temperature at the time of bonding. These parameters varied between 15% and 95% relative humidity and 35°F and 85°F.

The adhesive system develops green strength after 8–10 seconds. Currently we are evaluating the rate at which green strength reaches the ultimate bonding strength.

Cohesive failure of the substrate when the PTFE coating is separated from the Kevlar weave coincides with the lap shear bonding strength. Typically, it occurs between 180 psi and 250 psi. However, if the testing strips were bonded with a very big (over 2-inch) overlap, the substrate fails under a load of 280–400 lbs.

Cyanoacrylate adhesives are notorious for low peel strength. In fact, T-peel strength of the CBD shelter material bonded with the chosen adhesive system typically falls between 3 and 6 lbs/inch, which is not very much (though still more that the typical peel strength of cyanoacrylates described in literature). A detailed evaluation of this problem and possible solutions are still ahead, but now we would like to recommend sealing the edges of the bonded material with an adhesive tape that would protect them from accidental rips. PTFE Film Tape 5490 made by 3M now seems to be the most appropriate shelf item for this purpose. This PTFE extruded film with silicone adhesive provides a chemically resistant surface, and seals and protects the bonded edge.

4.3 Evaluating the Properties of the Adhesive System

During January, February and March, 2004 we evaluated the properties of the CBD shelter material strips bonded by the combination of POLYMERight's 9-5-4 S-Primer and Cyberbond's Apollo 2008 adhesive.

In the course of this work the following characteristics of the adhesive system were determined:

1. The average bonding strength of the lap shear specimens left indoors did not change after 2 months (220±40 psi);
2. The average bonding strength of the lap shear specimens left outdoors in a sealed Ziplock bag did not change after 2 months (220±40 psi);
3. The average bonding strength of the lap shear specimens left outdoors open to environment, but with the edges sealed by PTFE tape did not change after 2 months (220±40 psi);

[3] Cyberbond (Batavia, IL) is a major producer and distributor of cyanoacrylate adhesives worldwide. They have expressed a great interest in this project, and support POLYMERight efforts to solve this difficult technical task. They are ready to work with POLYMERight on developing and producing CB shelters repair kits, and otherwise commercialize this development. Their letter to this effect is attached to the report.

4. The average bonding strength of the lap shear specimens left outdoors open to the environment, without sealing of the edges, diminished after 2 months by 15% (190±20 psi), but the tear still resulted in a cohesive failure of substrate—the PTFE coating separated from the Kevlar weave;
5. The bonding strength of lap shear specimens that were kept at 55°C (131°F) with unsealed edges began deteriorating after 1 month, but retained the cohesive mode of failure. the bonding strength reached the level of 75±20 psi after 2 months, and had deteriorated to such a degree that the failure mode changed to adhesive failure;
6. It must be noted that peel bonding strength of the specimens that were kept indoors, gradually increased over time, and two weeks after bonding reached 7.5–8 lbs/in. At these bonding strengths the failure mode of the specimens has changed from adhesive to cohesive.
7. The activity of primed substrates remained unchanged for at least 30 minutes, *i.e.*, there can be a reasonable interval between application of the primer and application of adhesive. This allows sufficient time to organize the patching/repair process.
8. We have also evaluated the rate of development of lap shear bonding strength immediately after bonding at different temperatures. The results of these tests are shown in the following table.

Time after bonding	Temperature	Lap shear strength, psi	Failure mode
1 min	25°C	81	Adhesive
2 min	25°C	119	Partial Cohesive
3 min	25°C	129	Partial Cohesive
4 min	25°C	124	Partial Cohesive
10 min	25°C	160	Cohesive
10 min	5°C	140	Cohesive
10 min	-10°C	106	Cohesive

4.4 Work Above and Beyond the Requirements of the Topic Solicitation

Another problem encountered and solved by POLYMERight does not lie among the specific tasks listed in the work plan prepared for the Phase I work. This problem involves the difficulty that can be presented by trying to seal a breached, loosely hanging fabric panel while the personnel who can do the work are on one side if it—for example, when all the personnel are inside the CBD shelter during an attack, and a wall of the tent is breached. In this situation it will be nearly impossible to tightly press the patch over the rip in the fabric of the tent to hermetically seal it.

We have developed a solution that can solve this problem in principle. This solution involves a magnetic putty created by POLYMERight, which can be spread through the rip onto the outside of the tent fabric along the edges of the rip. Then the patch with an adhesive can be applied to the rip from inside, and held in place by a flexible magnet placed atop of it, for a time sufficient for the glue to develop some green strength. A lot of optimization work remains to be done, but the solution was tested and it works.

5. RECOMMENDATIONS FOR PHASE II

If POLYMERight is awarded funds for Phase II of this program, we will optimize and test the adhesive systems under both laboratory and field conditions. The samples bonded at different conditions will pass through accelerated lab testing that mimics typical harsh environmental conditions encountered in the field. Additionally, POLYMERight will demonstrate field serviceability and ease of application of the repair kits, as well as their producibility and cost effectiveness.

A major cyanoacrylate-producing and -distributing company, Cyberbond LLC, located in Batavia, Illinois, is interested in this development, and can assure its commercial accessibility to the DoD and to wider military and civilian applications. A letter from Cyberbond to this effect is attached to the report in Addendum 1.

6. CONCLUSIONS

Summarizing the Phase I project, we can say that the work was conducted successfully according to plan, and has proved beyond a reasonable doubt that the chosen adhesive system can satisfy all the requirements of the solicitation. Now POLYMERight plans to present the work to the US Air Force, and to convert this feasibility development into a commercial patching/repair kit for PTFE-coated shelters that will serve the needs of the Air Force CBD and other military and civilian organizations interested in this development.

7. POTENTIAL POST APPLICATIONS

The potential other applications of this development in the CBD area are miniature kits that could repair breached individual personal protective gear. The development can be also useful in any industrial fields where quick and dependable joining of Teflon® and other PTFE-based materials is of interest.

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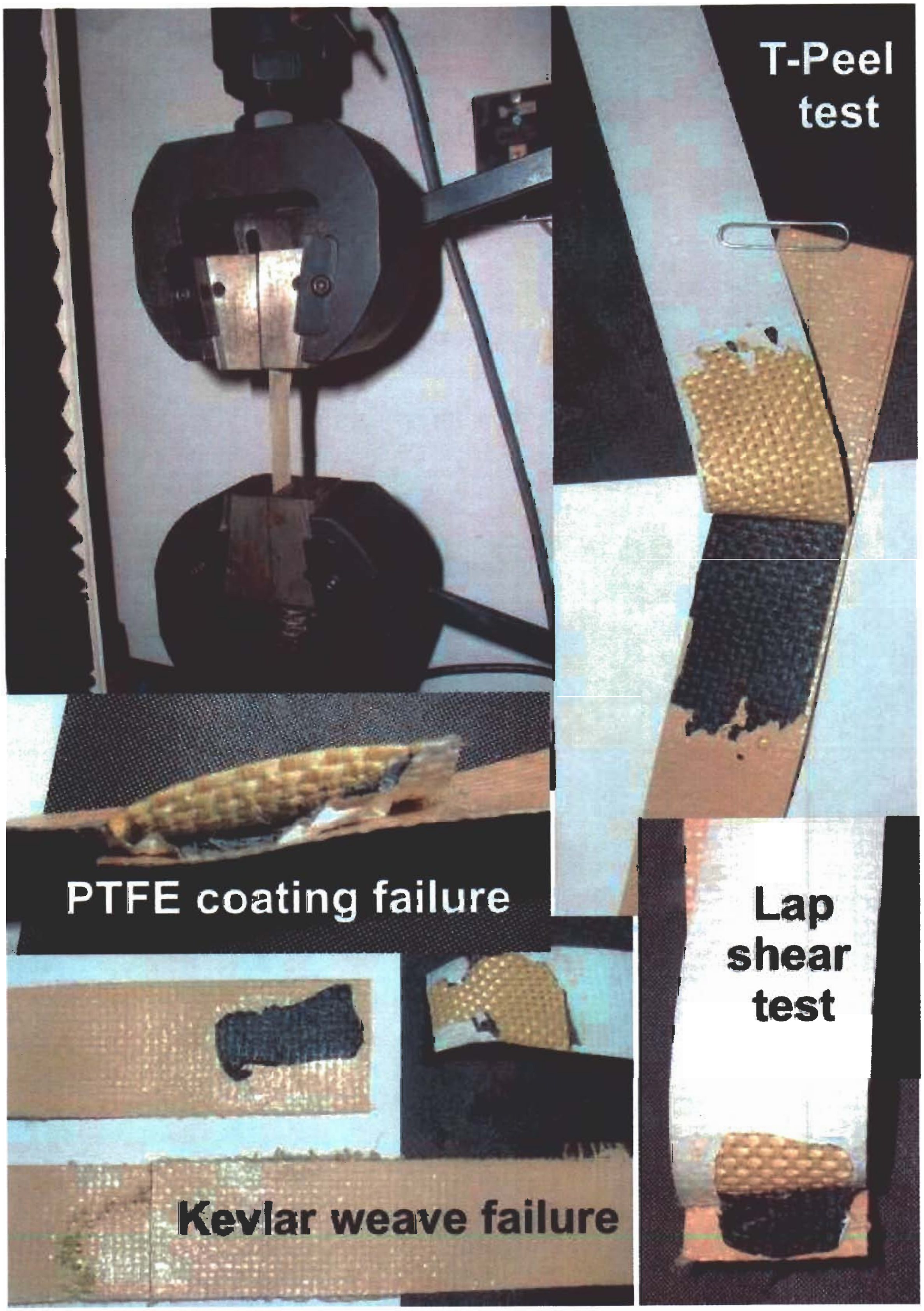
ASTM D1876-95, *Standard Test Method for Peel Resistance of Adhesives (T-Peel Test)*

ASTM D5868-95, *Standard Test Method for Lap Shear Adhesion for Fiber Reinforced Plastic (FRP) Bonding*

ADDENDUM 1

Photos of the Test Procedure and Results


T-Peel test
PTFE coating failure
Lap shear test
Kevlar weave failure

ADDENDUM 2

Letter from Cyberbond LLC

Cyberbond LLC
401 N. Raddant Rd. Batavia, IL 60510
Tel: 630-761-8900; Fax: 630-761-8989

January 16, 2003

Polymeright Inc.
4404 Enterprise Pl., Suite C
Fremont, CA 94538
Attn: Mr. Alex Vainer

Dear Alex,

I would like to confirm that with regard to adhesive needs, you have our full commitment and support in your efforts to develop and bring to commercialization a suitable shelter repair kit for the armed forces. As you know, we are experts in the development and manufacture of cyanoacrylate, acrylic and specialty urethane adhesives. With production and development facilities in Batavia IL and in Wunstorf Germany, we have both domestic and global reach, and have a solid history of providing the best technology available in this specialty adhesive niche marketplace.

Our Apollo 2008 is just such a product that was developed for rubber bonding and is now possibly the widest used CA type in automotive manufacturing today because of its quick grab and outstanding adhesive properties. We focus on making significant contributions in specialty areas like this all the time and are happy to develop specialty formulations for significant new uses such as yours.

You can trust us as a reliable working partner to count on for quality products (we are a QS-9000 certified manufacturer) and close product support as you move forward with your efforts.

Sincerely,

Larry Serkanic*
Vice President, Technology