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16 April 1998

Edward Bird
CSSD-TC-AP
U.S. Army Space and Strategic Defense Command
P.O. Box 1500
Huntsville, AL 35807-3801

Dear Mr. Bird,

Enclosed is the final report for our SBIR Phase 1 Contract Number DASG60-97-0106.

Sincerely,

William L. Johnson

William L. Johnson
Principle Investigator
Vice-President of IMP

DASG60-97-M-0106

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Infinite Materials & Products, Inc., has developed a revolutionary waterproof, 3-minute cure polyurethane resin which has no shrinkage, micro-cracking, water absorption or penetration, or stress related fatigue and failure common in other resins. Testing conducted by an independent test facility confirms this new resin is unique in its sealing and waterproofing abilities, its toughness, and its 3-minute room temperature cure, in addition to its environmentally friendly nature. This new resin is generating interest across many industries. Twenty-three national companies have expressed a keen interest in this new polyurethane resin.
IMP's waterproof, sprayable, injectable, room temperature 3-minute cure polyurethane resin system is currently available at low scale production rates. Licensing agreements have been entered into for increased production to meet expected demand for marketing and sales.
The continued R&D and testing within the Phase 2 program will prove that IMP's polyurethane is the superior product for aerospace and deep space applications and will provide a very durable, economical, environmentally friendly, and superior product for civilian commercial applications.

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FINAL REPORT

INFINITE MATERIALS & PRODUCTS, INC.

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"Environmentally Safe, Sprayable, Waterproof, Rapid Three Minute Room Temperature Cure Resin for the Manufacturing of Aerospace Composite Sealants"

SPONSORED BY
ARPA/BMDO Innovative Science and Technology Office

MANAGED BY
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EXECUTIVE SUMMARY/ABSTRACT FOR:

"Environmentally Safe, Sprayable, Waterproof, Rapid Three Minute Room Temperature Cure Resin for Use as an Aerospace Composite Sealant"

Infinite Materials and Products, Inc. has developed a revolutionary waterproof, 3 minute cure polyurethane resin which has no shrinkage, micro-cracking, water absorption or penetration, or stress related fatigue and failure common in other resins. Testing conducted by an independent test facility confirms this new resin is unique in its sealing and waterproofing abilities, its toughness, and its 3-minute room temperature cure, in addition to its environmentally friendly nature. This new resin is generating interest across numerous industries:

Shell/Exxon for anti-corrosion coating system for off-shore oil drilling platforms, above and below the waterline.

Learjet and Gulfstream Aerospace for exterior paint system for aircraft.

Kurt Boyd Enterprises for horse hoof repair (already being used commercially).

Intel, Braun AG, and General Electric for sealant and encapsulant for electronic components and assemblies.

Disney and Six Flags for durable coating for water rides and architectural theme designs.

Watkins Spas and Spas Technologies, Ltd., for replacement of all gelcoats on new manufactured and rebuilt spas.

W.L. Gore & Associates for adhesives and sealants.

Lord Corp., Easton Company, Taylor Corp., and G.T. Bicycles for waterproof sealant and paint for composites.

General Motors for exterior automotive paint.

Robert Bookwalter Company for waterproof sealant for steel cable systems for rock slide protection for highways.

U.S. Marine Byline and Columbia Sentinel Engineering for replace all gelcoats on watercraft hulls and exterior paint for watercraft, above and below waterline.

M.B.C.I. for waterproof sealant for metal panels.

Dinaudio for waterproof sealant for speaker cones.

IMP's waterproof, sprayable, injectable, room temperature 3-minute cure polyurethane resin system is currently available at low scale production rates. Licensing agreements have been entered into for increased production to meet expected demand for marketing and sales.

The continued R&D and testing within the Phase 2 program will prove that IMP's polyurethane is the superior product for aerospace and deep space applications and will provide a very durable, economical, environmentally friendly, and superior product for civilian commercial applications.

FINAL REPORT FOR

"Environmentally Safe, Sprayable, Waterproof, Rapid Three Minute Room Temperature Cure Resin for Use as an Aerospace Composite Sealant"

TASK OBJECTIVES:

The Phase 1 SBIR proposal oriented the research on Infinite Material & Products (IMP) polyurethane resin toward perfecting this material to seal the surface of aerospace composite structures against moisture absorption within an atmosphere and outgassing in the vacuum of space. ASTM test data indicate that IMP's polyurethane solves the current problems of shrinkage, micro-cracking, water absorption and penetration, and stress induced fatigue and failure in aerospace continuous fiber reinforced plastic (CFRP) composite components which use either room temperature cure or heat cure resin systems. For spacecraft and space-based assets, outgassing, general corrosion, ultraviolet attack, and, possibly, mono-atomic oxygen attack could be prevented. With the data obtained by lab and field testing by IMP and the data obtained by independent third party ASTM testing, this polyurethane resin system has shown potential for ***providing the best waterproofing, sealant, and corrosion protection for all CFRP composites and metals, and a complete waterproofing and sealant coating for a even wider range of materials and products than previously thought.***

Initially, IMP made the following assertions as to the assumed and projected properties of its revolutionary polyurethane resin system:

1) No Volatile Organic Compounds (VOCs).
2) Waterproof.
3) Room temperature 3-minute cure with no post cure.
4) No shrinkage or micro-cracking.
5) Ultraviolet proof.
6) Chemically resistant.
7) Extremely excellent adhesion properties.
8) Shore D Hardness of 85.

Other very important aspects of IMP's waterproof polyurethane resin system are a room temperature cure, its 3-minute cure time, and a resin cure that is independent of humidity. Ninety percent of all the other polyurethane resins require a minimum of *50 percent* humidity and *48 hours* to cure. Polyurethane resins which require a certain level of humidity to cure *will also trap that same moisture vapor inside the cured polyurethane resin.* This situation is unacceptable for a material used in space due to outgassing from the material's internal structure, which could easily compromise the integrity of the material. In addition, currently used polyurethane coatings and paints face a serious problem and an uncertain future due to new EPA emissions standards for aerospace. Both NASA and the U.S. Air Force are mounting a major effort to eliminate the use of ozone depleting chemicals and chemicals from the Toxics Release Inventory (TRI) and to reduce the levels of hazardous air pollutants used in many diverse processes. One source for airborne pollutants is the coatings and paints used on aerospace vehicles. Polyurethane resins are a coating of choice due to their excellent environmental toughness and longevity. However, polyurethane coatings and paints contain isocyanates, which are released to the atmosphere during mixing and spraying. IMP's polyurethane resin system should not outgas, making it an ideal candidate for the next generation of polyurethane coatings.

Although IMP performs in-house testing during the development phases of new products, IMP presents its final proof-of-concept testing performed by an independent, third party testing facility. All of IMP's final testing to ASTM Standards was conducted by SGS U.S. Testing Company, Inc., 5555 Telegraph Road, Los Angeles, CA 90040, an industry and Federally certified testing laboratory meeting all specification and testing standards. IMP's polyurethane resin system was tested to the following ASTM Standards for the physical properties listed:

1) Shore D Hardness (ASTM D 2240)
2) Tensile Strength in psi (ASTM D 638)
3) Compressive Strength in psi (ASTM D 695)
4) Flexural Strength in psi (ASTM D 790)
5) Glass Transition Temperature (Tg) in degrees F (ASTM D 3418)
6) Vapor Permeability (the degree to which the resin is waterproof) (ASTM E 96)
7) Coefficient of Thermal Expansion (ASTM D 696)

IMP wants to state why these tests were chosen, which are typically not done with products from the paint and coating industry. Since IMP's polyurethane was designed to overcome the deficiencies of currently used epoxy resins in the aerospace and commercial composites industries, IMP felt the strength and durability of the polyurethane must be tested to a standard to compliment and enhance the degraded characteristics of these same epoxies. Consequently, IMP now has available a polyurethane quite unlike anything previously formulated.

To illustrate this point, it would be instructive to note the physical properties of U.S. Paint Corporation's AWLGRIP® / ALUMIGRIP® LINEAR POLYURETHANE TOPCOAT - GLOSS AND SEMI-GLOSS (Modified Polyester Resin) and TOPCOAT CONVERTER FOR SPRAY APPLICATION (Modified Polyisocyanate Resin). These two paints are aerospace industry standard for painting civilian, commercial, and military aircraft. The following chart lists all the relevant physical properties ***available*** on these two paint coatings:

AWLGRIP® / ALUMIGRIP®	TOPCOAT CONVERTER
Formula Weight = 8.38-9.94 lbs./gal.	Formula Weight = 8.35 lbs./gal.
VOC of Material = 5.78-6.15 lbs./gal.	VOC of Material = 4.87 lbs./gal.
% Volatile by Weight = 58-68	% Volatile by Weight = 58.27
% Volatile by Volume = 73-81	% Volatile by Volume = 63.32

Continuous Operating Temperature Limit = 150 F
Intermittent Temperature Limit = 225 F
Cure Time @ 77 F / 50% R.H. = 24 hours to tape free, 2-3 days full cure

As will be shown in the following pages, IMP's polyurethane has a much higher operating temperature. IMP believes there are ***no*** VOC's given off by the polyurethane resin system, because the polyurethane has no solvents in its formulation.

TECHNICAL PROBLEMS:

Within this project, IMP discovered one major stumbling block in trying to manufacture the test samples. For the ASTM tests noted above, samples 1/4" thick with lengths varying from four to eight inches were required. This material was designed as a thin surface coating, which cured in 3 minutes. It proved impossible to make thick material samples by using the specialized two component airless impingement spray equipment necessary to apply this polyurethane as a surface coating. It took several months to develop a method to manufacture the samples for the ASTM testing. The final method took the form of an isolated dual component caulk gun that would squeeze correct amounts of the A (resin) and B (hardener) component through a specially designed long spiral mixing tip into the appropriate molds to make the sample slabs. IMP will recommend this caulk gun system for any application requiring the use of the polyurethane resin system to make objects with a mold or form.

The implementation of this dual component caulk gun system for bulk injection and transfer of IMP's polyurethane was an unanticipated research item within the Phase 1 contract. This problem had to be solved. IMP solved it.

Once the thick slabs of polyurethane resin were fabricated, the slabs had to be machined to make the samples the correct size. IMP discovered the cured polyurethane resin machined very similar to aluminum, with no balling or shredding while milling with a fly cutter or a standard twin flute mill bit, as is common when machining Teflon®, Delrin®, nylon, acrylics (Plexiglass®), polycarbonates (Lexan®), and other plastic materials.

The specialized dual component spray system from the Binks Sames Corporation worked well for bulk spraying for commercial surface coatings. However, there was a problem in achieving polyurethane coatings of only 1.3 to 2.7 mils thick, as would be necessary for aerospace vehicles to save weight. In addition, the polyurethane is being evaluated as a coating for both military and civilian firearms. For this application, the coating must be no more than 0.5 mils thick. IMP is continuing the design efforts with Binks Sames in seeking the right solution to achieve ultra thin coatings at a reasonable cost.

GENERAL METHODOLOGY:

All fabrication of test samples was performed in IMP's laboratory. Resin reformulation following testing of the resin's physical characteristics, as well as modifications and techniques for the airless spray gun and the caulk gun application methods, were also accomplished in the IMP lab. As stated previously, SGS U.S. Testing performed all ASTM Standards testing.

TECHNICAL RESULTS:

The driving force to create a composite material is to produce a functional marriage between several diverse component materials, which results in a new composite material that is greater than the sum of its parts. The intent is to have a material that will accomplish something that could not be done in the past. IMP's polyurethane was designed to cure the deficiencies in current CFRP composite structures by adding its capabilities to the total matrix, thus making the new composite matrix greater that the original whole. Therefore, a direct physical property comparison between IMP's polyurethane and current epoxies is necessary.

The tensile strength, as determined by ASTM D 638 Standard, was 4300 psi. This tensile strength is the same as the average tensile strengths of aerospace and commercial epoxies manufactured by AKEMI, Inc., which has been formulating and manufacturing epoxies since 1966. However, the compression strength of 3190 psi (ASTM D 695 Standard) and the flexural strength of 4160 psi (ASTM D 790 Standard) are much lower than current epoxies, a plus which will enable it to withstand an impact better than other epoxies which are usually hard and brittle. The Shore D Hardness (ASTM D 2240 Standard) was only 73, much lower than the 90 average value of almost any typical epoxy. As both the lab and field testing eventually indicated, these results were logical, *for the polyurethane resin system was found to have an elongation rate of 17.1%* (ASTM D 638 Standard). The hard and brittle nature of current epoxies contributes greatly to moisture absorption into the epoxy. The flexibility and durability of IMP's polyurethane contributes to the polyurethane's ability to be extremely waterproof.

IMP's polyurethane resin system has undergone an unusual form of field testing. A 9 inch by 9 inch slab, ¼ inch thick, was fabricated as a test target. Number 8 birdshot and double ought buckshot fired at the slab at point-blank range bounced off of the polyurethane slab without marring or starring the surface of the slab. The flexibility and elongation capability of this polyurethane produced this level of durability. As a coating or paint on a jet, rocket, or spacecraft traveling at high mach speeds, this polyurethane resin system would have a high degree of survivability.

This ballistic testing was not covered in the original Phase 1 proposal and contract. IMP added it to the R&D investigation as a necessary component.

The coefficient of thermal expansion (CTE) (ASTM D 696 Standard) was 5.42×10^{-5} in./in/ F (9.76×10^{-5} in./in/ C). This CTE value is in the range of typical aerospace and commercial epoxies, with AKEMI, Inc., being an excellent example. With a CTE comparable with other epoxy resins, IMP's polyurethane will be able to adhere directly to the surface of an epoxy resin on a composite and move with any temperature fluctuations experienced by the epoxy resin matrix, without having shearing stresses break the adhesion.

The data for the glass transition temperature (T_g) was very surprising. ASTM D 3418 Standard test revealed a T_g of 165.3 C (329.5 F). A T_g of this magnitude, *for a room temperature cure plastic resin, does not exist as far as IMP knows!* BRYTE Technologies, Inc., manufactures some of the most stable and widely accepted aerospace epoxies. BRYTE's EX-1515 is the extreme service epoxy of choice of the aerospace industry. The T_g of EX-1515 is only 274 F when heat cured at 250 F. When EX-1515 is post heat cured at 350 F, its T_g goes to 350 F. IMP's polyurethane resin system matches this T_g with a full cure in 3 minutes at room temperature.

However, the most important test result came from the water vapor transmission testing of IMP's polyurethane to ASTM E 96 Standard. Although ASTM D 570, Standard Test Method for Water Absorption of Plastics, is the typical test procedure performed by the vast majority of polymer manufacturers, it does ***not*** determine the degree to which a particular polymer is waterproof, because it assumes the polymer will absorb water. In D 570, the test specimen is totally immersed in water.

Instead of ASTM E 96 or D 570, a non-standardized passive moisture absorption test, which consists of placing a cured plastic resin test specimen in a test chamber environment set at 80 F with 85% relative humidity, is used by aerospace manufacturers to determine the amount of water absorbed by the resin. This test procedure is used by BRYTE Technologies. As with the ASTM D 570 test, this test assumes the test specimen will absorb moisture, with the only question being, "How much?" These tests *cannot* meet the standards of the electronic industry with regards to conformal polymer coatings for the encapsulation and protection of electronic components to provide complete waterproofing and hermetic sealing. To meet these stringent requirements, a test must be used that can demonstrate the material's ability to block water vapor transmission as a performance standard. In addition, the roofing industry and the waterproofing and sealant demands of the rest of the building construction industry does not rely on the above tests. ASTM E 96 is used by both the electronics and the building construction industries.

IMP used ASTM E 96 because IMP needed to know if the polyurethane was waterproof and to what degree it was waterproof. The polyurethane was tested to the more rigorous waterproof standard in order to seal aerospace epoxies. In turn, these same epoxies had only been tested to a standard that determined how much water they actually absorbed to equilibrium.

For ASTM E 96 Standard, there are six basic test methods comprising several variations on the dry-cup desiccant and the wet-cup water methods. Permeance readings *cannot* be mixed between the six different methods. A material can have a variance between data for the various methods by as much as two orders of magnitude or as little as only a factor of two. The inverted wet-cup water method is the most severe test. The test conditions and methods must always be selected to simulate the environment under which the material being tested is to be used in the real world. An example would be free-standing water on a surface, originating from rain or condensation at high humidity. ASTM E 96 is designed to duplicate those conditions.

ASTM E 96 Standard testing for IMP's polyurethane resin system was performed in accordance with the inverted water method (wet-cup). Thwing-Albert water vapor permeability cups were filled with water and sealed to the polyurethane test specimens with a composite wax composed of 60% white beeswax and 40% Fisher Tissueprep. Molten asphalt or wax is required for permeance tests below 4 perms. The cups are then inverted, with the polyurethane test specimens on the bottom and the water volume above the test specimen. There is a tendency to establish equilibrium between the water and the resin by osmosis working against gravity and the mass transfer driving forces, which try to drive water through the resin. Unlike the other water absorption tests previously mentioned, this test is an active, dynamic test. Weight measurements are taken every 24 hours to check water mass gain on the surface of the test specimens, per unit surface area. ASTM E 96 is the only way to evaluate a material as to the rate moisture will pass through the material and the performance of the material to resist or stop moisture penetration. Other tests will only provide the mass of moisture absorbed, at equilibrium, per unit mass of the material, but not address how waterproof the material is.

On an average, it took up to 16 days for IMP's polyurethane to gain weight and then stabilize. The average water vapor transmission weight gain was 0.193 perms. In more common terms, this data number equals 1.1×10^{-8} grams (0.000000011 grams) of water per Pascal • second • square meter of surface area. This permeance rating compares exactly to the best known roofing material, used specifically for hard to seal areas. Duplex sheet, asphalt laminated, aluminum foil roofing material has a permeance rating of 0.176 perms.

IMP believes the reason the resin is highly waterproof is because there are ***no*** volatile organic compounds (VOCs) given off by the polyurethane resin system. VOCs escaping through the resin matrix leave tunnels and micro-cracks behind, which allows water to permeate through the resin.

Tunneling and micro-cracking are the main reasons plastic materials lose their ability to be waterproof. VOC testing was not budgeted for Phase 1 and could not be performed during Phase 1, due to cost.

BRYTE Technologies' EX-1515 was picked for a comparison because of its manufacturer advertised low moisture absorption, low outgassing, low stress induction, no micro-cracking, and resistance to radiation and thermal cycling stress. A quote from NASA-JPL states "...a dramatic improvement in dimensional retention of at least one full order of magnitude..." A quote from Composite Optics, Inc., states "EX-1515 could very well be the Cyanate Ester matrix resin of the future for space applications."

IMP has negotiated with Kim Ford and John Emerson at Sandia National Laboratories, Albuquerque, NM, for $5,000 of free testing to subject IMP's polyurethane to the same bell jar test regimen used for vacuum deposited metals and glasses to form hermetic seals and for plastic encapsulants and conformal coatings used to hermetically seal electronic components. IMP learned of this opportunity at the SBIR National Conference held in Phoenix, AZ, on 27-29 October 1997. Mr. Emerson runs a dedicated test laboratory for Intel Electronics located inside Sandia. The bell jar testing was begun at the end of March 1998. The results will not be available in time for this final report. IMP's polyurethane may prove to be superior to currently used sealant materials within the electronics industry.

Mr. Emerson has stated there are specific differences between the concepts of water absorption and water vapor permeability, permeance, and transmission rate. ASTM D 570 concerns itself only with water absorption, which makes this test inadequate for the electronics industry. The material being tested absorbs moisture to equilibrium throughout its entire structure and thickness. The electronics industry needs a hermetic sealant that has extremely low *water vapor permeance*. The moisture cannot be allowed to penetrate through the material, in the first place. If it does, the electronic component will fail. Mr. Emerson tests for water vapor permeance electronically, by using an electrical circuit in a custom made IC chip to measure the performance of the material under test. Intel has set the desired performance standards, which include a maximum permissible water vapor transmission rate.

Both water vapor permeability and water vapor permeance are a time rate of water vapor transmission through a unit area of a flat material, which is induced by the unit vapor pressure difference between two specific surfaces, under specified temperature and humidity conditions. However, permeability takes into account a unit of thickness while permeance is unconcerned with thickness. Permeability is a property of a material and is the arithmetic product of permeance and thickness. Permeance is a performance evaluation and not a property of a material. The water vapor transmission rate is the steady water vapor flow in unit time through a unit area of a body, normal to specific parallel surfaces, under specific conditions of temperature and humidity at each surface.

On 26 March 1998, IMP visited OPTO Power Corporation in Tucson, Arizona, at their request to solve a severe production problem. OPTO Power manufactures lasers. In one particular assembly operation, a one millimeter diameter by 25 millimeter long glass lens is optically aligned, with the laser on, and glued at both ends onto a 20 watt CW infrared diode laser. The glue is an ultraviolet quick cured epoxy. The fast cure is necessary to minimize production time. However, there is a 60% failure rate for this subassembly due to the shrinkage rate in the epoxy. All types of epoxies and other plastic adhesives have been tried, but the shrinkage rate has not improved and the reject rate has not improved. During assembly, the laser's 780 nanometer wavelength is monitored to gauge the positioning of the glass lens. The epoxy will shrink anywhere between 6 to 8 wavelengths. The laser is targeted onto a grid screen, the glass lens is positioned and glued high, and the movement of the laser wavelength is watched by the operator to determine if the shrinking epoxy will bring the lens into alignment. If alignment does not occur, the part is rejected.

IMP applied the polyurethane to a laser device and glass lens. The laser was targeted directly to the alignment point and the glass lens was positioned directly at the alignment point. As the rapid cure of IMP's polyurethane progressed, there was no movement. The glass lens mounted to the diode laser stayed true. There was no shrinkage detected at a wavelength of 780 nanometers. There are no ASTM Standard tests that will measure shrinkage in the sub-micron range and be able to accommodate the fast 45 second gel, 3-minute cure of IMP's polyurethane. At this time, this procedure was the only way IMP could use to evaluate the shrink rate of the polyurethane. The opportunity with OPTO Power was an added bonus to IMP and the Phase 1 contract.

IMPORTANT FINDINGS, CONCLUSIONS, AND PLANS FOR COMMERCIALIZATION:

The five most important physical performance characteristics of IMP's polyurethane resin system are:

1) A high T_g of 165.3 C or 329.5 F.
2) Excellent flexibility and elongation.
3) Very low water vapor permeance, making it waterproof.
4) An apparent shrink rate that is not measurable as per the above test.
5) A CTE that matches epoxies.

Items 1 through 4 have been discussed in detail above. The CTE result deserves further discussion.

Due to the internal stresses in a composite caused by the curing process and outgassing, the epoxy matrix within the composite will tend to move separately from the embedded fibers under external thermal and physical loads. Therefore, in evaluating a coating system for a CFRP composite structure, it is important to select a material that has a CTE compatible with epoxy resins, so the polyurethane coating at the epoxy/polyurethane interface will not contribute any additional stresses to the epoxy/fiber composite internal matrix. The CTE of IMP's polyurethane coating is in the range of common epoxy CTEs. In addition, the inherent flexibility and the elongation capability of IMP's polyurethane will allow it to move with other composite structures, regardless of the CTE characteristics of a particular composite structure. Also, since IMP's polyurethane will not shrink at the sub-micron level, no external stress would be applied to a composite structure using IMP's polyurethane as a waterproof coating. If a heat source caused the epoxy in the polyurethane coated composite structure to shrink, the flexibility of the polyurethane would maintain adhesion to the epoxy and the composite structure.

During the original arguments presented to the Ballistic Missile Defense Organization to win this SBIR, IMP stated the resin had the following potential applications:

Paint for ground vehicles, watercraft, and aircraft.

Sealant/anti-corrosion coating for helicopter rotor blades, fiberglass and other composite boat hulls, storage tanks, and firearms and ordnance.

Sealant, paint, and surface structure for movie set/theme parks scenery and props.

Spray applied resin for rapid construction of barricades and shelters on battlefields or during natural disasters.

Since the start of this BMDO SBIR, the potential uses for this material has skyrocketed. As an example, IMP found one unusual commercial application for the resin – horse hooves.

Horse hooves normally split due to impact pressure, environmental effects, and the effects over time of damage from horseshoe nails. Hooves can crack or splinter in the toe or outer wall and can break off an entire quarter, taking out the hoof wall. In addition, a hoof can be too short compared to the other three, either due to damage or genetic defect. The gait of a horse may need improving due to uneven hoof wear. Products have been available for years to repair damaged feet, for balancing feet, for cosmetic improvements, as an adhesive for prosthetic devices, and for lengthening feet.

The hoof is a very tough location to apply a plastic adhesive or filler. In addition to the force impact on the plastic, the hoof not only is constantly changing shape due to growth but also exudes body oils which affect the adhesion of the plastic materials. Imagine the physical environment the horse hoof is subjected to. The thermoplastics currently available to repair hooves last only 2 to 3 weeks, have moisture absorption problems, are difficult to apply and finish, and have noxious odors and toxic fumes.

IMP's polyurethane has now been tried as a horse hoof repair material on several horses. The polyurethane has survived between re-shoeing operations, usually between 6 to 8 weeks, without failing. Generally, IMP's polyurethane does not need to be replaced when the hoof is re-shoed, because the bond adhesion remains adequate as the hoof material grows. The polyurethane's elasticity and elongation capability, extremely rapid room temperature cure, and extreme water resistance are critical to the horse hoof application.

Other applications for the polyurethane resin system include the coating of off shore oil drilling platforms, particularly the submerged portions, and the hulls of ships. The polyurethane is expected to stop saltwater corrosion and barnacle encrustation. Several fiberglass boat manufacturers and spa manufacturers are interested in either replacing their current gelcoat technology or adding an additional waterproof sealant coat with IMP's polyurethane resin system. Gelcoats absorb moisture and transfer it directly to the fiberglass and polyester resin, resulting in physical damage to the structure. This market could exceed $500,000,000.

Intel, Compaq, and Braun AG are interested in IMP's polyurethane as a conformal coating over electronic components, circuit chips, and circuit boards to prevent moisture absorption, corrosion, and electrical shorting. The epoxies currently used to embed electronic components in environmental and shock resistant encapsulations for commercial and military applications sometimes change shape due to moisture absorption or thermal cycling. Most of the high performance polymer hermetic sealants used in the electronics industry for encapsulation are heat cured epoxy resins, in which the applied heat may directly affect some of the electronic components. During the heat cure while the epoxy resin is still in the gel phase, the resin will slip around the components. When the resin sets and rigidly adheres to the components, the internal resin stresses become a force vector into the electronic components. Micro-cracking from internal stresses and porosities will allow moisture to penetrate to the inside of the sealant material. During thermal cycling, the epoxy can go into a post cure and shrink, if its original cure temperature is exceeded, thus shearing off electrical connections inside the encapsulation as the epoxy shrinks. Since IMP's polyurethane has such a high waterproofing capability, excellent elasticity and elongation rates, withstands high heat loads generated by electronics, and is a room temperature cure that is resistant to post cure effects, this new polyurethane would be an excellent candidate as a hermetic sealant for conformal coatings and for encapsulating electronic components and devices.

IMP's room temperature 3-minute cure polyurethane has found a commercial application within the entertainment industry. IMP's durable waterproof polyurethane is an excellent coating and sealant for hard polyurethane sculpting foam, high-density polyurethane foam, and solid gypsum sculptures. The potential customers include, but are not limited to, entertainment theme parks, set design for the motion picture industry, and ornate architectural design for hotels and other high value structures. The orders for these applications are pending. The potential value of this market has been estimated at over $100,000,000 per year.

An extremely durable and waterproof polyurethane paint is in great demand within the automotive and watercraft industries. IMP's polyurethane can fulfill this need. In addition to protecting all aircraft structures and surfaces, both metal and composite, the polyurethane may have another side benefit as an aircraft de-icer. IMP has discovered that if the polyurethane is sprayed upon a body of water, the polyurethane will cure *on top of the water and form a homogeneous film.* Water does *not* want to interfere with the cross-linking during the cure of IMP's polyurethane, due to the lack of bonding between the polar water and non-polar polyurethane. In addition, the lack of surface porosity, as demonstrated by the water vapor permeability testing, would also be of great benefit by reducing the adhesive forces of capillary attraction. If that is the case, IMP's polyurethane paint on an aircraft may become an automatic de-icer. Further study will be done to determine whether it may be possible to eliminate glycol usage during winter de-icing of aircraft.

IMP's polyurethane may provide an additional safety aspect for all manned aircraft. One leading theory concerning the destruction of TWA Flight 800 is that an electrical arc from the fuel pump and sensor system inside the center fuselage tank ignited fuel vapors mixed with air, causing the fuel/air explosion that ripped the 747 apart. IMP would propose coating the entire inside of ***all*** aviation fuel tanks, whether wing or fuselage mounted, with IMP's waterproof polyurethane resin system. The polyurethane should have a very high electrical insulating factor, which would prevent an electrical malfunction from grounding to the metal fuel tank, preventing an electrical arc from occurring. In addition, the polyurethane would protect the fuel tank from moisture corrosion. Even fuel tanks in military aircraft, which are protected by self-sealing fuel bladders and plastic foam dispersions inside the tanks and bladders, would benefit from having the metal portions of the fuel tank protected with the waterproof polyurethane. As of the middle of February 1998, the National Transportation Safety Board is recommending to the Federal Aviation Administration to issue an order requiring that all wiring contained within the center fuselage tank of every Boeing 747 be inspected for cracked insulation.

Besides these government and commercial applications, the resin has a guaranteed longevity in the market for the coming years because it does not give off VOCs. The following is what the **Environmental Protection Agency (EPA)** had to say regarding IMP's new polyurethane resin:

"Success of this project would have significant impact on the objectives of the Pollution Prevention topic."

"Development of a polyurethane coating without VOCs and a three-minute cure time is both innovative and original."

"There are major environmental benefits associated with the ability to remove VOCs from this product."

"If successful, there will be significant commercial application particularly in the pollution prevention arena and the industrial coating sector."

The following companies are immediately interested in the polyurethane resin system developed and manufactured by IMP:

Shell/Exxon = anti-corrosion coating system for off-shore oil drilling platforms, above and below the waterline.

Learjet and Gulfstream Aerospace = exterior paint system for aircraft.

Kurt Boyd Enterprises = horse hoof repair (already being used commercially).

Intel, Braun AG, and General Electric = sealant and encapsulant for electronic components and assemblies.

Disney and Six Flags = durable coating for water rides and architectural theme designs.

Watkins Spas and Spas Technologies, Ltd. = replace all gelcoats on new manufactured and rebuilt spas.

W.L. Gore & Associates = adhesives and sealants.

Lord Corp., Easton Company, Taylor Corp., and G.T. Bicycles = waterproof sealant and paint for composites.

General Motors = exterior automotive paint.

Robert Bookwalter Company = waterproof sealant for steel cable systems for rock slide protection for highways.

U.S. Marine Byline and Columbia Sentinel Engineering = replace all gelcoats on watercraft hulls and exterior paint for watercraft, above and below waterline.

M.B.C.I. = waterproof sealant for metal panels.

Dinaudio = waterproof sealant for speaker cones.

IMP's waterproof, sprayable, injectable, room temperature 3-minute cure polyurethane resin system is currently available at low scale production rates. Licensing agreements have been entered into for increased production to meet expected demand for marketing and sales.

A two component airless spray system, manufactured by Binks Sames, is available to apply the polyurethane to any surface. In addition, IMP has secured a licensing agreement from Binks Sames which gives IMP the right to be the sole United States and worldwide distributor for this very same dual component spray system, when used in conjunction with IMP's polyurethane. This agreement covers ***any*** market in which IMP's polyurethane may be used.

R&D will continue to explore modifications to the spray technology for different applications. The method of injecting the polyurethane into a form or mold will be further expanded.

Several investment groups are currently evaluating IMP's business plan with the intent of investing large sums of capital in IMP to enable full scale manufacturing, set up marketing and distribution networks for sales, and expand the R&D group for product development.

IMPLICATIONS FOR FURTHER RESEARCH:

Modification and optimization of IMP's polyurethane resin system will be carried out in Phase 2. Any modifications to the chemical formulation to improve the performance of the polyurethane will occur in the Phase 2 effort and will be proprietary. Examples of modifications will include, but are not limited to:

- introducing pigments to the clear polyurethane resin to formulate paints in gloss, semi-gloss, and flat colors for both military and civilian applications.
- creating specific primers and/or surface preparation systems to give the optimum adhesion for the polyurethane to each type of material and surface.
- optimizing the best formulation for horse hooves.
- enabling the polyurethane to wet cloth (carbon, fiberglass, Kevlar®, etc.) for instantaneous composite layups and patch repairs.
- determining how thin a layer of polyurethane is needed for corrosion protection.
- perfecting a spray method for thin layers (.0005 inch or less).

In addition during Phase 2, IMP will be evaluating various flame inhibitor additives. The combustion toxic by-product testing is expected to establish the baseline IMP will use to modify the resin to minimize combustion toxic by-product generation. IMP will use the results in its formulation to achieve the highest fireproofing capability possible for the polyurethane resin system.

The ultimate result will be a room temperature cure polyurethane which will be capable of coating and sealing most types of composite components and structures and metal surfaces for protection from the environment. The immediate benefit will be stronger, more durable, and waterproof aerospace CFRP composite components and structures, coated and sealed with a polyurethane which has no VOCs to create manufacturing liability or to pollute the environment. The long term benefit will be a polyurethane resin system that will replace other polyurethane coatings which pollute the environment.

The following testing will be performed in Phase 2:

1) Volatile Organic Compounds (ASTM D 3960/EPA 24).
2) Flash Point, Resin (ASTM D 92 or D 93).
3) Flash Point, Hardener (ASTM D 92).
4) Ignition Point, Cured Product (ASTM D 19290).
5) Smoke Generation (ASTM E 662).
6) Combustion By-Products (BSS 7239 Airbus, and ATS 1000.001). (The combustion by-products, that are tested for in the Airbus specification, are as follows: Carbon Monoxide, Hydrogen Fluoride, Hydrogen Chloride, Nitrous Gases, Sulfur Dioxide, and Hydrogen Cyanide.)
7) Surface Burning Characteristics (ASTM E 84-95b).
8) Flame Spread and Smoke Developed Values, Classification (UBC 42-1 [8-1]).
9) The polyurethane resin system will be tested in Phase 2 according to the stated

requirements of Military Specification MIL-C-85285B, with particular emphasis placed on the portions relating to volatiles and VOCs. The reason this Mil-Spec testing must be reserved for phase 2 is the requirement for a *one year* environmental outside exposure test conducted in Key West, Florida, (Page 8, paragraph 3.8.2 of the Mil-Spec document).

10) Chemical Resistance.
11) Shelf Life and Performance Over Time as a Function of Storage Duration.
12) Material Surface Preparation Requirements.
13) Primer Requirements, Military Specification MIL-P-23377.
14) Adhesion Requirements on Different Substrates.
15)Abrasion Resistance.
16) Shrink Rate.
17) Bell Jar Pressure Testing, both Ambient and Accelerated Life Cycle.
18) Helium Vapor Penetration, Ability to Prevent Helium from Passing Through the Material.
19) Vacuum Chamber Outgassing.
20) Mono-Atomic Oxygen Resistance.
21) Freeze Thaw Cycling ASTM C 67 @ 60 cycles and ASTM C 666 @ 300 cycles.
22) Salt Spray Resistance ASTM B 117 @ 14 days.
23) Copper Accelerated Acetic Acid Salt Spray ASTM B 368 @ 44 hours.
24) Weathering, Ultra-Violet Exposure ASTM G 23, Method 1.
25) Ability to Resist Vibrational Frequencies, i.e. space launch vehicles, combat aircraft.
26) Ability to Resist Barnacle and Algae Adhesion.
27) Dielectric Breakdown ASTM D 149.
28) Flex to Burst ASTM D 1037 (Modified) or ANSI/SAE Z 26.1.

SIGNIFICANT HARDWARE DEVELOPMENT:

Since the cure time for the polyurethane resin system is only 3-minutes, it has been difficult to apply the resin to a surface using conventional methods and equipment. It was necessary to work directly with the Binks Sames Corporation to find and modify a spray gun system that would be useful. Fortunately, a small subsidiary company belonging to Binks Sames manufactures, on a customer demand basis, an airless spray gun system that, when modified, works with IMP's 3-minute cure polyurethane. The system is a two component airless spray gun with dual tanks for the A (resin) and B (hardener) components, dual transfer pumps, dual airless delivery system, dual heaters and heated delivery lines, and specialized sprayer nozzles and extension tips. This impingement spraying system mixes the two components at the spray tip, allowing the use of only the amount of material sprayed, and keeping the two components always separate until the polyurethane material leaves the nozzle.

An isolated dual component caulk gun, that would squeeze correct amounts of the A (resin) and B (hardener) component through a special long spiral mixing tip into the appropriate molds to make sample slabs of polyurethane for physical property testing, was located, modified, and developed into a viable alternative method for applying large quantities of the polyurethane material. When the horse hoof application for IMP's polyurethane appeared, this two component caulk gun system proved to be ideal for delivering the polyurethane to the horse hoof to facilitate the repair. IMP will recommend this caulk gun system for any application requiring the use of the polyurethane resin system to make objects with a mold or form. The development of this caulk gun system was a bonus added into the Phase 1 contract by IMP.

SPECIAL COMMENTS:

At the conclusion of this Phase 1 contract, IMP has not been able to identify any safety hazards or any special handling problems with the polyurethane resin system. IMP's polyurethane appears to be very environmentally friendly, without any unexpected consequences.

There is only one physical property assumption IMP made concerning the polyurethane that proved to be incorrect. That assumption was stating a Shore D Hardness of 85. Instead, the polyurethane had a Shore D Hardness of 73, which, as it turned out, was better. The lower Shore D Hardness of 73 went hand-in-hand with the 17.1% elongation rating. The test data simply proved the ability of the polyurethane to withstand and survive impacts, which would shatter all other materials currently used for aerospace coatings.

The continued R&D and testing specified above for the Phase 2 program will prove that IMP's polyurethane is the superior product for aerospace and deep space applications and will provide a very durable, economical, environmentally friendly, and superior product for civilian commercial applications.

Finally, IMP would like to thank BMDO for its support, without which none of these successes would have been possible. As a brand new small company, IMP did not have the resources available to make the contacts and do the research to make any of these advancements possible. IMP is indebted to Jeff Bond for believing in this technology. Again, thank you for your support. IMP will look forward to working with you on the Phase 2 project.

APPENDIX

List of Illustrations

1) Initial claims as to the assumed and projected properties of the polyurethane.

2) ASTM Test Standards used in testing the polyurethane.

3) Physical properties of the polyurethane determined through ASTM testing.

4) Description of ASTM E 96 Standard test, water vapor transmission, inverted water cup.

5) Physical property comparison between the polyurethane and 3 popular epoxies.

6) Properties of various plastic coating materials compared to the polyurethane.

7) Properties of a typical aerospace polyurethane paint in current use.

8) Comments from the EPA concerning the polyurethane.

9) Commercial applications for the polyurethane.

10) Companies currently interested in immediately using the polyurethane.

11) Continued testing of the polyurethane to be performed in Phase 2.

12) Modifications of the polyurethane to be performed in Phase 2.

13) Binks Formulator "K" and Model 43P Spray Gun.

14) Binks Formulator "K" airless impingement spray system.

15) Horse hoof repair application using the polyurethane.

16) Dual cylinder caulk gun for applying the polyurethane to molds and forms and horse hooves.

Initially, IMP made the following claims as to the assumed and projected properties this very innovative polyurethane resin system:

1) No VOCs.

2) Waterproof.

3) Room temperature 3 minute cure, *only*, with absolutely no post cure of any type.

4) No shrinkage or micro-cracking.

5) Ultraviolet proof.

6) Chemically resistant.

7) Extremely excellent adhesion properties.

8) Shore D Hardness of 85

IMP's polyurethane resin system was tested to the following ASTM Standards for the physical properties listed:

1) Shore D Hardness (ASTM D 2240)

2) Tensile Strength in psi (ASTM D 638)

3) Compressive Strength in psi (ASTM D 695)

4) Flexural Strength in psi (ASTM D 790)

5) Glass Transition Temperature (Tg) in degrees F (ASTM D 3418)

6) Vapor Permeability (the degree to which the resin is waterproof) (ASTM E 96)

7) Coefficient of Thermal Expansion (ASTM D 696)

ASTM PHYSICAL PROPERTY TESTING FOR IMP'S POLYURETHANE RESIN SYSTEM

1) Shore D Hardness (ASTM D 2240) =	73
2) Tensile Strength in psi (ASTM D 638) =	4,300 psi
Modulus =	274,000 psi
Elongation =	17.1 %
3) Compressive Strength in psi (ASTM D 695) =	3,190 psi
Modulus =	100,000 psi
4) Flexural Strength in psi (ASTM D 790) =	4,160 psi
Modulus =	132,000 psi
5) Glass Transition Temperature (Tg) (ASTM D 3418) =	165.3°C or 329.5°F
6) Coefficient of Thermal Expansion (ASTM D 696) =	9.76×10^{-5} in./in./°C or 5.42×10^{-5} in./in./°F
7) Water Vapor Permeance (ASTM E 96) =	.193 perms

A perm = grains per hour per foot squared per inch of mercury.
A number lower than "one perm" is very low. A number in the low tenths is very, very low.

(Compare to Duplex sheet, asphalt laminated, aluminum foil, roofing material which equals 0.176 perms.)

ASTM E 96 Standard testing-inverted water method.

1) Thwing-Albert water vapor permeability cups were filled with water and sealed to the polyurethane test specimens with a composite wax composed of 60% white beeswax and 40% Fisher Tissueprep.

2) Molten asphalt or wax is required for permeance tests below **4** perms.

3) The cups are then inverted with:

A) the polyurethane test specimens on the bottom

B) the water volume above the test specimens

C) standard atmospheric pressure below the test specimens

D) the natural tendency for equilibrium to be established between two differential pressures by osmosis through the test specimens

E) a driving force of the mass of 100% water above the test specimens with gravity trying to drive the water vapor through the test specimens

4) This ASTM test is an active, dynamic test.

5) Weight measurements are taken every 24 hours to check water mass gain on the surface of the test specimens, per unit surface area.

PHYSICAL PROPERTIES

	IMP's Polyurethane	AKEMI AS 2203-1	AKEMI AL 2108	BRYTE EX-1515
Tensile Strength	4,300 psi	4,900 psi	7,000 psi	Data is not available as a neat resin. Only available data is with the resin inside a laminate.
Flexural Strength	4,160 psi	8,800 psi	13,000 psi	
Flexural Modulus	132,000 psi	699,000 psi	600,000 psi	
Compression Strength	3,190 psi	11,500 psi	14,000 psi	"
Elongation	17.1 %	not available	not available	not available
Shore D Hardness	73	83	85-90	not available
Coef. Thermal Exp. (CTE)	9.76 x 10^{-5} in./in./°C	7.74 x 10^{-5} in./in./°C	6.12 x 10^{-5} in./in./°C	3.4 x 10^{-5} in./in./°C
Water Vapor Permeance	.193 perms (grains/ft^2 · hr · in.H_g) (ASTM E 96 Standard)	not available	not available	0.04% ***water absorption***, tested within a P75 laminate @ 27°C & 85% relative humidity. This test is ***not*** an ASTM test Standard.
Glass Transition Temp. (T_g)	165.3°C	73°C	68°C	134°C cured @ 121°C 177°C post cured @ 177°C
Cure Cycle	3 minute room temp.	8-12 hrs. room temp. 7 days complete cure.	8-12 hrs. room temp. 7 days complete cure.	Heat cure, 4 hours @ 250°F, can be post cured @ 350°F.

PROPERTIES OF VARIOUS PLASTIC AND THERMOPLASTIC COATING MATERIALS

MATERIAL	T_g °C	CTE In./in./°C	ELONGATION	WATER ABSORPTION ASTM D 570, 24 hr., except as indicated
Epoxy-Glass Laminate	130	4.5×10^{-5}	----	0.3 %
Polyimide-Glass Laminate	220	1.4×10^{-5}	----	0.4 %
Dow Chem. Quatrex 5010 (Shell RSM-1151)	180	5.5×10^{-5}	2.4 %	1.6 %
Cyanate-Ester Epoxies	260	4.8×10^{-5}	2.2 %	1.0 %
Bisphenol Epoxy	----	3.3×10^{-5}	4.4 %	----
Polyimide Neat Resin	300	5×10^{-5}	----	0.3%
Bismaleimide + Aromatic Amine Neat Resin	275	5×10^{-5}	----	1.7 %
Compimide-Bismaleimide C795	290	7.34×10^{-5}	2.4 %	4.85%
FIBERITE X-86 (Bismal.)	290	----	----	4.4% (water boil)
FIBERITE 987A (Bismal.)	320	----	----	2.97% (water boil)
HEXEL F650 (Bismal.)	316	----	----	4.3%
AKEMI AS 2203-1	73	7.74×10^{-5}	----	----
AKEMI AL 2108	68	6.12×10^{-5}	----	----
BRYTE EX-1515	134 or 177	3.4×10^{-5}	----	0.04 % ***NOT*** ASTM D 570
IMP's Polyurethane	165.3	9.76×10^{-5}	17 %	0.193 perms @ grains/ft^2 · hr · in.H_g ASTM E 96 Water vapor *permeance*. Material does not absorb water.

Duplex sheet, asphalt laminated, aluminum foil, roofing material = 0.176 perms

PROPERTIES OF A TYPICAL POLYURETHANE PAINT SYSTEM CURRENTLY IN USE FOR MILITARY AND CIVILIAN AEROSPACE VEHICLES

AWLGRIP® / ALUMIGRIP®	TOPCOAT CONVERTER
Formula Weight = 8.38-9.94 lbs./gal.	Formula Weight = 8.35 lbs./gal.
VOC of Material = 5.78-6.15 lbs./gal.	VOC of Material = 4.87 lbs./gal.
% Volatile by Weight = 58-68	% Volatile by Weight = 58.27
% Volatile by Volume = 73-81	% Volatile by Volume = 63.32

Continuous Operating Temperature Limit = 150°F
Intermittent Temperature Limit = 225°F
Cure Time @ 77°F / 50% R.H. = 24 hours to tape free, 2-3 days full cure

(The above information is from U.S. Paint Corporation data sheets.)

IMP's polyurethane has a much higher operating temperature in the 300°F range. IMP believes there are ***no*** VOC's given off by the polyurethane resin system, because the polyurethane has no solvents in its formulation. ASTM D 3960/EPA 24 (VOCs) Standards testing could not be performed during Phase 1 due to cost. This test will be performed in Phase 2.

The following comments were made by the Environmental Protection Agency concerning IMP's polyurethane:

"Success of this project would have significant impact on the objectives of the Pollution Prevention topic."

"Development of a polyurethane coating without VOCs and a three-minute cure time is both innovative and original."

"There are major environmental benefits associated with the ability to remove VOCs from this product."

"If successful, there will be significant commercial application particularly in the pollution prevention arena and the industrial coating sector."

APPLICATIONS FOR IMP's 3 MINUTE CURE, WATERPROOF POLYURETHANE RESIN SYSTEM

1) PAINT FOR ALL TYPES OF MATERIALS:

DOD = Aerospace; All Ground Vehicles & Equipment; Watercraft.

CIVIL = Aircraft; Boats & Ships; Construction Equipment; Automobiles (Paint will match on metal & plastic adjacent panels.).

NASA = Spacecraft.

2) WATERPROOF SEALING & ANTI-CORROSION COATING:

HELICOPTER ROTOR BLADES = DOD & CIVIL.

SEAL GEL COATS FOR FIBERGLASS & OTHER COMPOSITE BOAT HULLS = DOD & CIVIL.

SEAL GEL COATS FOR ALL SPAS AND WHIRLPOOLS = CIVIL

CHEMICAL & INFLAMMABLE LIQUID STORAGE TANKS = DOD & CIVIL.

FIREARMS & ORDNANCE = DOD & CIVIL.

COATING METAL HULLS OF SHIPS = DOD & CIVIL

COATING COMPLETE OFF SHORE OIL WELL DRILLING PLATFORMS = CIVIL

CONFORMAL COATING OVER ELECTRONIC COMPONENTS = DOD & CIVIL

REPAIRING AND RESHAPING HORSE HOOVES = CIVIL

3) CONSTRUCTION:

PROPS & SETS FOR MOVIE & STAGE COMPANIES & THEME PARKS = Seal Surfaces Of Foam Props.

RAPID CONSTRUCTION OF BARRICADES, OBSTACLES, & SHELTERS ON BATTLEFIELDS = Marine Corps Combat Engineers For Beachhead Assault; Air Force Combat Engineers At Forward Secured Air Bases; **ALSO** Civilian Emergency Services During Natural Disasters.

4) ADHESIVE: Mounting of glass optics for laser applications.

The following companies are immediately interested in the polyurethane resin system developed and manufactured by IMP:

Shell/Exxon = anti-corrosion coating system for off-shore oil drilling platforms, above and below the waterline.

Learjet and Gulfstream Aerospace = exterior paint system for aircraft.

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M.B.C.I. = waterproof sealant for metal panels.

Dinaudio = waterproof sealant for speaker cones.

The following testing will be performed in Phase 2. Some of this testing is quite long in duration:

1) Volatile Organic Compounds (ASTM D 3960/EPA 24).
2) Flash Point, Resin (ASTM D 92 or D 93).
3) Flash Point, Hardener (ASTM D 92).
4) Ignition Point, Cured Product (ASTM D 19290).
5) Smoke Generation (ASTM E 662).
6) Combustion By-Products (BSS 7239 Airbus, and ATS 1000.001). (The combustion by-products, that are tested for in the Airbus specification, are as follows: Carbon Monoxide, Hydrogen Fluoride, Hydrogen Chloride, Nitrous Gases, Sulfur Dioxide, and Hydrogen Cyanide.)
7) Surface Burning Characteristics (ASTM E 84-95b).
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9) The polyurethane resin system will be tested in Phase 2 according to the stated requirements of Military Specification MIL-C-85285B, with particular emphasis placed on the portions relating to volatiles and VOCs. The reason this Mil-Spec testing must be reserved for phase 2 is the requirement for a <u>*one year*</u> environmental outside exposure test conducted in Key West, Florida, (Page 8, paragraph 3.8.2 of the Mil-Spec document).
10) Chemical Resistance.
11) Shelf Life and Performance Over Time as a Function of Storage Duration.
12) Material Surface Preparation Requirements.
13) Primer Requirements, Military Specification MIL-P-23377.
14) Adhesion Requirements on Different Substrates.
15)Abrasion Resistance.
16) Shrink Rate.
17) Bell Jar Pressure Testing, both Ambient and Accelerated Life Cycle.
18) Helium Vapor Penetration, Ability to Prevent Helium from Passing Through the Material.
19) Vacuum Chamber Outgassing.
20) Mono-Atomic Oxygen Resistance.
21) Freeze Thaw Cycling ASTM C 67 @ 60 cycles and ASTM C 666 @ 300 cycles.
22) Salt Spray Resistance ASTM B 117 @ 14 days.
23) Copper Accelerated Acetic Acid Salt Spray ASTM B 368 @ 44 hours.
24) Weathering, Ultra-Violet Exposure ASTM G 23, Method 1.
25) Ability to Resist Vibrational Frequencies, i.e. space launch vehicles, combat aircraft.
26) Ability to Resist Barnacle and Algae Adhesion.
27) Dielectric Breakdown ASTM D 149.
28) Flex to Burst ASTM D 1037 (Modified) or ANSI/SAE Z 26.1.

Examples of modifications to be performed in Phase 2 will include, but are not limited to:

1) Introducing pigments to the clear polyurethane resin to formulate paints in gloss, semi-gloss, and flat colors for both military and civilian applications.

2) Creating specific primers and/or surface preparation systems to give the optimum adhesion for the polyurethane to each type of material and surface.

3) Optimizing the best formulation for horse hooves.

4) Enabling the polyurethane to wet cloth (carbon, fiberglass, Kevlar®, etc.) for instantaneous composite layups and patch repairs.

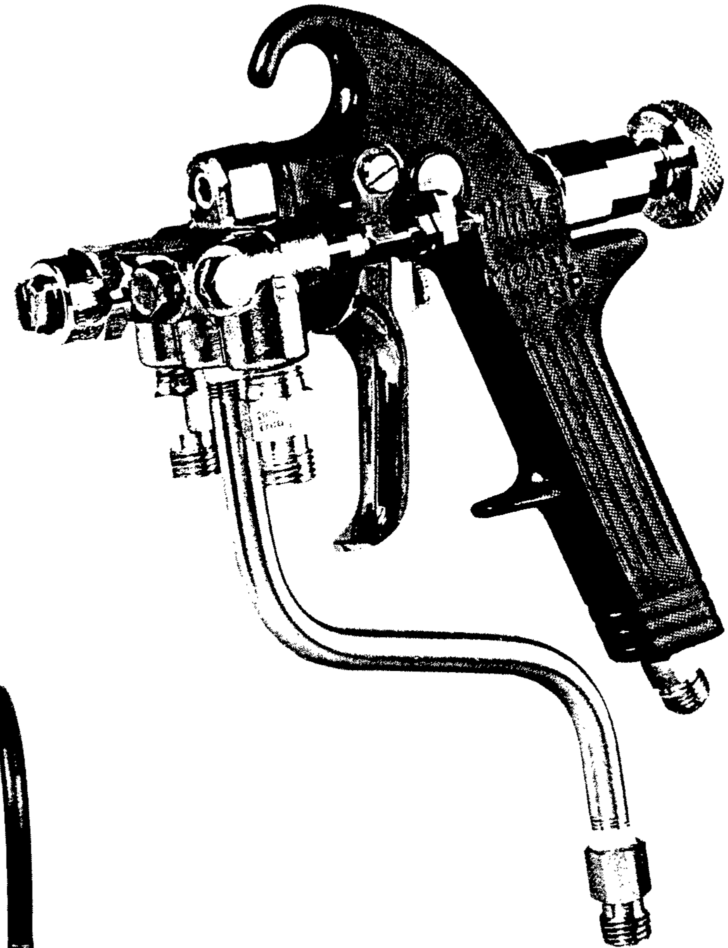
5) Determining how thin a layer of polyurethane is needed for corrosion protection.

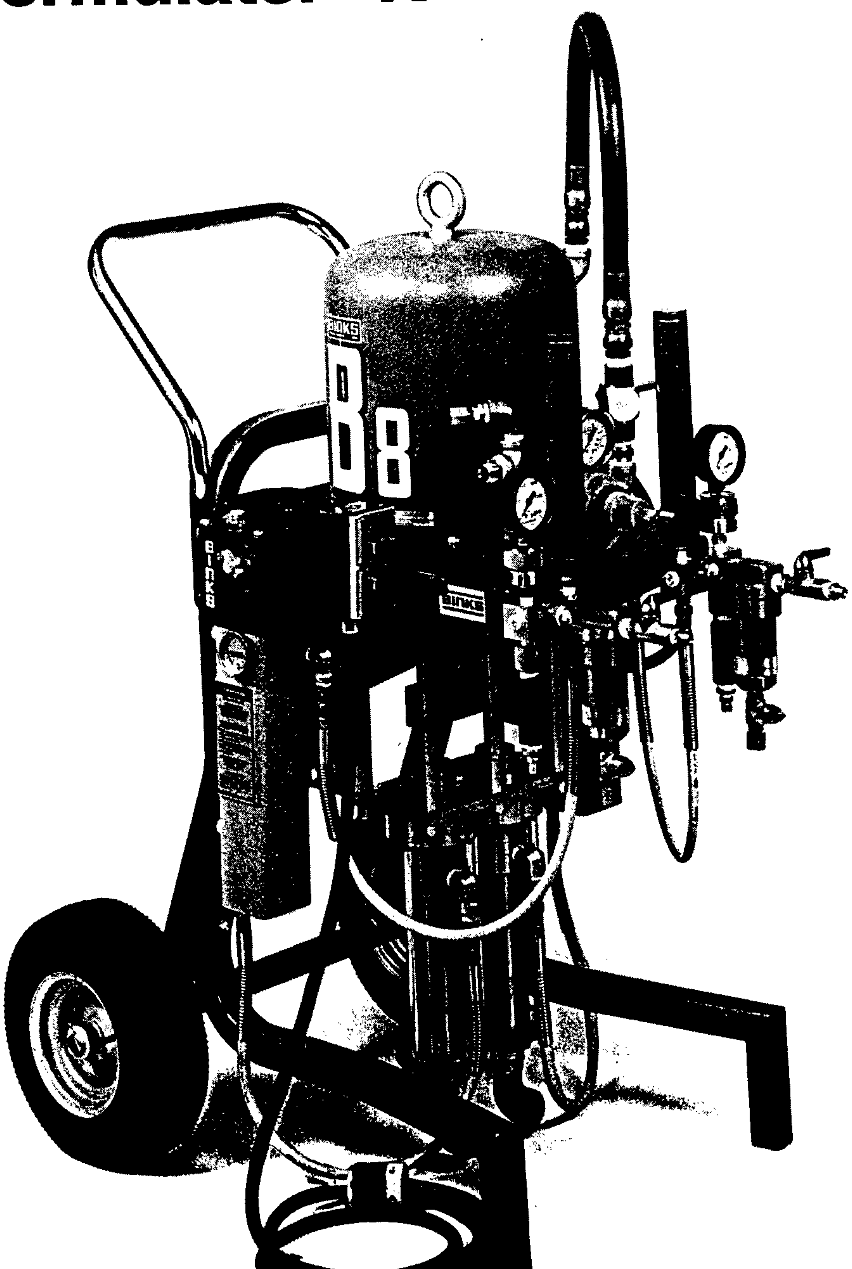
6) Perfecting a spray method for thin layers (.0005 inch or less).

7) Evaluate various flame inhibitor additives to achieve the highest fireproofing capability possible for the polyurethane resin system.

BINKS

Formulator "K"

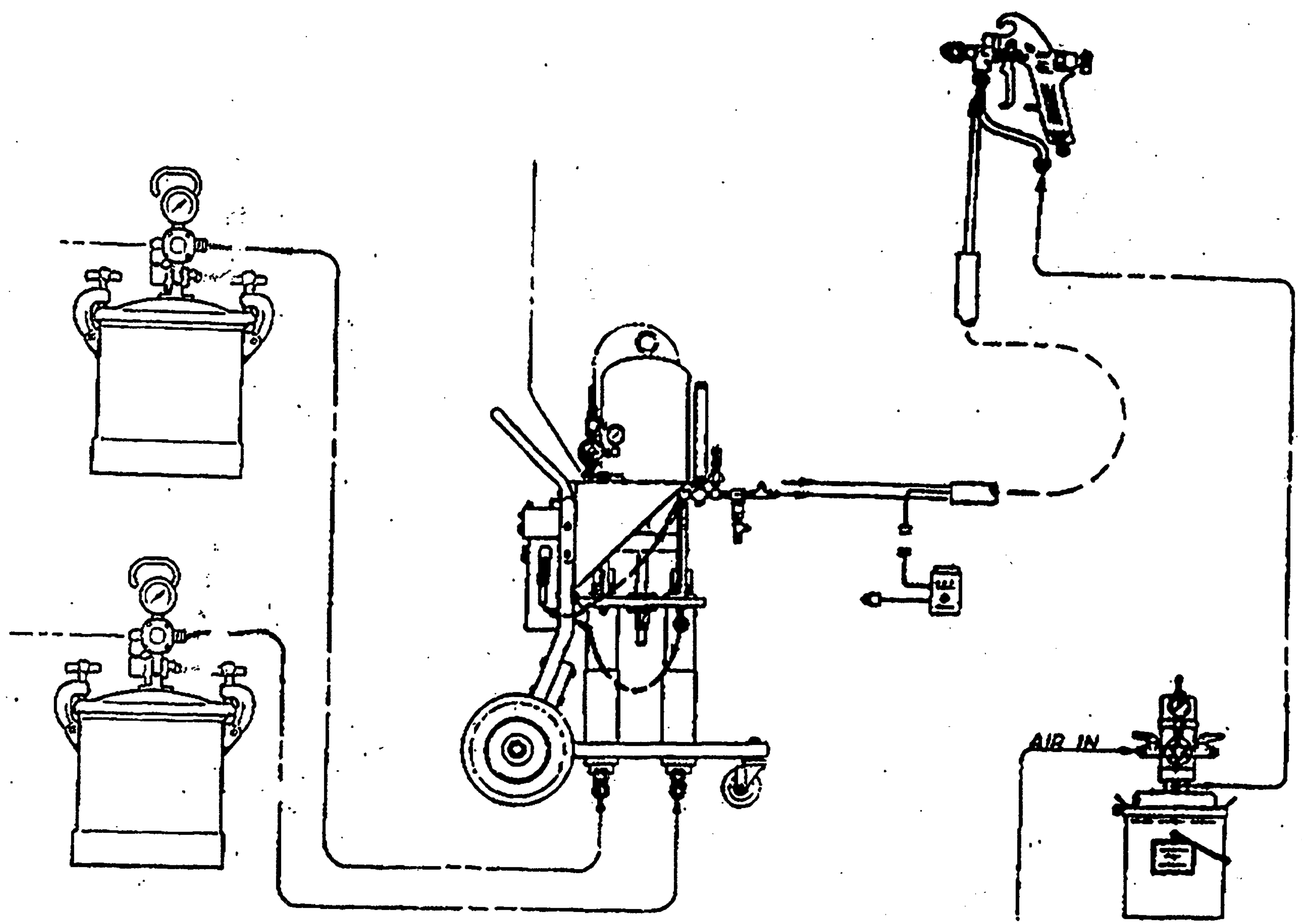


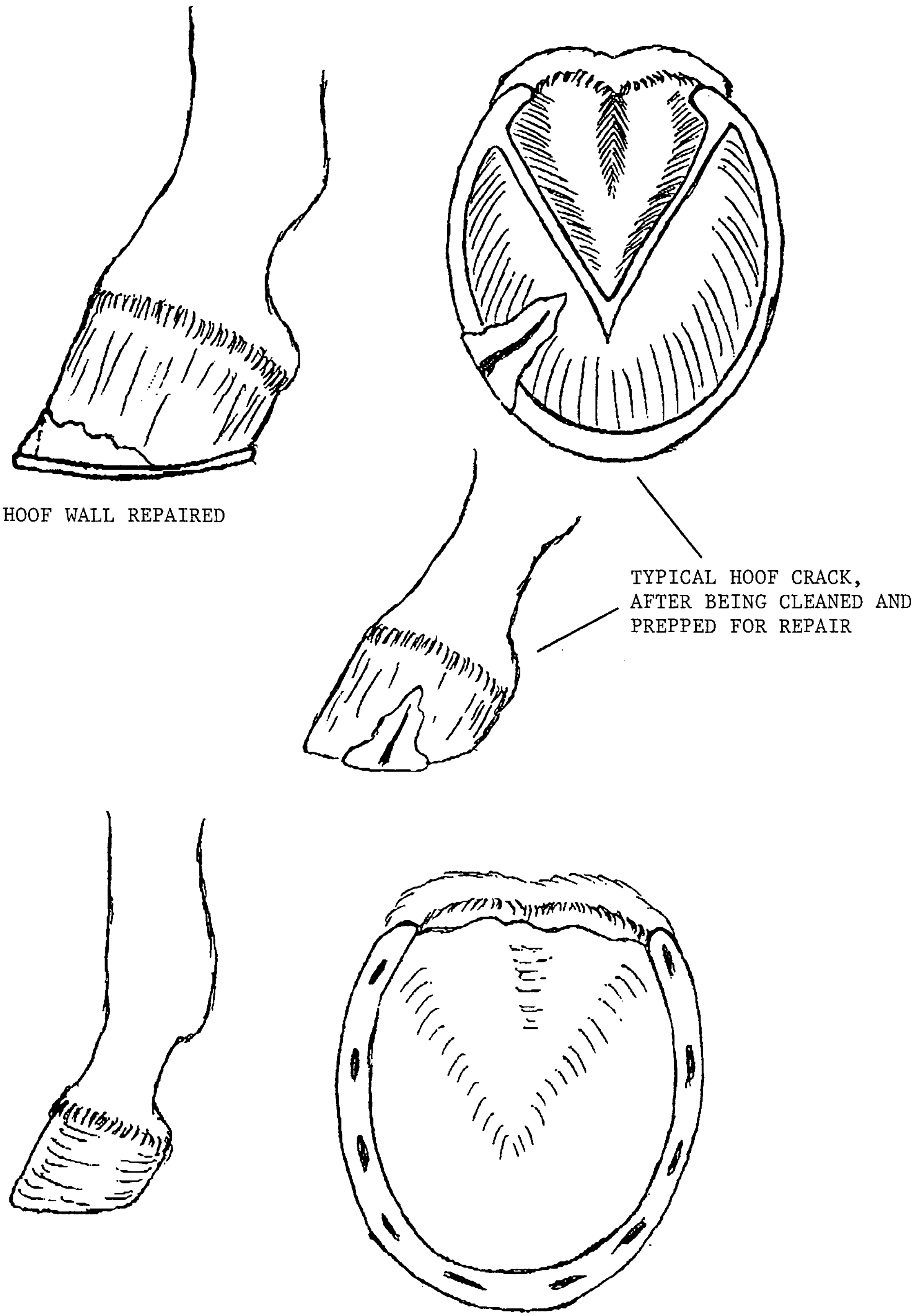


Model 43P Spray Gun

BINKS FORMULATOR "K" AIRLESS IMPINGEMENT SPRAY SYSTEM

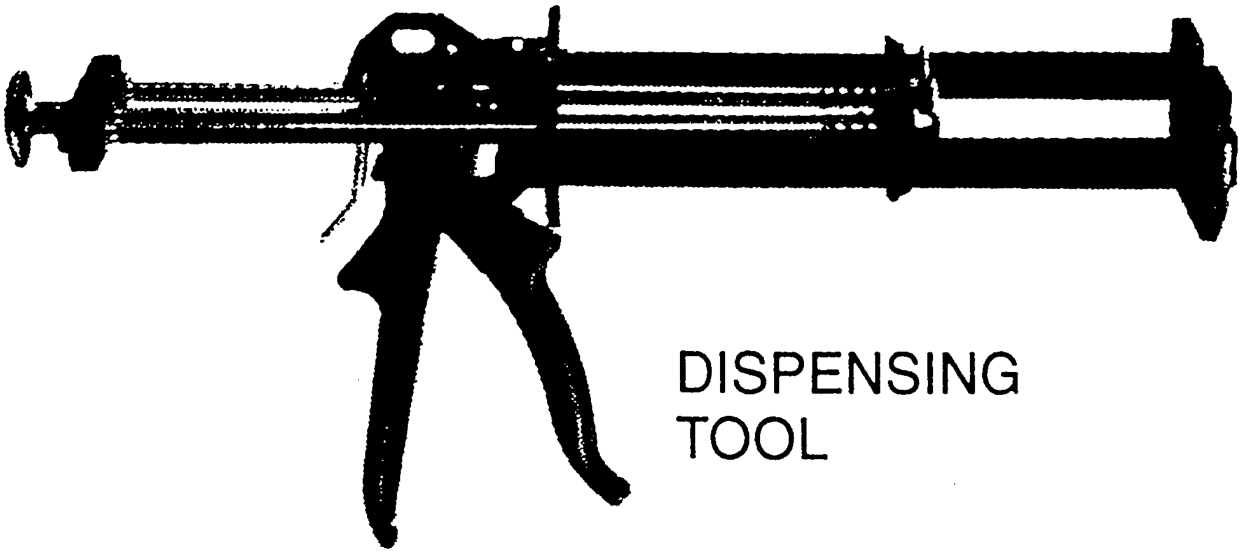
for the contractor's 3 minute cure, waterproof polyurethane enamel



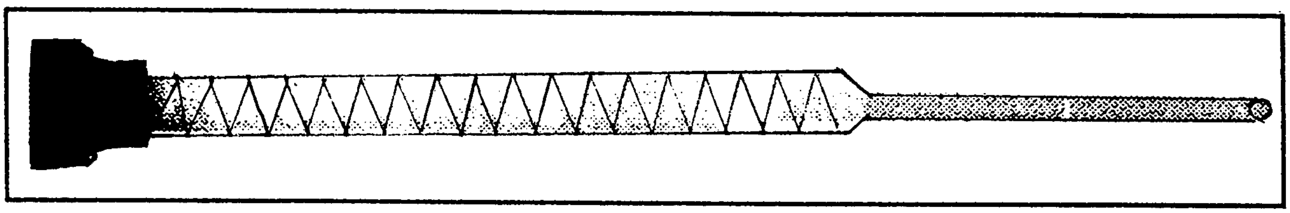


HORSE HOOF REPAIR APPLICATION FOR IMP'S POLYURETHANE

DUAL CYLINDER CAULK GUN FOR IMP'S 3-MINUTE CURE, WATERPROOF POLYURETHANE RESIN SYSTEM. USED TO INJECT MATERIAL INTO MOLDS AND FORMS AND FOR HORSE HOOF REPAIR.



DISPENSING TOOL



MIXING NOZZLE

DUAL CYLINDER UNIT FOR CAULK GUN