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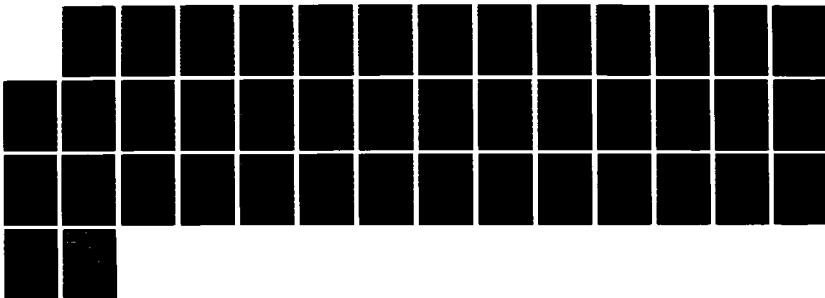
RESEARCHING URETHANE STRUCTURAL ADHESIVES(U) LITTLE
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DAAK70-83-D-0020

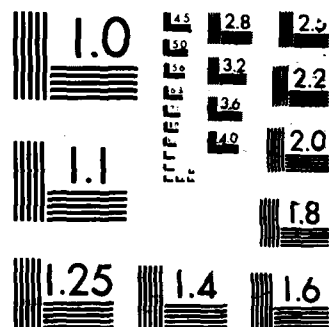
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Report to
U.S. Army Belvoir Research
Development and
Engineering Center
DAAK70-83-D-0020
Task Order 0015
November 1986

Researching Urethane
Structural Adhesives

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▲ Arthur D. Little, Inc.
Cambridge, MA 02140
Reference 56950

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FINAL TECHNICAL REPORT
PHASE I: RESEARCHING URETHANE STRUCTURAL ADHESIVES

Prepared for
U.S. Army Belvoir Research, Development
and Engineering Center
Fort Belvoir, Virginia 22060-5606
DAAK70-83-D0020, Task Order 0015

by

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56960-01
December 1986

Authorization for this research was contract No. DAAK70-83-D-0020, Task Order 0015, (Task order to a competitive contract awarded on a technical basis). The views, opinions, and/or findings contained in this report are those of the authors and should not be construed as an official Department of the Army position, policy or decision, unless so designated by other documentation.

Sponsor: A. Rabalais, Program Planning Division,
Directorate for Advanced Systems Concepts
Belvoir Research Development and Engineering
Center

Foreword

This work was performed under the sponsorship of the U.S. Army, Belvoir Research, Development and Engineering Center. The work was performed by Arthur D. Little, Inc., of Cambridge, Massachusetts, under Task Order 0015 of contract DAAK70-83-D-0020.

Peter W. Kopf was the principal investigator. The work was performed under the technical direction of Mr. Brian Hornbeck, Bridge Division, Directorate for Combat Engineering, Belvoir Research, Development and Engineering Center. The contracting officer's representative was Mr. A. Rabalais, Program Planning Division, Directorate for Advance Systems Concepts, Belvoir Research, Development and Engineering Center.



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An on-line search of business and technical literature data bases was conducted as well as manual searches of adhesive supplier references. A listing was made of manufacturers of urethane adhesives and technical data studied to ascertain typical characteristics. A comparison of mechanical and chemical properties was carried out to identify the six most promising candidates. Recommendations were made for the evaluation and testing procedures to be used to characterize the performance of these adhesives.			
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1.0 INTRODUCTION

1.1 Background

The U.S. Army requirements for bridging have become more rigorous in the past decade. The requirements have increased in load and span capability with the introduction of the M1 as the main battle tank. The bridges must remain transportable from site to site on tanks, trucks or trailers. The Army has gone to advanced materials for the construction of their bridges in order to meet these requirements. Epoxy-graphite fiber composites in combination with high strength aluminum are being developed as materials of construction for lightweight tactical bridging by the U.S. Army Belvoir Research, Development and Engineering Center. The construction and repair of these portable structures requires innovations in assembly technology since conventional riveting, bolting and welding are not as efficient as is required. The use of structural adhesives provides a bonding/fastening technology that can potentially meet the construction and repair requirements.

Several structural adhesives in the epoxy and acrylic chemical families have been evaluated for mobile bridge applications. Varying degrees of success have been obtained, but no adhesive system is totally satisfactory. An important class of structural adhesives, namely two-component urethanes, has not yet been investigated for its feasibility in this application. Urethanes are well established in application areas such as coatings and elastomers. They are now evolving into effective adhesive and sealant systems.

Urethanes are unique polymers with hard and soft segments synthesized into their molecular architecture. The mechanical properties of urethanes as a result can be varied over a much wider range than is possible with epoxy and acrylic systems. The viscoelastic nature of urethanes is an important attribute because it allows adhesive bonds to have better peel strength, impact resistance, and better adhesion to flexible substrates in comparison to epoxy and acrylic systems.

Therefore, a research program to evaluate two-component urethanes is recommended to determine their feasibility and usefulness as a structural adhesive. Since the bridges are fabricated from dissimilar materials, an adhesive with the properties of an urethane may be the solution.

1.2 Objectives

The objectives of this task order are to perform a technology assessment of urethane structural adhesives and as a result of this assessment determine which adhesives to select and acquire.

1.3 Tasks

Task I: Perform Technology Assessment and Interview with Suppliers

The first task is to perform a technology assessment for the application of urethane adhesives to similar situations. A discussion with suppliers of available urethane adhesives and urethane adhesives under development (C.1.a, b, c, d, e, f, g, h, j; C.2.a, b, c, d, e).

Task II: Selection/Acquisition of Adhesives

Systems selected will include the currently preferred epoxy adhesive as a control and up to six urethane adhesives. At least four of the urethane adhesives will be two-part ambient cure systems. A specific example of one of the urethane adhesives that will be included is product 6200 from Ashland which is currently used on glass/polyester composites in the automotive area (C.1.a, b, c, d, e, f, g, h, j; C.2.a, b, c, d, e).

Task III: Documentation

Document the results of each subtask along with supporting data and analysis in a final technical report (C.1.i).

1.4 SUMMARY

The objectives of this project were to perform a technology assessment of Urethane Structural Adhesives and as a result of this assessment determine which adhesives to select and acquire. The first task was to perform a technology assessment for the application of urethane adhesives to similar situations. This was accomplished principally through discussions with suppliers of available commercial urethane adhesives, developmental urethane adhesives, and adhesive raw materials. In addition, an extensive study of the technical and commercial literature on urethane structural adhesives was conducted.

Initially a list of 40 domestic suppliers of urethane adhesives and/or urethane resin components was developed. The companies have all been contacted and wherever possible extensive discussions with their adhesive specialists carried out. Of these companies, approximately fourteen companies were found to manufacture urethane structural adhesives with properties potentially suitable for the applications of interest. A close examination of technical literature available from seven of these companies has resulted in the identification of six specific adhesives from five companies. Additional technical information will be available shortly and will be examined for any additional adhesive candidate. These will be added to the list and reported.

With the most promising urethane structural adhesives identified, the next phase of the study may be initiated. In this phase the adhesives are evaluated for tensile strength and adhesive strength under a variety of environmental conditions using tests and procedures approved by the Belvoir Research and Development Center.

2.0 RESULTS

2.1 Technology Assessment

The first task in the program was to identify suppliers of urethane adhesives. This was done employing adhesive supplier directories as well as Arthur D. Little's knowledge of the adhesive industry. An initial list was generated of 40 companies which supply urethane adhesives or urethane resin components. These companies were contacted and wherever possible extensive discussions with adhesive technical service personnel carried out. The following is a list of the companies and a brief statement of the results.

COMPANIES CONTACTED

1. ARCO CHEMICAL CO.
Specialty Chemicals
Marshall Building
Westown Road at Westchester Pike
Westchester, PA 91382

No urethane adhesive product line. Makes only polyol and polyamine precursors. Suggested adhesive manufacturer.

2. ASHLAND CHEMICAL CO.
1745 Cottage Street
Ashland, OH 44805

Providing literature on their Pliogrip structural urethane adhesive systems.

3. B.F. GOODRICH CORP.
500 South Main Street
Akron, OH 44318

Providing literature on their one structural urethane adhesive (PL-550).

4. BOSTIK CO.
Boston Street
Middleton, MA 01949

Providing literature on their Supergrip 2000 urethane adhesive line.

5. CHEMICAL COMPONENTS, INC.
20 DeForest Avenue
East Hanover, NJ 07936

No urethane adhesive product line.

6. CHRYSLER, INC.
5437 West Jefferson
Trenton, MI 48413

No urethane adhesive product line.

7. PETER COOPER
7401-T Carmel Executive Park
Charlotte, NC 28226

Company was sold to Swift Adhesives.

8. AMERICAN CYANAMID CO.
One Cyanamid Plaza
Wayne, NJ 07470

Providing literature on their Cybond urethane adhesive line.

9. DEVCON CORP.
30 Endicott Street
Danvers, MA 01923

Providing literature on their Flexane urethane adhesive line.

10. DOW CHEMICAL CO.
1603 Building
Midland, MI 48674

No urethane adhesive product line. Supplies resin components.

11. EMERSON AND CUMING, DIV. W.R. GRACE, INC.
77 Dragon Court
Woburn, MA 01888

Providing literature on their Eccothane urethane adhesive line.

12. ESSEX CHEMICAL CO.
1401 Broad Street
Clifton, NJ 07015

Providing literature on their Betamate urethane adhesive line.

13. FIELCO CHEMICAL CORP.
1957 Pioneer Road
Huntington Valley, PA 19006

No urethane adhesive product line.

14. H.B. FULLER CORP.
40 Hayes Memorial Drive
Marlborough, MA 01752

Providing literature on their appropriate urethane adhesives.

15. FURANE CORP.

5121 San Fernando Road, West
Los Angeles, CA 90039

Providing literature on their #5767 and #5768 urethane adhesives.

16. GENERAL TIRE AND RUBBER CO.

One General Street
Akron, OH 44329

No urethane adhesive product line.

17. GOODYEAR TIRE AND RUBBER CO.

Industrial Products Division
215 First Avenue
Needham Heights, MA 02194

Their adhesives operation has been sold to Ashland.
Referred inquiry to Ashland Chemical Corp.

18. HENKEL CORP.

2010 East Hennepin Avenue
Minneapolis, MN 55413

No urethane adhesive product line. Supplies acrylic polyol resins.

19. HERNON MANUFACTURING, INC.

865 Essex Street
Brooklyn, NY 11208

No urethane adhesive product line.

20. HYSOL, DIV. OF THE DEXTER CORP.
2850 Willow Pass Road
Pittsburg, CA 94565

Providing literature on their one structural urethane adhesive (EA 9525).

21. LOCTITE CORP.
705 North Mountain Road
Newington, CT 06111

No urethane adhesive product line.

22. LORD CORP.
Industrial Adhesives Division
2000 West Grandview Boulevard
P.O. Box 10038
Erie, PA 16514

Providing literature on their Tyrite urethane adhesives line.

23. METHODS RESEARCH PRODUCTS, INC.
P.O. Box 1367
North Wales, PA 19454

No urethane adhesive product line.

24. MOBAY CORP.
Mobay Road
Pittsburgh, PA 15205

Component manufacturer for urethane adhesives only.
Recommended several urethane adhesives manufacturers.

25. MONSANTO CHEMICAL CORP.
703 Worcester Street
Springfield, MA 01151

No urethane adhesive product line.

26. MORTON-THIOKOL
1275 Lake Avenue
Woodstock, IL 60098

Providing literature on appropriate urethane adhesives.

27. POLYURETHANE CORPORATION OF AMERICA
P.O. Box 8
Everett, MA 02149

Providing literature on their appropriate urethane adhesives. Manufacturers of urethane adhesives to specifications.

28. K.J. QUINN CO.
195 Canal Street
Malden, MA 02148

Providing literature on their urethane adhesive line.

29. ROHM & HAAS CO.
399 Thornall Street
Edison, NJ 08837

No urethane adhesives product line.

30. RUCO POLYMER CORP., DIV. OCCIDENTAL PETROLEUM
New South Road
Hicksville, NY 11802

Providing literature on their urethane adhesive line.

31. JOHN SHELLEY CO. (Distributor)
16 Mica Lane
Wellesley Hills, MA 02181

Providing literature on 3M structural urethane adhesives. Refer to 3M.

32. SWIFT ADHESIVE CO.
9724 Industrial Drive
Pineville, NC 28134

Providing literature on their urethane adhesives line.

33. SYNTHETIC SURFACES, INC.
P.O. Box 241
South Plains, NJ 07076

Providing literature on their urethane adhesives line.

34. TEXACO CHEMICAL CO.
4800 Fournace Place
Bellaire, TX 77401

No urethane adhesive product line. Supplies polyol and polyamine intermediate.

35. 3M
Adhesives, Coatings and Sealers Division
3M Center
St. Paul, MN 55144

Providing literature on three structural urethane adhesives (3532, 3535, 3549).

36. TRA-CON ADHESIVES CO.
55 North Street
Medford, MA 02155

No urethane adhesive product line.

37. UNION CARBIDE CORP.
39 Old Ridgeberry Road
Danbury, CT 06817

No urethane adhesive product line. Component manufacturer for urethane adhesives.

38. UNIROYAL CORP.
Spencer Street
112-2 TSSC Building
Naugatuck, CT 06770

No urethane adhesive product line.

39. UPACO ADHESIVES, INC.
3 East Spit Brook Road
Nashua, NH 03060

Providing literature on their urethane adhesives line.

40. UPJOHN CORP.
P.O. Box 685
La Porte, TX 77571

Company has been sold to Dow.

2.2 Selection/Acquisition of Adhesives

Nineteen companies have indicated that they manufacture structural urethane adhesives which have potential use in this particular application. As of this time, the information from 17 of these companies has been received and is summarized below. Information from the remainder of these companies is expected shortly.

1. American Cyanamid Co.

Cyanamid's urethane adhesives products have been discontinued.

2. Ashland Chemical Co.

A. Pliogrip 6600

- o Two-part, 100% reactive urethane structural adhesive.
- o Bonds engineered plastics, metals.

Viscosity - 27,000 (#6 @ 10RPM)
Tensile - 2,500 psi
Elongation - 60-70%
Lap shears (alum.) - 2,200 psi @ room temperature
(primed alum.) - 2,500 psi @ room
temperature
Shelf life - 6 months
Gel time - 1-10 minutes (dep. on curative)
Handling time - 12 minutes @ 60°F

B. Pliogrip 6000

- o Two-part, 100% reactive structural urethane adhesive.
- o Bonds plastics and metals.

Viscosity - 27,000 cps
Gel time - 2-15 minutes (dep. on curative)
Tensile - 2,400 psi
Elongation - 52%
Shelf life - 6 months

Note: The main difference between Pliogrip 6600 and 6000 is that 6600 has a slightly stronger bond strength.

3. Bostik Co.

A. Supergrip 9601

- o Solventless urethane adhesive.
- o Solid, one-part moisture cure.
- o Outstanding hydrolytic and chemical resistance.
- o No heat cure required.
- o Bonds most plastics and metals.
- o Flexible adhesive film.

Viscosity - 55,000 cps @ 140°F

Water resistance - excellent

Cured film tensile - 3,000 lbs

Heat resistance - 93-121°C

Elongation - 550%

B. Supergrip 9701

- o Solventless urethane adhesive.
- o One-part, moisture-cure, rapid setting, no heat.
- o Bonds most plastics and metals.

Viscosity - 27,000 cps @ 75°F

Water resistance - excellent

Heat resistance - 93-121°C

Cured film tensile - 4,100 lbs

Elongation - 660%

C. Supergrip 9702

- o Solventless urethane adhesive.
- o Solid, moisture curing with delayed setting characteristics, no heat.
- o Bonds most plastics and metals.

Viscosity - 55,000 @ 140°F
Water resistance - excellent
Heat resistance - 93-121°C
Cured film tensile - 2,600 lbs
Elongation - 500%

D. Supergrip 9704

- o Solventless urethane adhesive.
- o Solid, one-part, moisture-cure with rapid setting characteristics, no heat.
- o Bonds most plastics and metals.

Viscosity - 70,000 @ 167°F
Water resistance - excellent
Heat resistance - 93-121°C
Cured film tensile - 4,100 lbs
Cured film elongation - 660%

E. Supergrip 9705

- o High viscosity solid, one-part moisture cure with rapid setting characteristics, no heat.
- o Bonds most plastics and metals.
- o Solventless urethane adhesives.

Viscosity - 250,000 @ 212°F
Water resistance - excellent
Heat resistance - 93-121°C
Cured film tensile - 4,100 lbs
Cured film elongation - 650%

4. Devcon Corp.

Devcon's Flexane line of urethane adhesives does not provide the properties required.

5. Emerson & Cuming, Div. of W.R. Grace, Inc.

Two-component systems.

A. Eccothane 7541

Very hard, rigid, low cost system. Good high temperature capabilities.

- o Tensile - 7,000 psi
- o Elongation - 13%
- o Pot life - 40 mins
- o Cure - 24 hrs @ 25°C
- o Viscosity - 6,000 cps @ 25°C
- o Gel time - 3 hrs
- o Coefficient of thermal exp. - $71 \times 10^{-6} / ^\circ\text{C}$
- o Service temperature - -30 to 125°C

B. Eccothane 7031

Super high impact, crystal clear system that is highly resistance to yellowing, ozone and UV attack.

- o Tensile - 4,800 psi
- o Elongation - 25%
- o Pot life - 30 mins
- o Cure - 24 hrs @ 25°C
- o Viscosity - 3,000 cps @ 25°C
- o Gel time - 2 hrs
- o Coefficient of thermal exp. - $105 \times 10^{-6} / ^\circ\text{C}$
- o Service temperature - -30 to 125°C

C. Eccothane CPC-18

- o Tensile - 2,800 psi
- o Elongation - 300%
- o Pot life - 30 mins
- o Cure - 24 hrs @ 25°C
- o Viscosity - 55,000 cps @ 25°C
- o Gel time - 2 hrs
- o Coefficient of thermal exp. - $221 \times 10^{-6} / ^\circ\text{C}$
- o Service temperature - -68 to 149°C

D. Eccothane CPC-19

- o Tensile - 2,400 psi
- o Elongation - 450%
- o Pot life - 30 mins
- o Cure - 24 hrs @ 25°C
- o Viscosity - 24,000 cps @ 25°C
- o Gel time - 3 hrs
- o Coefficient of thermal exp. - $282 \times 10^{-6} / ^\circ\text{C}$
- o Service temperature - -68 to 149°C

E. Eccothane CPC-41

- o Tensile - 2,000 psi
- o Elongation - 150%
- o Pot life - 30 mins
- o Cure - 24 hrs @ 25°C
- o Viscosity - 8,000 cps @ 25°C
- o Gel time - 4 hrs
- o Coefficient of thermal exp. - 217×10^{-6}
- o Service temperature - -70 to 105°F

F. Eccothane CPC-39

- o Tensile - 1,500 psi
- o Elongation - 300%
- o Pot life - 30 mins
- o Cure - 8 hrs @ 66°C
- o Viscosity - 6,800 cps @ 25°C
- o Gel time - N.A.
- o Coefficient of thermal exp. - $200 \times 10^{-6} / ^\circ\text{C}$
- o Service temperature - -57 to 121°C

6. Essex Chemical Co.

Betamate 57.541/57.542

- o Two-part, ambient cure, non-sagging adhesive.
- o Tough elastomeric character, provides noise and vibration dampening to a structure.

Viscosity - 30-35,000 cps (RVF #6 @ 4 rpm @ 77°F)
Work life - 6-8 minutes
Shelf life - 6 months
Shear strength (alum.) - 1500-2000 psi
(FRP) - 600-1000 psi

7. H.B. Fuller

A. UR - 1100

- o One-component, heat-cured.
- o Bonds plastics and metals.
- o Good heat resistance.

Viscosity - 120,000 cps
Cure rate - 15 minutes @ 260°F
Tensile strength - 4,186 psi @ -67°F
- 3,957 psi @ 77°F
- 1,518 psi @ 180°F

B. UR - 2139

- o Two-component system for plastics and metals.
- o Good sag and acid resistance.

Viscosity - 25,000 cps
Pot life - 45-75 minutes
Cure rate - 30 days @ 77°F or 4-5 hours @ 140°F
Tensile strength - 4,780 psi @ -67°F
- 1,400 psi @ 77°F
Coefficient of thermal expansion - $7.4 \times 10^{-5}/^{\circ}\text{F}$

C. UR - 2183

- o Fast-cure, two-component system
- o A polyester urethane for bonding plastics

Viscosity - 7,500

Pot life - 10-15 minutes

Cure rate - 3-5 days @ 77°F or 2-3 hours @ 150°F

Shelf life - 6 months

Hardness (Shore A) - 92 ± 8

D. UR - 2170

- o Two-component system with good chemical resistance.
- o Bonds metals and plastics.
- o Good moisture resistance and dry heat aging.

Viscosity - 37,000 cps

Pot life - 30 minutes

Cure rate - 5-7 days @ 77°F or 1-2 hours @ 158°F

Shelf life - 6 months

Note: More detailed product data on all H.B. Fuller urethanes is currently being compiled.

8. Furane Corp.

A. Uralane 5738 A/B

- o Moisture resistant.
- o Does not craze most plastics.

Consistency - semi-paste

Pot life - 15 minutes

Cure rate - 20 hours @ 77°F and 4 hours @ 150°F

Upper operating temperature - 150°F

Lap shear strength (alum.) - 2,450 psi @ -67°F
- 2,000 psi @ 77°F
- 380 psi @ 180°F

Lap shear strength (epoxy) - approx. 800 psi @ 77°F

Weathering - good

B. Uralane 5767 A/B

- o High temperature adhesive.
- o Bonds various metal substrates.

Consistency - semi-paste

Pot life - 15 minutes

Cure rate - 2 hours @ 77°F and 16 hours @ 150°F

Upper operating temperature - 270°F

Lap shear strength (alum.) - 3,000 psi @ -67°F
- 1,700 psi @ 77°F
- 700 psi @ 250°F

Lap shear strength (epoxy) - approx. 800 psi @ 77°F

Weathering - good

C. Uralane 5768 A/B

- o Bonds plastics and metals.
- o Somewhat higher bond strengths than 5767 A/B.

Consistency - semi-paste

Pot life - 30 minutes

Cure rate - 16 hours @ 150°F or 7 days @ 75°F

Upper operating temperature - 250°F

Lap shear strength (alum.) - 3,000 psi @ -67°F

- 1,800 psi @ 77°F

- 700 psi @ 250°F

Lap shear strength (epoxy) - approx. 900 psi

Weathering - good

D. Uralane 88800 A/B

- o Quick set, non-flow adhesive.
- o Used to bond interior aircraft parts.

Consistency - paste

Pot life - 1 minute

Cure rate - 24 hours @ 77°F

Upper operating temperature - 175°F

Lap shear strength (alum.) - 3,400 psi @ -67°F

- 1,200 psi @ 77°F

- 800 psi @ 180°F

Weathering - good

9. B.F. Goodrich Corp.

PL-550

Viscosity - Part A 50-70,000 cps

Part B 1,000 cps

Pot life - 15-30 minutes

Handling time - 2 hours

Full cure @ room temperature - 7 days

Service temperatures - -20°F to 160°F

Weatherability - good

Tensile - 2,000 psi (with room temperature cure)

- 2,800 psi (with room temperature cure and
post bake)

Elongation - 50%

Lap shear strength (alum.) - 1,200 psi (with room
temperature cure)

- 2,000 (with room
temperature cure and
post cure)

10. Hysol, Division of the Dexter Corp.

EA-9525

o Two-component urethane with wide service
temperature.

o Bonds plastics and dissimilar materials.

Viscosity (mixed) - 10,000 cps @ 77°F

Pot life - 15 mins.

Cure time - 10 days @ 77°F or 1 hr @ 77°F plus 1 hr @
250°F

Service temperature - -100°F to +300°F

Tensile strength - 7,000 psi
Elongation - 275%
Shear strength (alum.) - 3,000 psi

11. Lord Corp.

A. Tyrite 7500

- o Two-part structural urethane for plastics and metals.
- o Room T cure or heat accelerated.
- o Flexible, non-sagging, 100% solids.

Pot life - 6-10 mins

Handling strength - 2 hrs @ 75°F

Impact resistance - -30°F to 240°F

Viscosity - 500,000 @ 25°C

Lap shear (alum.) - 2130 psi (COH) Room T

- 1540 psi (COH) 2 wks @ 100°F
& 100% R.H.

- 1640 psi (COH) 2 wks salt spray

Lap shear (lexan) - 1140 psi (COH) Room T

- 1150 psi (COH) 2 wks @ 100°F
& 100% R.H.

- 1130 psi (COH) 2 wks salt spray

Shelf life - 6 months

B. Tyrite 7520

- o Two-part structural urethane for plastics and metals.
- o 100% solids, room temperature cure, fast cure.
- o Semi-rigid, non-sagging, good impact strength.

Pot life - 7 mins

Handling strength - 40 mins

Viscosity - 15,000 cps

Full cure - 24 hrs

Lap shear (alum.) - 1500 psi (COH) 2 hrs @ Room T
- 1900 psi (COH) 1 wk @ Room T
- 1300 psi (COH) 1 wk salt spray
Lap shear (ABS) - 500 psi (COH) 2 hrs @ Room T
- 480 psi (COH) 1 wk @ Room T
- 540 psi (COH) 1 wk salt spray

Shelf life - 6 months

C. Tyrite 7602

- o Single pack moisture cure.
- o Bonds metals and plastics.
- o Semi-flexible, good chemical resistance,
non-sagging.

Handling strength - 4-6 hrs

Viscosity - 310,000 cps

Full cure - 5-10 days (R.H. dependent)

Tensile (alum.) - 479 psi (COH) 48 hrs
- 741 psi (COH) 96 hrs
(FRP) - 506 psi (COH) 48 hrs
- 651 psi (COH) 96 hrs

Shelf life - 6 months

12. Morton-Thiokol

Morton-Thiokol's urethane adhesives do not provide the properties required.

13. 3M Corp.

A. EC-3549

- o Two-component, room temperature cure.
- o Impact resistant structural adhesive.
- o Excellent adhesion to many primed or painted metals and various plastic substrates.
- o Use Primer EC 1945 B/A (or Corogard 9) for maximum resistance to water, humidity and salt spray environments.

Viscosity - 22,500 cps (#4 Spindle, 10 RPM)

Work life - 60 mins @ 72°F

Shear strength - 1170 psi (48 hrs) plastic to steel
- 1400 psi (48 hrs) steel to steel

Pot life - 8 hrs

B. EC 3532

- o Two-component room temperature cure.
- o Tough impact resistant
- o Excellent adhesion to many primed or painted metals and various plastic substrates.
- o Use 3M Primer EC-1945 B/A or Corogard 9 for metals.

Viscosity - 22,500 cps (#4 Spindle, 10 RPM)

Work life - 9 mins @ 65°F

Shear strength - 2190 psi (72 hrs @ 75°F) alum. to
alum.

- 1130 psi (72 hrs @ 75°F) phenolic
laminate

Tensile - 3000 psi (1 hr @ 250°F, 30 mins @ 285°F)
(ASTM D-738)

Elongation - 96%

Pot life - 8 hrs

C. EC 3535

- o Two-component urethane which cures at room
temperature or with heat.
- o Water, humidity, salt spray, and impact
resistant.
- o Bonds primed or painted metals and various
plastics.

Viscosity - 22,500 cps

Work life - 1-4 minutes

Shear strength (alum.) - 2,000 psi @ 75°F
(epoxy) - 1,500 psi @ 75°F

Tensile - 3,000 psi

Elongation - 96%

Pot life - 8 hours

Note: The main difference in the 3M urethanes is cure
time and work life.

14. Polyurethane Corporation of America

Polyurethane Corp.'s urethane adhesives do not provide the
properties required.

15. K.J. Quinn Co.

Quinn's urethane adhesives do not provide the properties required.

16. Ruco Polymer Corp.

Ruco's urethane adhesives do not provide the properties required.

17. Swift Adhesives

Swift's urethane adhesive line does not provide the properties required.

18. Synthetic Surfaces, Inc.

Synthetic Surfaces' urethane adhesives do not provide the properties required.

19. Upaco Adhesives, Inc.

Upaco's urethane adhesives do not provide the properties required.

MANUFACTURERS' TECHNICAL DATA ON URETHANE ADHESIVES

<u>Company Product/Property</u>	<u>Room Temp. Viscosity</u> (cps)	<u>Room Temp. Work Life</u>	<u>Full Cure</u> ¹ <u>@ Room Temp.</u>	<u>Tensile Strength</u> (psi)	<u>Elongation</u> (%)	<u>Lap Shear Strength</u> (Alum./Epoxy) (psi)	<u>Service Temperature Range</u> (°F)	<u>Weatherability</u>
ASHLAND								
Pliogrip 6600	27,000	8-10 mins.	24-48 hrs. or 20-30 mins. @ 250°F	2,500	60-70	2,200/N.A.	-60 to 180	Very Good
BOSTIK								
Supergrip 9701	10,000 ₂ @ 100°C	<1 min.*	24-48 hrs.*	4,100	660	700*/N.A.	Up to 160	Good to Very Good
Supergrip 9704	50,000 ₂ @ 100°C	<1 min.*	24-48 hrs.*	4,100	660	700*/N.A.	Up to 160	Good to Very Good
Supergrip 9705	250,000 ₂ @ 100°C	<1 min.*	24-48 hrs.*	4,100	650	700*/N.A.	Up to 160	Good to Very Good
Supergrip 9601	11,000 ₂ @ 100°C	<1 min.*	24-48 hrs.*	3,000	550	700*/N.A.	Up to 160	Good to Very Good
EMERSON & CUMING								
Eccothane 7541	6,000	3 mins.	24 hrs.	7,000	13	N.A.	-22 to 250	N.A.
Eccothane 7031	3,000	2 mins.	24 hrs.	4,800	25	N.A.	-22 to 250	N.A.
Eccothane CPC-18	55,000	2 mins.	24 hrs.	2,800	300	N.A.	-90 to 235	N.A.
Eccothane CPC-19	24,000	3 mins.	24 hrs.	2,400	450	N.A.	-90 to 235	N.A.
Eccothane CPC-41	8,000	4 mins.	24 hrs.	2,000	150	N.A.	-95 to 220	N.A.
ESSEX								
57.541/57.542	30-35,000	6-8 mins.	24 hrs.*	2,000*	5*	1,500-2,000/ 600-1,000	Up to 180	Very Good

MANUFACTURERS' TECHNICAL DATA ON URETHANE ADHESIVES (Continued)

Company Product/Property	Room Temp. Viscosity (cps)	Room Temp. Work Life	Full Cure ¹ @ Room Temp.	Tensile Strength (psi)	Elongation (%)	Lap Shear Strength (Alum./Epoxy) (psi)	Service		Weatherability
							Temperature	Range	
FURANE									
Uralane 5738A/B	Semi-paste	15 mins.	20 hrs. @ 77°F ³ & 4 hrs. @ 150°F	N.A. ⁴	N.A.	2,000/800*	<150		Good
Uralane 5767A/B	Semi-paste	15 mins.	2 hrs. @ 77°F ³ & 16 hrs. @ 150°F	N.A. ⁴	N.A.	1,700/800*	<270		Good
Uralane 5768A/B	Semi-paste	30 mins.	7 days or 16 hrs. @ 150°F	N.A. ⁴	N.A.	1,800/900*	<250		Good
Uralane 88800A/B	Paste	1 min.	24 hrs.	N.A. ⁴	N.A.	1,200/N.A.	<175		Good
B.F. GOODRICH									
PL-550	50-70,000	15 mins.	7 days	2,000	50	1,200/N.A.	-20 to 160		Good
HYSOL									
EA-9525	10,000	15 mins.	10 days or 1 hr. @ R.T. & 1 hr. @ 250°F	7,000	275	3,000/800*	-100 to 300		Good
LORD									
Tyrite 7500	500,000	6 mins.	24 hrs.* or 15 mins. @ 240°F	1,000*	80-100*	2,130/1,000*	Up to 200		Good
Tyrite 7520	15,000	7 mins.	24 hrs.	2,000*	N.A.	1,900/500*	Up to 200		Good

MANUFACTURERS' TECHNICAL DATA ON URETHANE ADHESIVES (Continued)

Company Product/Property	Room Temp. Viscosity (cps)	Room Temp. Work Life	Full Cure ¹ @ Room Temp.	Tensile Strength (psi)	Elongation (%)	Lap		Service Temperature Range (°F)	Weatherability
						Shear Strength (Alum./Epoxy)	(psi)		
3M									
EC-3532	22,500	5-15 mins.	24 hrs.	3,000	96	2,000/1,500*		Up to 180	Very Good
EC-3535	22,500	45-240 secs.	24 hrs.	3,000	96	2,000/1,500*		Up to 180	Very Good
EC-3549	22,500	40-70 mins.	7 days	3,000	96	2,000/1,500*		Up to 180	Very Good

N.A. - Not available.

*Approximate value.

¹ Many cure much faster with heat.

² Hot melt-type urethane, adhesive is applied at 100°C.

³ Heat is required for cure.

⁴ Tensile value will be higher than lap shear value.

3.0 CONCLUSIONS

The following six urethane adhesives ~~have been~~ determined to possess the most interesting and desirable properties for use in this application. When all information is received, a modified list of preferred adhesives will be prepared describing their most important characteristics.

1. Ashland - Pliogrip 6600

Pliogrip 6600, a two-component system, has been selected as a result of its rapid setting ability and proven use in bonding automotive composites.

2. Emerson and Cuming - EC 7541

Although the cure rate is somewhat slow, this two-component system possesses a very high tensile strength (7000 psi).

3. Emerson and Cuming - EC 7031

EC 7031, also a two-part system, shows very good environmental resistance and tensile strength (4800 psi).

4. Furane-Uralane 5738 A/B

A two-part semi-paste with good tensile and lap shear strength, also has suitable weatherability.

5. Hysol EA-9525

A two-part ambient cure system with exceptionally high tensile strength and good lap shear strength. Excellent low temperature properties.

6. 3M - EC 3532

EC 3532 is a two-component system which has excellent impact resistance and bonds especially well to primed metals and plastics.

4.0 RECOMMENDATIONS

The technology assessment and identification carried out in Phase I, demonstrates that viable urethane structural adhesives are commercially available. These adhesives should be evaluated in a test program designed to measure their performance over a range of environmental conditions and in comparison with the most suitable acrylic and epoxy adhesives identified to date. The test evaluations should include (1) lap shear bond strength evaluation, (2) environmental testing of cast systems (such as the Mecklenburg Stress Relaxation Test), and (3) torsional bond strength evaluation (such as described by Lin and Bell).

At the conclusion of this experimental program, it should be possible to identify the best structural adhesive system for use in the construction and repair composite containing mobile bridging systems.

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