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AEROSPACE INFORMATION REPORT

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Aircraft Sealant Removal Techniques

RATIONALE

This Aerospace Information Report is being created to provide information on the possible methods of sealant removal.

INTRODUCTION

The goal of this Aerospace Information Report entitled "Aircraft Sealant Removal Techniques" is to provide information on the possible methods of sealant removal. The report will compare methods and give the strengths and weaknesses of each method. Finally, there is an analysis chart to help the user determine the best method for their application.

FOREWORD

Some of the information in this report was taken from a previous AFRL aircraft coating removal study performed by the University of Dayton Research Institute (UDRI)[1] as well as other deseal/reseal programs including F-111, B-1, Joint STARS, KC-10, KC-135.

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[1] AFRL Contract F33615-95-D-5516, UDRI Study "Rapid Removal of Radar Absorbing Coatings", UDR-TR-2000-00031, February 2000.

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1. SCOPE

This SAE Aerospace Information Report (AIR) provides information on the possible methods of sealant removal. The discussion will focus on the methods of sealant removal and give the strengths and weaknesses of each method.

1.1 Purpose

The purpose of this document is to assist those concerned with aircraft sealant removal to choose the best available method for their purpose considering a number of factors. Recognition of the ESOH (Environmental, Safety, and Occupational Health) hazards involved in the traditional (chemical based) sealant removal processes as well as the ever increasing cost of the associated waste disposal involved, prompted the DOD to initiate a number of programs to test and evaluate alternative sealant removal processes, as well as, to develop new technology approaches. This DOD activity is also driven by the need to comply with numerous environmental regulations and statutes promulgated by the EPA (Environmental Protection Agency) initiatives to include: the Clean Water Act (CWA), Clean Air Act (CAA) amendments of 1990, the Resource Conservation and Recovery Act (RCRA) and the Occupational Safety and Health Act (OSHA).

1.2 Field of Application

The field of application includes aircraft sealant removal at the manufacturing, depot, and field levels.

2. APPLICABLE DOCUMENTS

Shall be in accordance with AS5502 (1.1).

2.1 UDRI Reports

UDR-TR-2000-00031, (February 2000) Rapid Removal of Radar Absorbing Coating.

3. BACKGROUND DISCUSSION

Sealant removal technology may conveniently be separated into four rather broad categories. These are Chemical, Biological, Mechanical and Thermal. A number of the processes available use a combination of the technology in these categories to ensure complete sealant removal. Traditional methods for the removal of sealants from aircraft structures and components involve the use of chemical formulations containing strong solvating chemicals such as methylene chloride (MECL) and methyl alcohol (MA) activated with strong organic acid or base materials. In most instances repeated applications of these formulations were required in order to remove multiple coats of sealant material. Scraping and/or sanding was required between applications of the strippers to remove the blistered and loosened sealant. This process involved the release of Ozone Depleting Chemicals (ODC), Volatile Organic Compounds (VOCs), Hazardous and Toxic vapors, (HAZTOX), Hazardous Air Pollutants (HAPs) as well as the production of large volumes of contaminated wastewater from the rinsing process that is required. These processes are still prevalent today but are not the only option, and likely not the best option.

This AIR will introduce you to currently available sealant strip methods and help you choose the best method for your application using the following attributes listed in Table 1.

TABLE 1 - ATTRIBUTES USED IN RATING/RANKING CURRENTLY AVAILABLE SEALANT REMOVAL METHODS

Process Attributes
1. ESOH (environmental/safety/occupational health)
2. Field level applicability
3. Portability/mobility/size
4. Potential for substrate damage
5. Cost to implement (equipment/training/waste disposal, etc.)
6. Process effectiveness (completeness of sealant removal)
7. Rate of sealant removal

4. REMOVAL METHODS

Currently used methods for the removal of sealants from aircraft surfaces, at the field level, involve the use of hand tools (scrapers) and/or solvent base strippers. The process is very time consuming and can result in damage to the aircraft substrate material.

Alternative sealant removal methods that are: safer, more environmentally friendly, faster, and lower cost can be viewed in terms of both alternative materials and alternative technologies or a combination of both. A listing of the processes presently in use or in the final stages of development is presented in Table 2.

TABLE 2 - SEALANT REMOVAL/CLEANING PROCESSES

Chemical	Biological	Mechanical	Thermal
Methyl Ethyl Ketone Methylene Chloride Methanol Thiolates dissolved in Dimethylformamide Sealant Removal Wipe Thixotropic Gels Soy Based Strippers Low VOC Non-Hazardous Solvents	Bacillus subtilis Proteus vulgarius Pseudomonas aeruginosa Streptoverticillium reticulum	Dry abrasive blasting Wet abrasive blasting Water jet blasting CO_2 pellet blasting Fluidized bed stripping Ice crystal blasting Ultrasonic activated knives and scrapers Ultrasonic jet Hand tools Power Hand Tools	Laser Flash Lamp Molten Salt Bath Cryogenic (liquid nitrogen)

4.1 Chemical Stripping

Sealant removal can be accomplished with chemical solvents that are far less hazardous than those used in traditional formulations. Such alternative stripping chemicals include SkyKleen®, Elixair® Skywipes, Elixair® Skywash, Elixair® Skyrestore, Poly-Gone 535, Franmar Soystrip, Polychem Acrastrip 600BL, and Solvent Solutions 75. The process utilized with this alternative material is essentially the same as that used with the traditional formulations, such as Methyl Ethyl Ketone (MEK) shown in Table 2. The stripping solution is sprayed or otherwise applied onto the work area to soften, blister or dissolve the sealant. Some form of mechanical action including hand scraping, brushing, CO_2 or water jet, etc then removes the loosened sealant. Rinsing may be required after using particular chemical sealant removers. Heat can be used to facilitate efficient rinsing. Multiple stripper applications and sealant removal steps are required in cases where many layers of sealant are encountered. The waste produced via the chemical stripping methods may or may not be a HAZTOX material depending upon the sealant formulation and the solvent chemicals chosen. Chemical stripping is very effective on sealant coated metallic surfaces due to the existence of a high impedance coating-metal interface and is probably one of the least likely processes to cause substrate damage. This is due to the relatively low levels of mechanical energy required to remove the softened sealant residue. Chemical stripping is not recommended for organic resin base composites (glass or carbon fiber reinforced plastics). The lack of a high impedance interface to stop the penetration of the stripper chemical allows the ready penetration into the composite substrate and the potential for substrate damage exists. The stripper cannot distinguish between the sealant and the urethane coatings and will soften the coating upon prolonged contact.

Chemical stripping via the use of more environmentally friendly chemicals and water free secondary sealant removal processes may be the process of choice for thin metallic substrates that may be damaged by the more aggressive methods. The pros and cons of chemical stripping sealant removal methods are shown in Table 3.

The two most common application techniques for chemical strippers are hand applications or mechanical applications. Most small area applications can be accomplished with hand application techniques. The most common techniques are brush or cloth wipe applications. For large area applications mechanical spray systems are most frequently used. If the system is automated it allows personnel to remain at a safe distance, or in the best situations, entirely outside the room where the stripping is being performed.

CAUTION: MEK, MIBK, and MIL-C-38736 are flammable and toxic to eyes, skin, and respiratory tract. Skin and eye protection are required. Avoid prolonged or repeated contact. Use adequate ventilation or respiratory protection. Keep away from open flames and other sources of ignition.

4.1.1 Soy Strip, Franmar

Franmar manufactures this alternative to high VOC hazardous strippers. It is part of an entire line of marine coating and paint strippers all made from 100% soybeans. Soy Gel is a potential choice to replace high VOC strippers. It contains 0% VOCs. Soy Gel's thick consistency makes its application neater and easily controlled. It can be applied to the underside of a surface and will not drip off. Soy Gel was tested at the University of Dayton on coatings and polysulfides. Its removal rate was noticeably quicker than the other low VOC strippers tested. For more information from the manufacturer of these products please reference: http://www.franmar.com/MSDS/ms.pdf.

4.1.2 Skywash/Skyrestore, Elixair®

Elixair's family of environmentally friendly sealant strippers includes Elixair® Skywash, Elixair® Skywipes, and Elixair® Skyrestore. Skywash is a wipe or brush on cleaning agent. Skywipes are a lint free cloth with the stripper already impregnated, for a wipe on application. Skywipes use the Skywash stripper only in a different medium. Skyrestore is a second environmentally friendly chemical stripper, and can be applied with a brush or wipe method. For more information from the manufacturer of these products please reference: http://www.elixair.co.uk/full-brochure.pdf.

4.1.3 Acrastrip 600 BG MOD, Polychem

Originally designed as a coating removal material, Acrastrip has proven effective in removing polysulfide sealants. According to Polychem's website Acrastrip 600 B&G MOD is specially designed to purge (chemical agent resistant coating) CARC paints. Polychem Acrastrip 600 B & G MOD is a neutral, completely biodegradable and water dilutable composition designed for flushing paint lines and stripping of particular military specification paints such as urethanes, acrylics, epoxies, waterborne, and high solid bake enamels. For more information from the manufacturer of Acrastrip please reference: http://www.uspoly.com/bgmmil.html.

CAUTION: UDRI testing has shown that Acrastrip 600 BG attacks Epoxy/Graphite composite substrate.

4.1.4 Poly-Gone 535, RPM Technology

Formerly known as GenSolve 335, Poly-Gone 535, according to the manufacturer, is a high performance liquid chemical stripper designed to remove silicone, novalac resin, rosin, acrylics, and other sealants from a variety of surfaces including some composites where a water rinse is not desirable. It may be sprayed or used in immersion-based cleaning systems. Heat (120 °F/49 °C) and/or agitation, including ultrasonic, is not necessary, but will significantly enhance performance. Testing results according UDRI's testing showed Poly-Gone had moderate success at softening polysulfide, but multiple application were required to fully strip the sealant (as is common with all strippers). For more information from the manufacturer of Poly-Gone please reference: http://www.rpm-technology.com/PG535.htm.

TABLE 3 - PROS AND CONS OF CHEMICAL STRIPPING SEALANT REMOVAL PROCESS

PROS
- Easy to apply in the field
- Low potential for substrate damage
- Low investment (equipment/training/facilities)
- Wide application temperature window

CONS
- Slower than traditional solvents
- Multiple applications may be needed
- Requires secondary coating removal step
- Produces waste stream (may be HAZTOX)
- Potential for ODC release
- ESOH concerns
- Potential Damage to Fay Surface Seals

4.2 Biological Degradation

Some Small Business Innovation Research (SBIR) has been done in the area of biological degradation as reported by Technical Research Associates (TRA). Various bacteria and fungi can be used to break down fluorocarbons, fluorosilicones, and polysulfides. The process of degrading sealant, using bacteria, involves the use of no hazardous materials (other than those that may be present in the sealant formulation) as chemical sealant removal does, so it is more environmentally friendly. Also the bacteria used do not decompose metal or composite structures, so there is essentially no risk of substrate damage. The process also reduces the number of man-hours currently needed to deseal an aircraft. This leads to lowered costs.

A potential problem with this method is in the area of fuel tank deseal operations. The tanks are drained before desealing, but some residual fuel remains trapped in voids and some fuel is absorbed into the sealant itself. The fuel remaining in the tanks slows the process the bacteria use to decompose the sealant. Some fuels even have an additive in them to kill unwanted microorganisms to prevent them from degrading the sealant during normal operations. When the time comes to remove the sealant, however, residue from these biocides remaining in the tanks can kill the bacteria placed there to deseal the tank. Obviously if the bacteria are dead they cannot perform the needed tasks.

This method for sealant removal is still in the development stage, but it is expected to be applicable to sealant removal operations upon further development. The pros and cons of biological degradation sealant removal methods are shown in Table 4.

TABLE 4 - PROS AND CONS OF BIOLOGICAL DEGRADATION SEALANT REMOVAL PROCESS

PROS
- Less costly than other methods (fewer man-hours)
- Low potential for substrate damage
- Low investment

CONS
- Requires strict environmental conditions
- Difficult to control
- Secondary coating removal step required
- Incubation time required for bacteria
- Jet fuel slows effect (making fuel tank applications difficult)
- Potential Damage to Fay Surface Seals

4.3 Mechanical Stripping

Mechanical methods for the removal of sealants can encompass everything from hand tools such as power sanders, scrapers, and wire brushes to abrasive blasting, and water jetting. Hand tools in the hands of a skilled and careful worker are effective for removing relatively small areas of sealant (see Figure 1 for examples). While these methods remove sealants rather quickly, the potential for substrate damage is great and process effectiveness is highly dependent upon operator skill and care during the process. Power tools easily damage aerospace aluminum alloy and composite component skins. Surface scratches in aluminum and ply damage in composites can drastically reduce the useful life of an aircraft component. Conventional methods for the hand removal of aerospace sealants are well documented in the specific Air Force aircraft Technical Orders (TOs). Air Force TO 1-1-3 describes removal of curing type sealant, sealant top coating, and chalking sealant. Sealant removal from fasteners, access doors/components, and fuel cells are also discussed. Currently approved tools, as reported in TO 1-1-3, include the non-spark producing sealant scraper, sealant spatula, hot knife blade, and stitcher horizontal offset.

In the past 15 years the DOD has tested and evaluated numerous alternative mechanical techniques for the removal of paints, sealants, and other coatings from both aluminum and composite aircraft skins. The majority of the mechanical processes for sealant removal fall into one of the following categories: Dry Abrasive Blasting, Wet Abrasive Blasting, and Cold Abrasive Blasting. Abrasive blasting sealant removal processes require the use of abrasive solid particles that are propelled, either by air or mechanical means, against the sealant coated surface thus removing the sealant by mechanical action. A wide range of abrasive materials (media) has been tested and evaluated for this application. Some of these abrasive media are listed in Table 5. Ultrasonic activated cutters, scrapers, pneumatic vibrating scrapers, and ultrasonic jet do not fit into the above categories, but are considered mechanical removal tools as well.

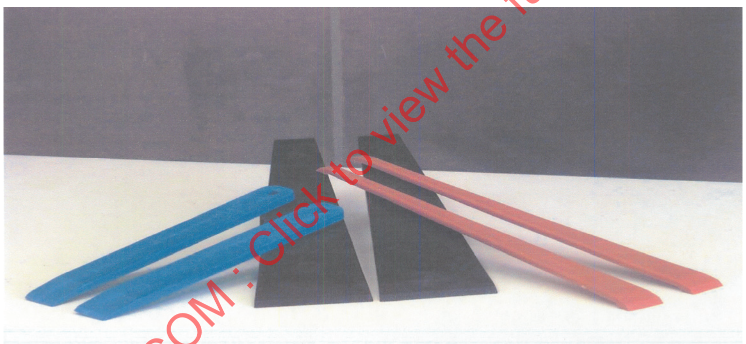

FIGURE 1 - COMMONLY APPROVED HAND TOOLS

TABLE 5 - ABRASIVE MEDIA MATERIALS

• Thermoset plastic beads	• Corn cob grit
• Thermoplastic beads	• Rice hulls
• Garnet	• Glass beads
• Walnut shells	• Ice crystals
• Peach pits	• Carbon dioxide pellets
• Aluminum oxide	• Sand
• Wheat starch	• Sponge/foam
• Sodium bicarbonate	

4.3.1 Dry Abrasive Blasting

Dry abrasive blasting physically removes sealant from a substrate by propelling solid particles, either by mechanical means or by an air stream, at the sealed surface. The interaction of the abrasive media with the sealant and the substrate is controlled by the parameters listed in Table 6.

Dry abrasive blasting sealant removal processes tend to create extensive quantities of dust and fines composed of degraded media and sealant particles. Even the best of dust removal systems can be overwhelmed when large areas are being rapidly stripped. ESOH concerns mandate stringent worker protection systems. Where smaller areas are being stripped at lower rates, simultaneous vacuum removal of the effluent from the process makes the dry abrasive blast process inherently safe and clean for field level operations. Filter masks, eye, ear, and hand protection is required where manual control of the nozzle is required. Robotic control of the blast nozzle allows operators to be removed from the blasting operation environment.

Dry abrasive sealant removal processes can be tailored, by control of the process parameters listed in Table 6, to be as aggressive or as benign as is required for the task at hand. In some instances dry blasting leaves a media residue that if it is undesirable for subsequent resealing operations, it must be removed by a secondary solvent wash or wipe step. Surface interaction of the abrasive media with the substrate material may likewise be controlled by means of the parameters listed in Table 6. Aggressive blasting processes can easily damage both aluminum and composite substrates. Great caution should be taken, and testing and analysis should be completed prior to the qualification of any abrasive sealant removal process. The pros and cons of the processes discussed are presented in Table 7.

CAUTION: Airworthiness Advisory, AA-01-05, Use of Aluminum Oxide (Al2O3) as the Grit-Blasting Medium During the Removal of Organic Coatings on USAF Aircraft Fuel Tanks, issued 10 December 2001, cautions the use of aluminum oxide inside fuel tanks.

TABLE 6 - ABRASIVE BLASTING PROCESS PARAMETERS

• Abrasive particle size/shape/hardness • Rate of media flow • Velocity of particles • Velocity profile of stream • Angle of particle impingement • Nozzle stand off distance • Stream dwell time

TABLE 7 - PROS AND CONS OF DRY ABRASIVE BLASTING

PROS • Rapid coating removal • Secondary operations may not be necessary • Inherently controllable • Wide range of media available • Sophisticated equipment available • Environmentally acceptable • Easy to apply in the field • Moderate investment in equipment and training • Wide temperature application window • Manual operation option
CONS • High potential for substrate damage • Dust and fines a problem for high rate stripping • Waste may be HAZTOX • ESOH concerns

4.3.2 Wet Abrasive Blasting

In wet abrasive blasting, a stream of water under closely controlled (low to medium) pressure and flow rate containing abrasive particles (garnet, quartz, or sodium bicarbonate, etc.) is directed at the sealant coated surface to be stripped. The stream here is much smaller in diameter than in the case of the air blast process. This is due to the relatively high weight of a large column of water. The forces involved would easily deform or otherwise damage many thin skinned aircraft components. Nozzle stand off distances are generally much less when compared to that used in the air blast process. Many of the process parameters listed in Table 6 also apply in the wet abrasive process. Here we would add water pressure and flow rate. In this process the dust, fines and sealant debris are contained in the liquid waste stream in the form of sludge. The waste here could be a HAZTOX material depending on the sealant formulation. Process over spray and mist must be contained and worker protection requirements would be similar to those required for the dry abrasive process. In this process water can be driven into the joints and fasteners in the aircraft skin. This water may not be easily removed and may cause corrosion problems. See Figure 2 for an example of a wet abrasive system.

CAUTION: Sodium bicarbonate may accelerate corrosion processes and should not be used unless there is total assurance that it can be completely removed. The pros and cons of the processes discussed are presented in Table 8.

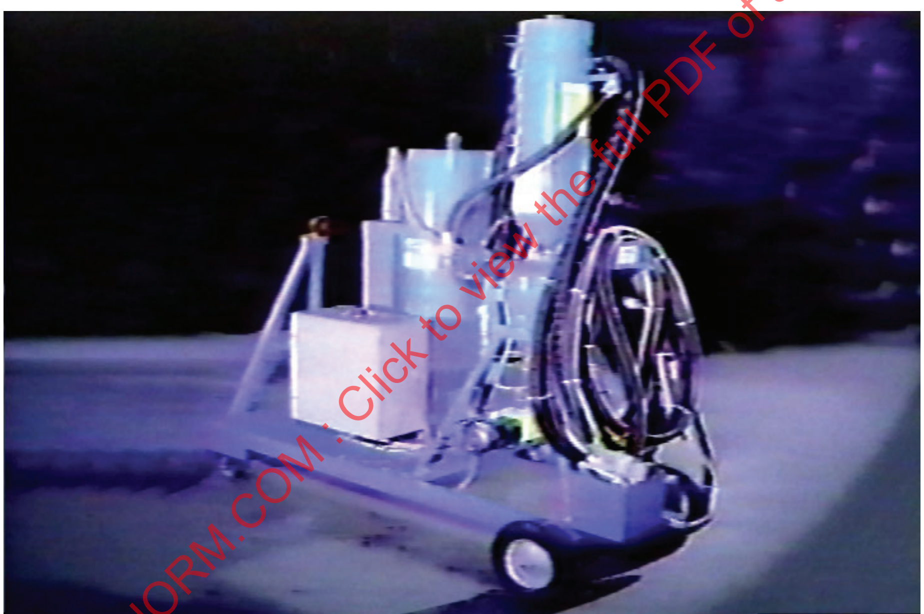

FIGURE 2 - PAULI SYSTEM'S RAM 45 VCC PORTABLE WET ABRASIVE SYSTEM

TABLE 8 - PROS AND CONS OF WET ABRASIVE BLASTING

PROS
• Rapid coating removal
• Inherently controllable
• Wide range of media available
• Sophisticated equipment available
• Moderate investment in equipment and training
• Manual operation option
CONS
• Water waste stream may be hazardous
• Potential for substrate damage
• ESOH concerns
• Overspray containment required
• Water penetration in joints and fasteners
• Limited to use temperatures above the freezing point of water

4.3.3 Water Jet Blasting

Water jet blasting generally operates at high pressures and lower flow rates than in the wet abrasive process. This process utilizes the force of the water jet to remove the sealant; thus no abrasive media is required. At higher pressures the water jet is used to strip ceramic coatings from turbine engine components. As in the wet abrasive blast, the water jet can drive water in skin joints and fasteners causing potential for corrosion. The waste from the water jet process is sludge formed by the sealant debris and the process water. This sludge may or may not be HAZTOX, depending on the formulation of the sealant being removed. The water jet process normally produces a very clean surface on the substrate that requires little if any subsequent treatment prior to the resealing process.

Since the water jet is generally a high-energy process requiring very precise control, manual control of the jet is not always a viable option, and robotic control is often utilized. This situation was encountered with the deseal operations of the F-111. For the first deseal/reseal program, water jet blasting with human operators was used to remove the old sealant. It was found that the maintenance workers that operated the blast nozzles became fatigued after a fairly short amount of time (an hour or two) due to the stress on them from the high water pressures associated with the process. It was then necessary to form a rotation of workers to keep the process moving. In this particular instance there was limited working space inside the fuel tanks being desealed. All of these factors led to the development of a robotic system for the second deseal/reseal program as reported by General Atomics. With the new robotic system, it was no longer necessary for workers to enter the confining spaces of the fuel tanks. The new process involved the use of video cameras to show the operator what was happening inside the fuel tanks without actually going inside. Robotic control also eliminated the fatigue problems associated with the workers controlling the water jets by hand. This greatly reduced the number of man-hours required to complete the deseal/reseal program. The pros and cons of the processes discussed are presented in Table 9.

TABLE 9 - PROS AND CONS OF WATER JET BLAST

PROS
• Rapid coating removal
• No secondary operations needed
• Inherently controllable, Sophisticated equipment available
• No abrasive media required
• Low volume waste stream
CONS
• Manual control difficult, but possible
• High investment (equipment/facility, not as high as manual control)
• Waste may be HAZTOX
• Water penetration (joints/fasteners)
• Potential for substrate damage
• Limited temperature application window

4.3.4 Cold Media Blasting

Cold media blasting uses particles such as carbon dioxide pellets (dry ice) or water ice crystals to remove sealants from surfaces. Cold media blasting processes operate on the same general principles as the other mechanical abrasive processes. In the case of the CO_2 pellets, however, some low temperature sealant embrittlement may assist in the sealant removal process. Both the water ice crystal and the CO_2 pellet blast processes produce clean substrates that require little or no secondary cleaning prior to the resealing process. In the case of the water ice crystal process, the waste stream would be very similar to that formed in the water jet process. In the case of the CO_2 pellet process the CO_2 pellets sublime to the gas and leave the sealant debris as a dry residue that is easily vacuumed into containers for disposal. Since the water ice crystals and the CO_2 pellet processes are slower and not as energetic as some of the other abrasive blast processes, manual control of the blast nozzle is a convenient option. Worker protection requirements, however, are similar to those of the other blast processes. Control of the process would again be governed by the parameters listed in Table 6. The pros and cons of the processes discussed are presented in Table 10. An example of a Cold Media Blast system is shown in Figure 3.

FIGURE 3 - AERO 30 COLD MEDIA BLAST SYSTEM FROM COLD JET

TABLE 10 - PROS AND CONS OF COLD MEDIA BLASTING

PROS
• Low potential for substrate damage
• Sophisticated equipment available
• Environmentally acceptable
• Moderate investment (equipment/facilities/training)
• Dry waste stream (CO_2)
• Wide range of temperature application
• Inherently controllable
CONS
• Slow to moderate rate of coating removal
• Water coating debris sludge may be HAZTOX (water ice)
• Secondary operations may be necessary

4.3.5 Ultrasonic Activated Tools

Ultrasonic activated tools (knives, scrapers, and waterjets) were developed about 15 years ago and have found some niche applications in the aerospace and medical industries. Ultrasonic activated cutters; knives and scalpels have been developed and are commercially available. Ultrasonic cutters are used to cut and shape honeycomb prior to adhesive bonding of the skins. The scalpels are in use in the medical field. Scrapers have been used to remove difficult to remove adhesive materials in aircraft repair operations. Ultrasonic activated water jets are used in the dental field to clean teeth.

Ultrasonic activated tools, as described above and pictured in Figure 4, are generally hand held tools most suitable for small area sealant removal and repair operations. Power ratings for the ultrasonic generators are in the 750 to 2000 W range and frequencies in the 20 to 60 KHz are most generally used. In the case of the cutters and scrapers the tool blade is activated by the ultrasonic horn, causing the blade to vibrate very rapidly (20 KHz), at very low amplitudes (50 to 70 µm). The energy, concentrated at the cutting edge tip of the blade, causes very localized, high instantaneous temperatures, which combined with the manual scraping or cutting action causes rapid sealant removal or cutting of material. Since power to the blade can be set at any level desired, up to the maximum available, the process is controllable and potential for substrate damage is low. There are few ESOH concerns involved in the operation of the available ultrasonic activated tools.

Proper worker training, hand, eye and ear protection should be provided. Secondary operations, such as radial bristle discs and solvents, may be required to remove the last traces of the sealant material prior to the resealing process. These tools are very lightweight and the ultrasonic generators are relatively low cost, generally reliable, small, and portable. Mechanical methods for sealant removal from aircraft have been highly developed from an equipment, control and abrasive media standpoint. The methods can be tailored to nearly any degree of aggressiveness required by the task at hand. The pros and cons of the processes discussed are presented in Table 11.

FIGURE 4 - ULTRASONIC CUTTER

TABLE 11 - PROS AND CONS OF ULTRASONIC ACTIVATED TOOLS

PROS
• Rapid coating removal
• Easy field application
• Light weight/portable
• Low investment (equipment/training)
• Environmentally acceptable
• Solid waste stream (coating debris)
CONS
• Secondary operations may be required
• Worker Protection necessary (eye/ear/hands)
• Best for small area coating removal

4.3.6 Rotary Power Tools

These tools have been evaluated at the University of Dayton, and maintainers at Tinker Air Force Base. The tools are effective at removing sealant and accessing tight areas around fasteners. These hand tools require operator experience to achieve an enhanced removal rate and are skill dependent to avoid substrate damage. Removal rates are also dependent on the cutter or brush attachment used. Some examples of attachments are shown in Figure 5. Most attachments require frequent replacement. The pros and cons of the processes discussed are presented in Table 12.

FIGURE 5 - 3M FIRST GENERATION ROTARY CUTTERS AND RADIAL BRISTLE BRUSH

TABLE 12 - PROS AND CONS OF ROTARY POWER TOOLS

PROS
• Quick removal rate
• Handheld, Small Portable system
• Can access tight area
CONS
• Possibility for substrate damage with some attachments
• Power Tools must be properly grounded for use in aircraft fuel tanks
• Attachments must be replaced often

4.3.7 Pneumatic Vibrating Scrapers

The Mastic, the most powerful of Outzone's 3 pneumatic scrapers, has the quickest removal rate but also has a high potential for substrate damage. Testing conducted at UDRI demonstrated that inexperience and a minimal lack of control lead to damage on metal and composite substrates. The high vibration limits the time the operator can perform the removal process.

The Outzone Super Gun is the newest generation of Outzone pneumatic scrapers. When tested at UDRI, it produced the best strip rate without overly fatiguing the operator or causing damage to the substrate. As with the Mastic, there is potential for substrate damage if the operator is inexperienced.

The Vibro Gun, the low power version, shown in Figure 6, is currently used at the F-117 SPO and F/A-22 SPOs. Removal rates are only slightly better than hand scrapers, but the wear on the operator is much lower, allowing increased man-hours per operator.

All vibrating scrapers can be outfitted with blades of any material. The most popular blade materials include acrylic, epoxy, BMI composites, polyimide, and polyimidamide.

The pros and cons of the processes discussed are presented in Table 13.

FIGURE 6 - OUTZONE VIBRO GUN PNEUMATIC SCRAPER

TABLE 13 - PROS AND CONS OF PNEUMATIC VIBRATING SCRAPER

PROS
• Flexibility of Blade material for different applications
• Blades can be changed easily/quickly
• Quick removal rate
• Small portable systems available for field application
CONS
• Potential for substrate damage with more powerful tools
• High vibration wears on operator
• Power Tools must be properly grounded for use in aircraft fuel tanks
• Blades wear down quickly and must be replaced often

4.4 Thermal Stripping

Thermal (heat) based sealant removal processes rely upon a rapid thermal pulse to degrade (char or vaporize) the sealant so that a clean surface is produced or that the remaining degraded sealant material may be easily removed by low energy mechanical methods. Table 2, under the thermal category lists three processes, two of which are probably not applicable to aircraft sealant removal operations. The molten salt bath requires that the coated component is immersed in the bath for some period of time, this is not really convenient for many aircraft. In addition, the molten salt bath temperature would most certainly destroy most aerospace aluminum and composite materials. In the cryogenic stripping process cryogenic liquid, such as, liquid nitrogen, is sprayed onto the surface to be stripped to create a contraction of the substrate and compression in the embrittled sealant. Thus allowing the sealant to be easily removed by a secondary mechanical operation, such as plastic media blasting. Again this process could be applied to sealant removal from aircraft parts only with difficulty.

4.4.1 Laser Sealant Removal

Laser sealant removal is the most recently developed thermal stripping process that is presently available. This process uses the very short duration, rapidly applied high-energy light pulses, only available via the use of lasers, to ablate and separate the sealant from the substrate. In general with laser based processes secondary operations are not required. Waste stream recovery (volatiles and inorganic ash) can be achieved on a continuous basis with vacuum systems and filters. Laser sealant removal and cleaning processes have received extensive DOD, DOE, and EPA R&D funding over the past ten years. As a result sophisticated laser based systems are commercially available. These systems are, however, large and presently not well suited to field level operations. The package footprint is continually decreasing and reaching a point where it is becoming field applicable. An example of a laser system can be seen in Figure 7.

The technology has been demonstrated to be an environmentally acceptable, affordable and controllable process for the removal of aircraft sealants. Laser based processes have been developed for the cleaning and coatings removal of aircraft components ranging from turbine engine blades to landing gear, aircraft skins and radomes (rain erosion coatings). The Air Force and the Navy have completed extensive tests and evaluation on laser radiation effects for both aluminum and composite substrate materials. Based on multiple cycles of coating removal using the laser, no mechanical property changes were detected in either the aluminum or composite materials. Industrial high power lasers including CO_2, eximer and Nd:YAG (Neodymium doped, Yttrium Garnet) have been utilized successfully for the rapid removal of aircraft coatings.

Laser energy removes sealants by a combination of ablation (evaporation and vaporization) and a thermal pulse shock wave that essentially debonds the sealant from the substrate. The laser beam pulse spot can vary in size from less than a centimeter to a few centimeters in diameter. The sealant is removed gradually after many pulses of the laser. The laser beam is either a rastering or a single spot beam, and requires a very short dwell time (fractions of a second) on any given spot. Thus the sealant is removed with little or no increase in substrate temperature. Highly sophisticated control technology has been developed that insures safety and decreases the likelihood of substrate damage. Technology such as color recognition systems, added to the laser system, enable the system to recognize the substrate and prevent substrate overheating by not sending a pulse to the spots where all of the sealant has been removed. Robotic control of the laser beam delivery system removes the operators from any danger from the laser. The pros and cons of the processes discussed are presented in Table 14.

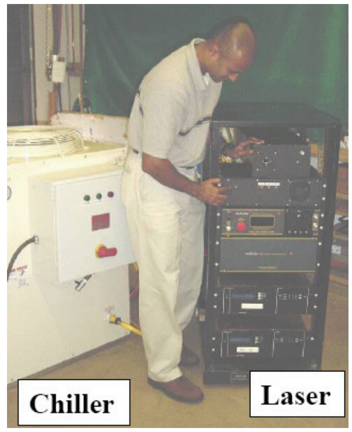

FIGURE 7 - GENERAL LASERTRONICS END EFFECTER/ LASER SYSTEM AND CHILLER

TABLE 14 - PROS AND CONS OF LASER BASED STRIPPING

PROS • Environmentally acceptable • Secondary operation not required • Highly controllable • Sophisticated systems available
CONS • High investment (equipment/facilities/maintenance/training) • Modest rates of coating removal • Long term reliability • Difficult to apply in the field

4.4.2 Flash Lamp Stripping

Xenon flash lamps were applied to the removal of aircraft coatings over twenty years ago. The xenon flash lamp uses high intensity light pulses from a high-pressure xenon bulb to pyrolyze (char and blister) a sealant into a weak predominantly inorganic ash. The ash is then removed from the surface by one of the low energy mechanical processes, usually the CO_2 pellet blasting process. Vacuum system recovery of the ash and gaseous material is used to capture and contain the waste stream products. A capacitor bank high-energy electrical discharge through the xenon lamp is used to generate the thermal pulse. Early lamps were plagued by short service lives and deposition on the bulb surface of the products of the pyrolysis of the sealant, thus reducing thermal output. Improved bulbs have been developed and the "Pinch Lamp" which has even higher thermal output has been developed.