Laser Strip: A Portable Hand-Held Laser Stripping Device for Reducing VOC, Toxic and Particulate Emissions

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ABSTRACT

Paint stripping formulations and methods used today result in emissions of Volatile Organic Compounds (VOCs), toxic air contaminants, particulate matter and various metals. The techniques also lead to generation of a substantial amount of hazardous waste. Water use and contamination and high energy use for controls can also result from use of some of the methods.

An alternative method of stripping paint that minimizes air emissions, waste, water pollution and energy use has been developed by Laser Strip. The company assembled a portable hand-held carbon dioxide laser stripping device. Laser Strip partnered with the Institute for Research and Technical Assistance (IRTA), a small nonprofit technical environmental organization, and Southern California Edison, a large electric utility, to conduct an Innovative Clean Air Technology (ICAT) project. This project involved conducting four demonstrations of the laser stripping device in applications where it might offer an environmental and cost advantage. The applications included aircraft and aircraft parts stripping, water storage tank stripping, ground vehicle stripping and Navy parts and hull paint stripping.

The laser prototype device had low power and was designed to demonstrate the feasibility of the concept. Laser Strip is building two larger lasers, one a portable laser and the other a fixed laser which will have a much higher strip rate. The cost of stripping with one of these larger laser stripping devices was compared with the cost of stripping with the method that is used conventionally in the four applications where the prototype was demonstrated. The results indicate that the cost of using a laser for stripping is lower than the cost of using alternative technologies except in cases where a substantial amount of surface area must be stripped or the coating to be stripped is very thick. The laser offers a number of advantages over conventional stripping methods. It has lower energy requirements, it is easy to use, it minimizes air emissions of VOCs, toxics and particulate matter and it generates a much lower volume of waste. A conference that involved demonstrating the prototype device was held to communicate the project findings to interested parties.

I. INTRODUCTION AND TECHNOLOGY DESCRIPTION

For several years, there have been attempts to develop a portable laser system that could cost effectively strip paint, coatings and other contaminants of various kinds from surfaces. Such a technology could reduce or eliminate the use of chemical and abrasive strippers that generate Volatile Organic Compound (VOC), toxic and particulate emissions, generate large quantities of hazardous waste and often pollute water bodies.

This project involved testing and demonstrating a portable laser device in four stripping applications where such a laser system could be used. The laser successfully stripped a variety of different paints applied to a range of substrates. The project also involved performing a cost analysis of using a laser for stripping in the four applications and comparing the cost of using the device to the cost of using the most commonly used conventional stripping method. The results indicate that the laser stripping technology holds promise for some applications.

Description of Laser Technology

A portable hand-held pulsed carbon dioxide laser has been developed by Laser Strip Corporation for stripping paints or contaminants from surfaces of various kinds including metals, composites and concrete. The laser generates pulses in the 10.6 micron infra-red wavelength range. The light is absorbed by paints or other contaminants and the high peak power results in a small explosion of the paint or contaminant which is vaporized. The light is not absorbed by the substrate and the laser can be tuned to remove coatings or contaminants one at a time. The paint or contaminant is drawn through a High Efficiency Particulate Arrestor (HEPA) filtration system as it is blown from the surface, removing it from the airflow and the air is returned to the atmosphere.

Pulsed carbon dioxide lasers have been around since the 1960s. Although these lasers could deliver high peak power and high energy per pulse, they could not be pulsed at a high enough rate to economically strip paint. The problem was known as thermal bottlenecking. Even though the efficiency of the carbon dioxide laser is high compared to other types of lasers, it is still only in the neighborhood of 10 percent. A huge amount of energy must go into heating the gas mixture and this heat must be removed or the gas must be replaced before the laser can be pulsed again.

Previous approaches utilized large blowers designed to operate at low pressure (usually less than $1/40^{th}$ of atmospheric pressure) to circulate the gas through the cavity and heat exchangers to remove the heat. These devices were the size of a room. One innovation of the Laser Strip system is the resolution of the cooling problem. The gas in the laser is moved by an internal fan and is alternatively pulsed and cooled in alternating chambers. Resolution of the cooling problem made it possible to develop a compact laser which delivers the required pulse characteristics for stripping paint and other contaminants. The prototype device can easily be moved around an aircraft or inside enclosures and it can be held in a worker's hand for stripping. It is small enough to fit in a pickup truck and has its own trailer for transport.

Another innovation of the Laser Strip system is a new method of exciting the laser's plasma. It involves a technique for generating and applying a string of nanosecond time scale, ultra high voltage pulses to the plasma. No other laser is capable of meeting the same physical requirements and operating reliably for extended periods of time.

There is one major patent, US6,771,684 B2, that describes in detail the features of the laser stripping system that was used during this project. The patent is assigned to Dr. Alan Hill and he has licensed the technology to Laser Strip.

Advantages of the Laser Strip System

Many different types of technologies are used today to strip paint or contaminants from surfaces. They include:

- Manual removal techniques like sanding with sand paper or abrasive discs and scraping with wire brushes
- Abrasive blasting methods using sand, steel shot, plastic media, wheat starch media, sodium bicarbonate and water
- Thermal methods like steam or burn-off ovens
- Chemical methods using methylene chloride or VOC solvent based strippers

Manual removal methods are obviously very labor intensive and therefore costly and slow. In aircraft stripping, this method is not selective. It not only removes the coating, it also removes the aluminum clad and/or anodizing as well. Stress cracks can also be created and can remain undetected by a buildup of paint dust.

Abrasive blasting methods all rely on a medium to abrade the paint or contaminant from the surface of the substrate. The paint residue and the stripping medium residue together account for a very large volume of material that is emitted to the atmosphere, is discharged to the wastewater treatment system or is disposed of as waste. This large volume of material has to be controlled or treated at a high cost. Generally, blasting technologies require a very high capital investment. Sand and steel shot blasting can damage some substrates and the particulate emissions must be captured. Plastic media and wheat starch blasting can harm substrates if they are not controlled carefully and cracks in the substrate may be masked by the dust. Medium pressure water blasting and sodium carbonate blasting also require large capital investments.

Steam stripping, like water blasting, creates a large volume of wastewater that must be treated and/or disposed of, again at a high cost. This process must also be carefully controlled so that substrate damage does not occur. Use of burn-off ovens for stripping is energy intensive and generates large amounts of NOx emissions.

Methylene chloride has been used for paint stripping for many years. The chemical is a carcinogen and is classified as a Toxic Air Contaminant (TAC) in California. Stripping with methylene chloride strippers generates air emissions and a large volume of hazardous waste that requires disposal. Other chemical strippers based on n-methyl pyrrolidone have been used more recently. They are not very effective and the chemical is a VOC and a reproductive and developmental toxin. Again, the material is emitted and a large volume of waste is generated.

A major advantage of the Laser Strip system over these other technologies is that, because light is the stripping medium, no emissions or waste material other than the ablated coating residue is generated during the stripping process. The ablated coating remains on the surface of the substrate and looks like char. The vacuum system attached to the laser collects the particulate coating residue which is small in volume. Previous work indicates that the organic content of the paint film is largely converted to carbon dioxide and water (Head and Niedzielski) but this issue may have to be pursued in more detail if large scale systems are used. Another advantage of the system is that it does poses a minimal health hazard to workers or community members from emissions of particulates, carcinogens or reproductive toxins. Still another advantage of laser stripping is that it has significantly lower energy use than the other conventional technologies. Finally, because the laser is portable and hand-held, it provides a convenience in use that other technologies generally do not.

Companies that use chemical strippers containing methylene chloride or VOC solvents are generally required to have control devices installed in their facilities. Companies stripping with blasting media are required to use control devices like bag houses. Use of the laser technology would not require a control device. Users could meet emission standards without the need for a control device and this would reduce capital and operating costs. Use of the laser technology would also reduce energy use and costs for the users compared with some of the technologies used today. Use of the laser would significantly reduce the generation of waste and cost of waste disposal.

<u>Potential Applications for Laser Stripping</u>

There are a variety of possible applications for the Laser Strip technology. One of these is aircraft stripping. There are a number of companies, small and large, that perform aircraft maintenance which can involve stripping and painting corporate jets and various types of commercial and military aircraft. Historically, methylene chloride based strippers have been used for stripping the coatings from aircraft. Many aircraft stripping operations still rely on methylene chloride and others have converted to less effective VOC strippers or abrasive media blasting of different types. Methylene chloride based strippers have also been used by wheel manufacturers to strip polyester coatings from wheels.

Other potential applications for the technology include stripping various metal substrates like large storage tanks, bridges, oil platforms, ship hulls, ship internal tanks and ground vehicles of various types. Hundreds of companies in California that perform these operations use abrasive blasting processes of various types. Steel shot is used by many companies including engine rebuilders. Sand blasting is used routinely for stripping metal parts or vehicles. All of these types of operations are potential candidates to adopt the Laser Strip technology.

Many companies use water blasting to strip paint and graffiti from buildings and other structures. These companies could potentially use the Laser Strip device as an alternative.

All of these possible customers could realize a cost savings from adopting the laser technology. Companies that do chemical stripping generally have control devices that are expensive to purchase and operate and are energy intensive. Disposal of the chemical strippers is also costly. Companies that use media to strip have baghouses for control. These control methods, again, are very costly to purchase and operate and have high energy requirements. Again, disposal of the media is an additional expense. Companies that use water blasting do not require controls for air emissions but they may be required to collect the effluent from the operation. They would then need to treat the effluent before discharging it or ship it off-site for disposal. The laser technology would make it unnecessary to have control devices or effluent collection and treatment and waste disposal costs would be reduced substantially. Some companies with permit limits on their control devices could increase their throughput through use of the laser.

Business Model

Laser Strip plans to build portable hand-held units that could be leased to California companies that would perform stripping services. Laser Strip also plans to perform the service themselves in the early years. In some cases, military bases in California for example, the customer might want to purchase a unit. Laser Strip also plans to build large fixed lasers based on the same technology. In principle, hundreds and perhaps thousands of facilities in California could either purchase the device or lease the service and use the laser for stripping.

Project Approach

A project team was assembled for this project to conduct the testing and evaluate the results. The team consisted of Laser Strip, the technology developer, the Institute for Research and Technical Assistance (IRTA), a technical nonprofit organization and Southern California Edison (Edison), a large electric utility interested in finding new technologies for their customers. A 100 watt portable hand-held prototype was tested in four applications during the project. These included:

- stripping aircraft components at Aero Pro, an aircraft maintenance facility located at the San Bernardino Airport
- stripping a large steel water storage tank at the San Bernardino Airport
- stripping ground vehicles at the Barstow Marine Base
- stripping ship components and panels at the Navy Southwest Regional Maintenance Center, located in San Diego

Laser Strip is currently building a more powerful portable laser that is designed to have the same footprint as the prototype tested during this project. The new laser will have a power level of 3,000 watts, 30 times that of the laser used during the project. The strip rate is roughly proportional to the power and the new laser should be able to strip 30 times faster than the prototype. Laser Strip is also building a much larger fixed laser that will have a power level of 6,000 watts and plans to offer fixed lasers for sale to customers with greater stripping needs.

Structure of Document

This document focuses on the results of the testing conducted during the project. Sections II, III, IV and V present the results of the aircraft parts stripping, the water storage tank stripping, the ground vehicle stripping and the ship component and panel stripping respectively. In all cases, the project team conducted a cost analysis for the laser and a comparison of the cost of using the laser technology in place of the technology most commonly used currently. Cost information on the stripping processes was obtained from the facilities where the demonstrations were conducted or from contractors who offer stripping services. Cost information on the laser stripping process was provided by Laser Strip. The cost analysis assumes that the more powerful portable 3,000 watt laser will be available for the stripping and that a larger fixed laser will also be available for certain potential users. All assumptions used for the analysis are presented clearly. Section VI describes a conference and demonstration that were held to disseminate the results of the research. Section VII summarizes the results of the project. Finally, Section VIII provides a list of references.

II. AIRCRAFT COMPONENT STRIPPING AT AERO PRO

This section focuses on the testing that was conducted at Aero Pro, the aircraft maintenance facility, on several different aircraft components. The company, like most other aircraft stripping companies, uses methylene chloride based strippers currently. The section provides background on the paints used on aircraft and also includes a cost analysis and comparison of using the laser technology in place of the methylene chloride stripping used today.

Background on Aircraft Stripping

Aircraft coatings generally consist of an epoxy primer and a polyurethane topcoat. Material Safety Data Sheets (MSDSs) for a typical coating system are shown in Appendix A. The first three MSDSs represent an epoxy primer system consisting of the HS Epoxy Yellow Primer, a Solvent Catalyst SC-11 and Epoxy Hardener, High Solids EH-12. The next two MSDSs show a high fill polyurethane topcoat system that is sanded during application. These include the Conventional Urethane Surfacer Primer SP-11 and the Polyurethane Curing Solution PH-20. After this polyurethane system is sanded, another polyurethane topcoat system is applied. This system consists of High Solids Matterhorn White Polyurethane Topcoat PG-6-W83 and Polyurethane Curing Solution PH-34. MSDSs for these coatings are also provided in Appendix A.

Laser Stripping Demonstration for Aircraft Parts

For the aircraft stripping demonstration, the project team used the prototype laser stripping device to strip the coatings systems described above from three types of substrates. These include:

- a 727 engine cowling made of aluminum
- a Krueger flap made of magnesium
- an aileron made of graphite and aluminum

Composite materials like honeycomb glass and graphite cannot be stripped with conventional methylene chloride stripping formulations because of incompatibility. The same is true of the Krueger flaps which are made of magnesium. As aircraft are increasingly made of composite, other technologies will be needed. It is important to include such materials in the stripping tests. The project team did not expect to be able to strip the radome or the graphite portion of the aileron because of the long pulse rate of the 100 watt laser prototype. The long pulse duration causes the laser to dwell on the composite material for a substantial period of time and it is destroyed in the process. The larger laser which is under development has a very short pulse rate. The dwell time is minimized and the composite can be effectively stripped without being destroyed.

A picture of the laser system used during the aircraft parts stripping is shown in Figure 2-1. A picture of the generator used to power the laser is shown in Figure 2-2. A picture of the arm connected to the laser is shown in Figure 2-3.

Figure 2-1. Laser System

Figure 2-2. Generator Used with Laser

Figure 2-3. Laser Arm Connected to Laser

For the aircraft parts stripping, portions of three items were stripped. The first item was an engine cowling made of aluminum which was removed from the aircraft for the test. The cowling contained a Chemical Agent Resistant Coating (CARC) which had an average thickness of 3.9 millimeters. CARC is a very hard paint and is difficult to strip. A section of the cowling was taped off and stripped. The section included a seam. The taped section of the engine cowling is shown in Figure 2-4. A picture of the Laser Strip owner, Joe Ermalovich, stripping the section is shown in Figure 2-5. Figure 2-6 shows the stripped portion of the cowling; the rivets in the cowling are clearly visible.

Figure 2-4. Engine Cowling Taped Off


Figure 2-5. Cowling Being Stripped

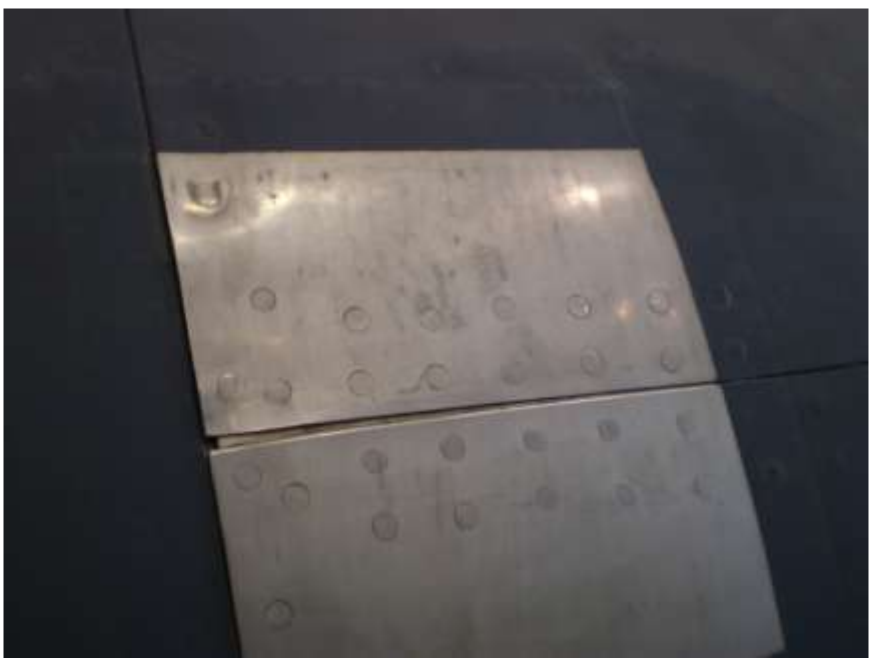
Figure 2-6. Cowling after Stripping

The second item stripped during the demonstration was a Krueger Flap made of magnesium on a 727 aircraft that was being worked on at the hanger. A picture of a section of the Krueger Flap containing a window is shown in Figure 2-7. The thickness of the coating combination (a primer and a topcoat) on the Krueger flap was measured at 14.5 millimeters. A picture of the Krueger flap being stripped is shown in Figure 2-8. A close-up view of the stripped portion of the Krueger flap is shown in Figure 2-9; the laser was able to strip the sealant between the window and the flap, as shown in this picture.


Figure 2-7. Krueger Flap Taped Off


Figure 2-8. Krueger Flap Being Stripped

Figure 2-9. Krueger Flap after Stripping

The third item stripped was an aileron made of graphite and aluminum on the same 727 aircraft. A picture of the taped off portion of the aileron is shown in Figure 2-10. The thickness of the coating on the aileron averaged 2.35 millimeters (the coating is thinner on ailerons for weight reduction). The raised portion of the aileron is made of graphite and it was not successfully stripped by this laser. As discussed above, the laser used in the demonstration is not suitable for stripping composite materials.   A larger laser with a short pulse rate capable of stripping composite is currently under development by Laser Strip. The aluminum portion of the aileron was stripped successfully as shown in Figure 2-11.

Figure 2-10. Aileron Taped Off


Figure 2-11. Aileron after Stripping

Cost Analysis for Aircraft Parts Stripping

The costs for the current stripping process using methylene chloride were provided by Aero Pro. Prior to stripping an aircraft, the portions of the aircraft that will not be stripped with the chemical stripper are masked off with four to six millimeter polyethylene plastic and barrier paper. The stripping process first involves applying the methylene chloride stripper to an aircraft and agitating the surface with brushes. The workers then apply a second application of the stripper. A tarp is placed on the floor and the stripped coating residue and stripper residue is pulled off the aircraft onto the tarp. The waste material is shoveled into a drum. The aircraft is then rinsed down with high pressure low volume heated water and the water is collected and placed in a storage tank for waste disposal.

The case study used for the cost analysis is a 727-200 fuselage and vertical stabilizers. The wings are not stripped. The area of surface required to be stripped is 5,400 square feet. The plane is masked and six workers perform the stripping operation which requires a total of 415 labor hours. The elapsed time for the stripping is 36 hours. At a labor rate of $65 per hour, the total labor cost is $26,975. The cost of the masking materials used in the stripping operation amounts to $1,620. Six drums of methylene chloride stripper are used during the stripping at a cost of $3,960. Hazardous waste disposal of four drums of waste coating and stripper residue generated in the process has a cost of $2,475. Some 1,200 gallons of water waste are generated during the operation; at a disposal cost of 40 cents per gallon, the disposal cost amounts to $480. The hanger where the stripping is conducted has a high air flow during the stripping to protect the workers. Three motors with 75 horsepower each are used for the fan. The energy use during the stripping operation amounts to 6039 kWh, assuming a stripping time of 36 hours. At an electricity rate of 12 cents per kWh, the total energy cost is $725. Taking into account all these costs, the total cost of stripping the 727 aircraft with methylene chloride stripper is $36,235.

The laser tested during this project has very low power, about 100 watts when it is operating optimally. During the testing, this laser had a very low strip rate. Laser Strip is currently building a portable laser with substantially higher power, about 3 kW or 3,000 watts. Assuming the strip rate is proportional to the power output, this new laser could be expected to strip 30 times faster than the laser used during the testing. Laser Strip indicates that the strip rate for this laser will be 600 square feet per hour per millimeter of coating stripped. To be conservative, the strip rate was assumed to be somewhat lower, about 500 square feet per hour per millimeter of coating stripped. The cost analysis described below assumes this strip rate.

Laser Strip's commercialization plan involves locating four lasers each at six different locations. Laser Strip has arrived at an overall service fee of $500 per hour per machine that customers would pay. This fee includes all labor, overhead, administrative, maintenance, energy and materials costs as well as a profit for the company. Laser Strip would use a generator for the stripping operation so the host facility would not be responsible for the electricity used by the laser. Assuming that one machine is used, the $500 per hour cost of the service and the 500 square feet per hour per millimeter thickness of coating stripped leads to an overall stripping cost of $1 per square foot per millimeter of coating. Assuming 5,400 square feet of aircraft requires stripping and assuming an average thickness of coating of 4.5 millimeters based on measurements and contract requirements, the total cost of leasing the laser is $24,300.

The laser stripping, like the methylene chloride stripping, requires masking of the aircraft. The cost of the masking materials, $1,620, must be included in the laser stripping cost. The total stripping cost with the laser amounts to $25,920.

Table 2-1 summarizes and compares the costs of stripping with the methylene chloride formulation and the laser. The laser stripping cost is significantly lower than the cost of using the methylene chloride stripping process. Each of the processes would require masking of the aircraft. In the current chemical stripping process, workers must manually hand clean the skin laps and seam joints prior to resealing. The laser demonstration showed that it was capable of removing sealant. Thus the hand removal would not be necessary in the case of the laser which would reduce the labor cost. It is also not necessary to wash down the aircraft with water after stripping and very little hazardous waste is generated in the stripping process. The only waste product is the HEPA filters that capture particulate emissions.

Laser Strip's overall stripping cost of $500 per hour for the laser includes many cost components. The laser stripping rate includes the cost of leasing space for the laser operation, the administrative cost and the overhead cost of administering the laser stripping service, the materials cost (HEPA filters, gloves, etc.) and maintenance costs. The cost of stripping with the methylene chloride also includes these overhead costs; the cost is representative of what Aero Pro routinely charges for stripping. Thus the cost elements are comparable and should be representative of the cost of stripping a 727 with methylene chloride versus the cost of stripping with a 3,000 watt laser stripping device. The cost of stripping with the laser is 28 percent lower than the cost of stripping with methylene chloride.

Table 2-1
Cost of Stripping Options for Aero Pro

	Methylene Chloride Stripping	Leasing Laser Stripping Service
Labor Cost	$26,975	-
Masking Materials Cost	$1,620	$1,620
Stripper Cost	$3,960	-
Hazardous Waste Disposal Cost	$2,475	-
Water Waste Disposal Cost	$480	-
Energy Cost	$725	-
Laser Leasing Cost	-	$24,300
Total Cost	$36,235	$25,920

III. WATER STORAGE TANK STRIPPING AT THE SAN BERNARDINO AIRPORT

This section focuses on the stripping tests that were performed on the water storage tank. The stripping method generally used for large storage tanks is sand blasting. The section includes background information on the coatings used for storage tanks and a cost analysis and comparison of using the laser technology in place of the sand blasting operation used conventionally.

Background on Water Storage Tank Stripping

The coatings that are used for applications like water storage tanks are classified as Industrial Maintenance (IM) architectural coatings. These materials generally consist of two sets of coatings. In cases where the surface is blasted, the first coating is a zinc rich primer; the zinc is used to provide a galvanic surface. The second coating is a polyurethane topcoat to seal the zinc primer. In cases where the surface is chemically stripped, the first coating is an epoxy primer and the second coating is a polyurethane or a polysiloxane topcoat.

The project team stripped and applied a known coating to a portion of a ground level water storage tank at the San Bernardino Airport. It was necessary to strip and apply coating to the tank since the project team did not know what coating system is currently on the tank. The characteristics of the coating must be known for the testing.

The project team obtained the coating from a local supplier and the Aero Pro painters stripped a 20 square foot area of the tank with a chemical stripper. Ameron (PPG), a supplier of IM coatings, provided coatings at no cost to the project team for the stripping test. Appendix B shows MSDSs for the coatings used on the storage tank. The epoxy IM coating, called Amerlock Sealer Cure Res, was applied to the area after stripping. It also requires a curing material; the MSDS for the curing agent, called Amerlock Sealer Cure, is also shown in Appendix B. The MSDS for the polysiloxane topcoat, called PSX 700 Montu Tan, was applied over the epoxy primer. The MSDS for the curing material for this topcoat is called PSX 700 Cure.

Laser Stripping Demonstration

A picture of the tank on which the laser was tested is shown in Figure 3-1. The stripping demonstration was conducted at night. The storage tank demonstration involved placing the laser on a lift, transporting it to the storage tank and stripping a small portion of the industrial maintenance coating on the tank. The project team did one stripping test where both the primer and the topcoat were removed. The team did a second stripping test where only the topcoat was stripped from the tank. The second test was performed to show the capability of the laser to strip one coating and leave the other intact. Potential users would often need this feature. The third test was designed to demonstrate that the laser could strip rust and a small rust spot was stripped effectively.

Figure 3-1: Ground Level Water Storage Tank

The strip rate is related to the laser power. During this demonstration, the electrodes in the laser were not functioning properly and the laser was operating at about 20% of its full power potential. As a result, the power was very limited. For the first demonstration, the strip rate was about one square inch per minute. This rate was doubled during the second demonstration test as one of the team members ramped up the power.

Figure 3-2 shows the lift and Figure 3-3 shows the laser system. Figure 3-4 shows the laser being loaded onto the lift with a fork lift. Figures 3-5 and 3-6 show views of the laser positioned at the water storage tank. Figure 3-7 shows the laser stripping the coating. Figure 3-8 shows the section stripped of both topcoat and primer (the larger section) and the section stripped of topcoat only (the smaller section).

Figure 3-2. Lift for Laser

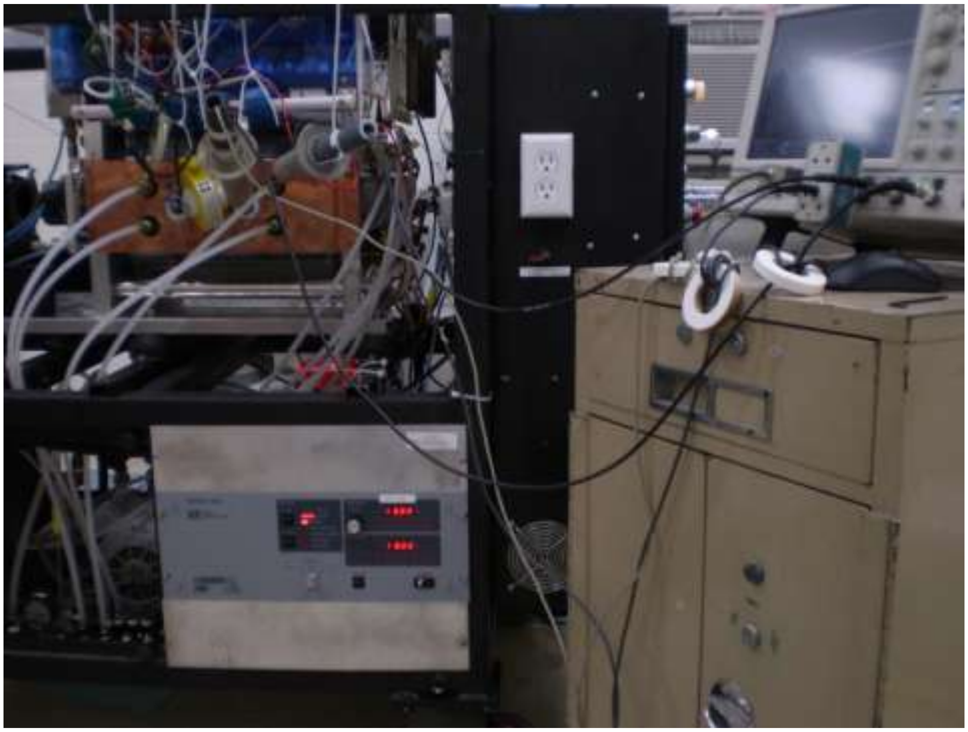

Figure 3-3. Portable Laser System

Figure 3-4. Laser Loaded on Lift

Figure 3-5. Laser Positioned at Water Tank

Figure 3-6. Another View of Laser Positioned at Water Tank

Figure 3-7. Laser Stripping Coating

Figure 3-8. Sections Stripped by Laser

Cost Analysis for Water Tank Stripping

Several nationwide companies offer stripping services for tanks of various kinds. IRTA obtained a cost estimate from one such company for sand blast stripping. This estimate was compared to the cost of stripping with the 3,000 watt laser stripping device currently under development by Laser Strip.

The water storage tank located at the San Bernardino airport is 50 feet in diameter and 40 feet high. The sides and the top of the storage tank must be stripped. This translates into 8,243 square feet of surface that must be stripped. The storage tank is within the jurisdiction of the South Coast Air Quality Management District (SCAQMD). SCAQMD regulations require the tank to be shrouded if it could impact any other facility over the fence line of the airport. Since there is a golf course located next to the property, the cost analysis assumes that the water storage tank must be shrouded for the stripping operation.

The cost of the shrouding and the sand blasting stripping is based on the square footage of the item to be stripped. The shrouding involves encasing the item (in this case, the water storage tank) in shrink-wrap and leaving a work zone between the shrink-wrap and the tank for workers doing the stripping. It also involves erecting three foot wide scaffolding around the water tank to act as an outside perimeter for the shrink-wrap. Additional frames are required along the top rim and top of the tank since stripping is required there as well. The shrink-wrap has a thickness of 9 millimeters and it is fire rated.

Industrial maintenance coatings are used for painting metal structures like the water storage tanks. The primers used for this purpose contain a substantial amount of zinc. Some of the zinc from the primer will end up in the sand residue that remains after the stripping operation. The California Department of Toxic Substances Control (DTSC) has regulations on disposal of hazardous waste. The waste will be classified as hazardous waste if the waste contains a certain concentration of zinc. It is not possible to know the concentration of the zinc in the waste before the sand blasting operation. Hazardous waste hauling companies partner with the sand blasting company and the scaffolding company in stripping operations of this type. These companies build a secondary containment plastic sheeting structure under the shrink-wrap in which the waste is generated. They haul off the waste on a daily basis as the stripping progresses. They dismantle the plastic sheeting and secondary containment material at the end of the process and dispose of it. If the waste is classified as hazardous, then the plastic sheeting must also be disposed of as hazardous waste.

In this case, the sand blasting company estimates that it would require five to seven days to strip the 8,243 square foot storage tank, assuming an eight hour day. The sand blasting company estimates the cost for stripping the tank on a rule of thumb at $2 per square foot. On this basis, the sand blasting company's cost for stripping the tank would amount to $16,486.

The shrouding company also provided an estimate based on the square footage of the tank. The shrouding company's cost for erecting the scaffolding is $6,080 and the cost of the shrink-wrap containment is $10,240. The total cost of the operation is $16,320.

The waste hauling company provided two estimates, one assuming the sand blast and coating residue is hazardous waste and one assuming it is not hazardous waste. The cost estimates involve setting up containment inside of shrink-wrapped scaffolding provided by others. The company would set up containment, clean blast media from the containment, bag the waste, profile the waste and properly dispose of the waste. Assuming six shifts (six days) are required for the operation, the company estimates that the total amount of waste that would be generated is about 10 tons. If the waste is classified as hazardous waste, the cost would amount to $24,990; if it is not hazardous waste, the cost would be $22,100.

The cost of using the laser is based on a strip rate of 500 square feet per hour per millimeter of coating stripped and a price for the service of $500 per hour. This indicates a cost of $1 per square foot stripped per millimeter of coating stripped. In this case, the storage tank surface area is 8,243 square feet and the average coating thickness on the tank is 3.5 millimeters based on measurement. On this basis, the cost of the stripping operation using the laser amounts to $24,729.

Table 3-1 summarizes and compares the cost of the blasting and laser stripping operations. The first column provides the costs of the sand blasting operation assuming the waste is not hazardous waste. The second column presents the costs assuming the waste is hazardous waste. The values show that the cost of stripping with the laser is less than half the cost of using sand blasting.

Table 3-1
Cost of Stripping Options for San Bernardino Airport

	Sand Blasting Operation (Non-Hazardous)	Sand Blasting Operation (Hazardous)	Leasing Laser Stripping Service
Stripping Service Cost	$16,486	$16,486	$24,729
Shrouding Cost	$16,320	$16,320	-
Waste Disposal Cost	$22,100	$24,990	-
Total Cost	$54,906	$57,796	$24,729

IV. GROUND VEHICLE PARTS STRIPPING AT BARSTOW MARINE BASE

This section describes the testing that was conducted at the Barstow Marine Base on portions of several different ground vehicles and components of ground vehicles. Barstow currently uses various types of blasting operations to strip the vehicles. The section describes the coatings encountered at the base and also includes a cost analysis and comparison of using the laser technology in place of the blasting operations.

<u>Background on Ground Vehicle Stripping</u>

The Barstow Marine Base in Barstow, California strips, repairs and refurbishes many different types of ground vehicles and ground vehicle parts including engines and assembled radar systems. The Base must strip mild aluminum, hard aluminum, cast iron, steel, composite and fiberglass. These parts are coated with a variety of different paints including chemical agent resistant coating (CARC), epoxy and latex. The type of paint that the Base routinely strips is:

- a primer that meets MIL-P-53030
- a topcoat that meets MIL-DTL-64159

The primer is a waterborne, air dry, corrosion inhibiting, epoxy primer. The topcoat is a waterborne CARC aliphatic polyurethane for use on military tactical equipment. An MSDS for the topcoat is shown in Appendix C.

<u>Laser Stripping Demonstration</u>

The project team stripped portions of ground vehicles at Barstow Marine Base. The laser was transported on a trailer to the Base and this was the first time it was transported such a long distance.. It was not damaged and it performed very well. This demonstrates the portability of the laser device. A picture of the laser at the Base is shown in Figure 4-1.

A ground vehicle called a Light Armored Vehicle (LAV) was stripped. A picture of the LAV is shown in Figure 4-2. Portions of the top and the side were stripped during the demonstration. A picture of one of the project team stripping the top of the LAV is shown in Figure 4-3. A picture of the side of the LAV after stripping is shown in Figure 4-4. The LAV had a chemical agent resistant coating (CARC) that was very thick, between 27 and 30 millimeters. Figure 4-4 shows the surface of the side of the vehicle after stripping the CARC and an adhesive tape that was on the vehicle. A close-up picture of the LAV side is shown in Figure 4-5.

The project team also stripped a steel front plate for an armored humvee. It contained an epoxy primer and a CARC topcoat which was 14 to 15 millimeters thick. A picture of the front plate is shown in Figure 4-6. Figure 4-7 shows one of the project team stripping a portion of this part. A closer view of the stripped area is shown in Figure 4-8.


Figure 4-1. Laser at Barstow Marine Base


Figure 4-2. Light Armored Vehicle (LAV)


Figure 4-3. Stripping Top of LAV


Figure 4-4. LAV Surface after Stripping

Figure 4-5. LAV Close-up after Stripping CARC and Tape.

Figure 4-6. Front Plate for Armored Humvee

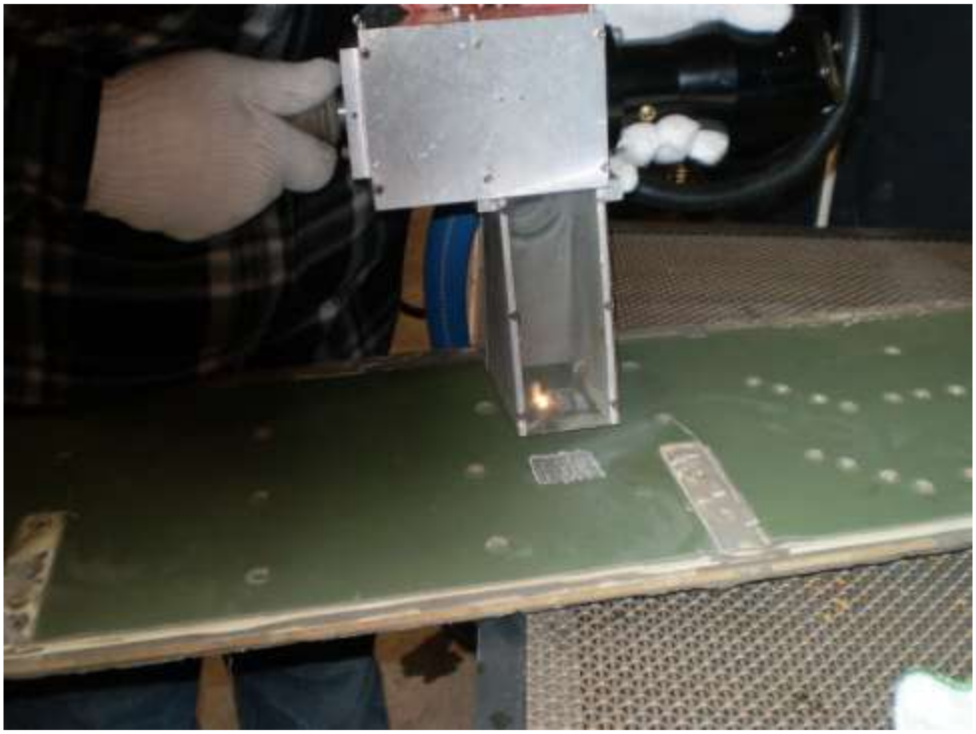

Figure 4-7. Stripping Humvee Front Plate

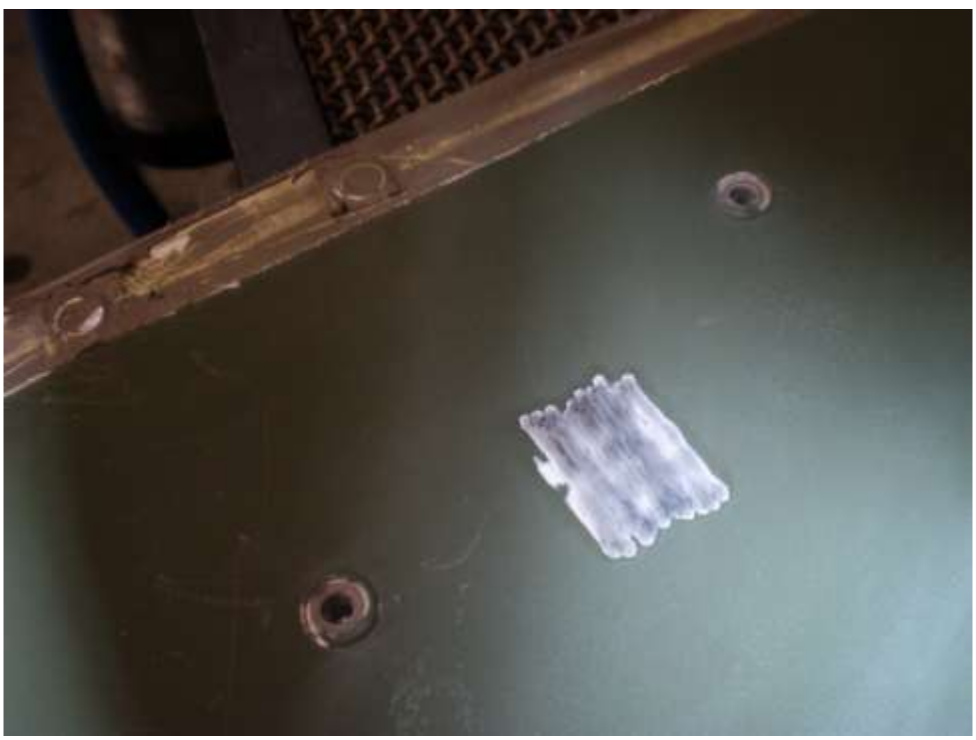

Figure 4-8. Close-up of Humvee Front Plate after Stripping

Another set of parts that were stripped comprised a tool kit for the P7 made of steel and aluminum. The coating on these parts was seafoam green enamel which ranged in thickness from about 1 millimeter to 17 millimeters. These parts are shown in Figure 4-9. Figures 4-10, 4-11 and 4-12 show each of the parts during stripping. Figure 4-13 shows the stripped portion of one of the parts.

Figure 4-9. Tool Kit Parts for P7

Figure 4-10. P7 Toolkit Part #1

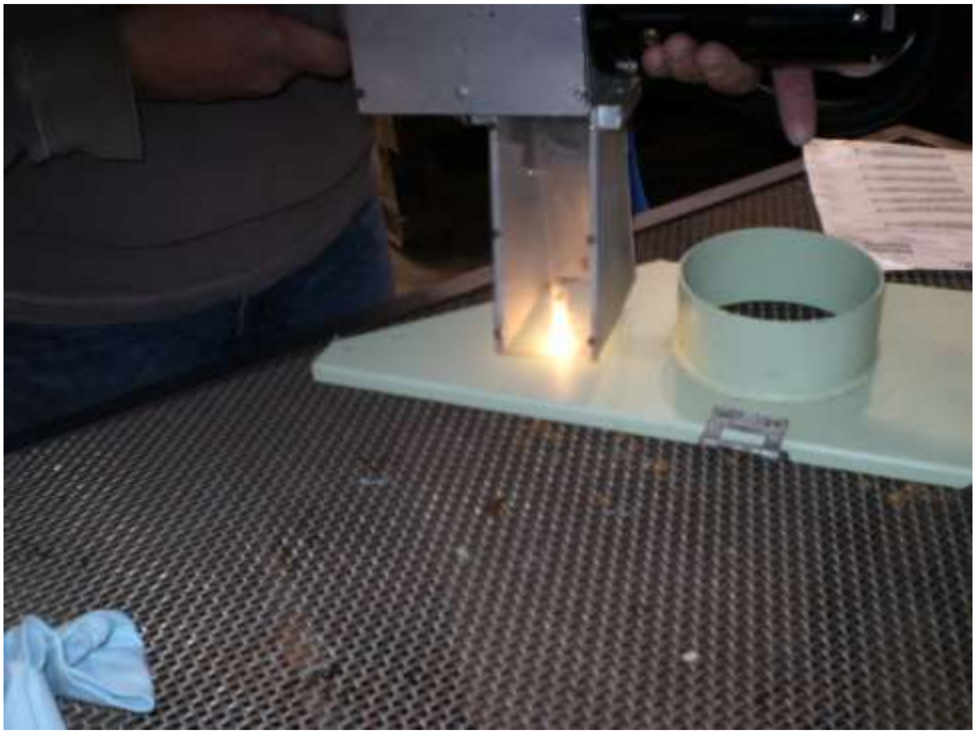

Figure 4-11. P7 Toolkit Part #2

Figure 4-12. P7 Toolkit Part #3

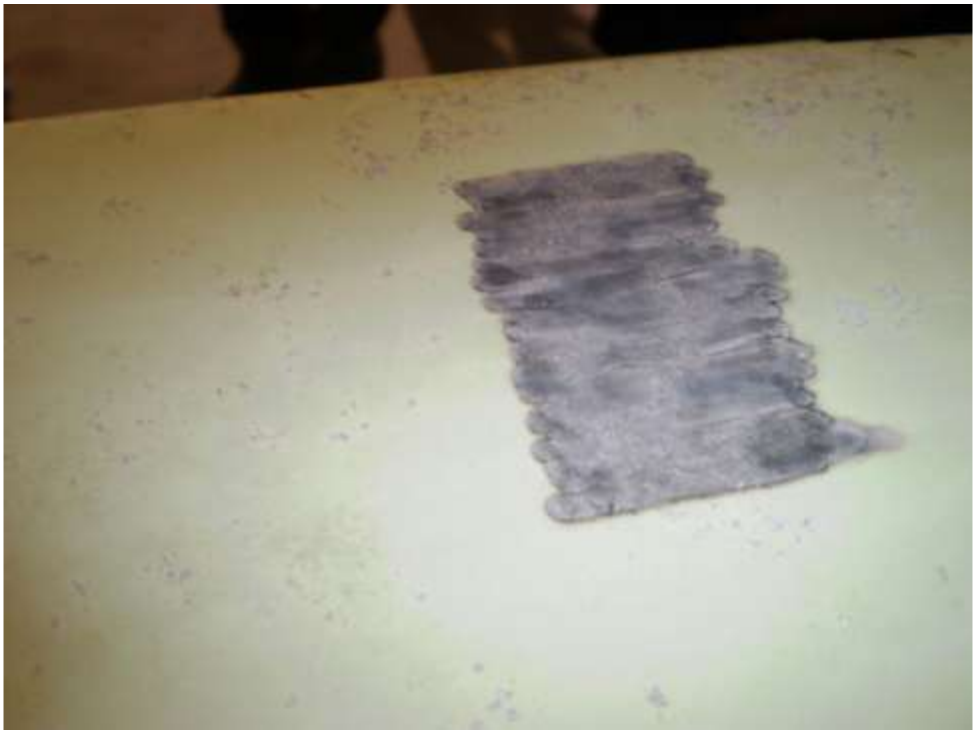
Figure 4-13. Stripped Portion of P7 Toolkit Part

The project team successfully stripped corrosion and sealant from an electrical plug shown in Figure 4-14. An anodized aluminum part with an epoxy coating, shown in Figure 4-15, was also stripped. The coating thickness was 3 millimeters.


Figure 4-14. Electrical Plug after Stripping

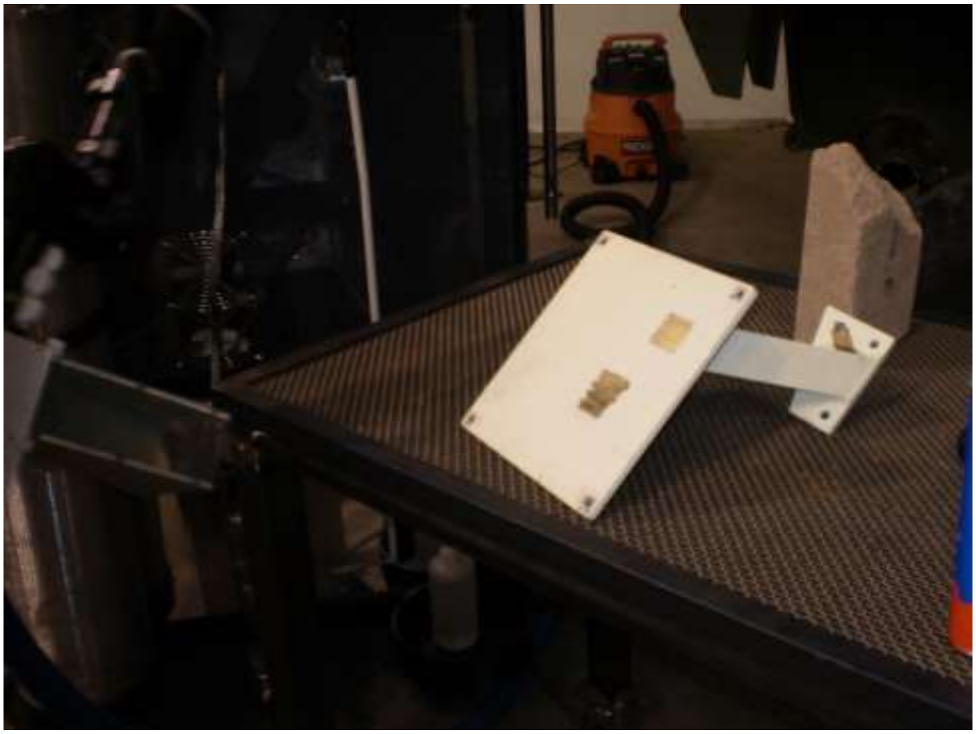

Figure 4-15. Anodized Aluminum Part after Stripping

<u>Cost Analysis for Ground Vehicle Stripping</u>

IRTA obtained information from the Barstow Marine Base and conducted a cost analysis of the stripping. The stripping is currently performed in four booths using garnet media. An MSDS for a typical garnet media is shown in Appendix D. The vehicles and vehicle parts are placed on pallets and stripped in the four booths during the day shift. Two of the booths are used for stripping during a night shift.

Barstow pays 49 cents per pound for the garnet and, in 2007, purchased and used 85,400 pounds of the media. The cost for purchasing the media amounted to $41,846.

The media is recycled but eventually requires disposal at a cost of 29 cents per pound. Assuming 85,400 pounds requires disposal, the cost is $24,766. The Base also must use drums for the disposal. The density of the garnet is 145 pounds per cubic foot. A 55 gallon drum has a volume of seven cubic feet. On this basis, 84 drums would be required for the disposal. Assuming the Base would require 21 drums four times a year, the cost of the drums each time is $200 plus a $45 delivery fee and tax of 8.25 percent. This amounts to $1,069. The labor required for disposal is estimated at 30 minutes per drum or 42 hours. The Base did not provide a labor rate for proprietary reasons so IRTA obtained a labor rate from a contract stripping company. For Monday through Friday operations, this company charges $30 per hour. Assuming this labor rate for the Barstow personnel, the annual labor cost for disposal is $1,260. The total disposal cost for the media is $27,095.

Maintenance costs for the stripping operation are estimated by the base at $20,000 per year for safety equipment and between $35,000 and $50,000 per year for general maintenance. Assuming the midpoint of $42,500 for the general maintenance, the total annual maintenance cost is $62,500.

IRTA used the labor rate provided by the contract stripping company to estimate the labor cost of the stripping. Four booths are operated for nine hours per day and two of them are operated for nine hours during a night shift. Assuming there are six workers who perform the stripping and that each works an eight hour shift five days per week for 52 weeks a year and assuming the labor rate of $30 per hour, the total annual labor cost for the stripping amounts to $374,400.

The energy costs were estimated using the hours of operation for the booths provided above. Two of the booths have 12 three horsepower auger motors, one 20 horsepower elevator motor and one 200 horsepower primary exhaust fan. These booths each have one 150 horsepower compressor. The booths are operated for nine hours during the day shift and nine hours during the night shift. The other two booths have eight three horsepower auger motors, one 20 horsepower elevator motor and one 125 horsepower primary exhaust fan. There is also one 100 horsepower compressor in each of these booths. The two booths are operated for nine hours during the day shift. The load factor for the compressors is 50 percent. Using these assumptions, and an efficiency of 95 percent, the total energy use for the booth operations is 3,246,750 kilowatt hours per year. The base pays a rate of 13 cents per kilowatt hour which leads to an annual energy cost of $422,076.

Summing the media cost, the media disposal cost, the maintenance cost, the labor cost and the energy cost leads to a total cost for the stripping operations of $927,017 per year.

IRTA analyzed two different scenarios to compare the cost of using the laser stripping method with the garnet media blasting method used by the base currently. The first scenario is that the base would lease the stripping service from Laser Strip which would require using several different portable handheld lasers. The second scenario is that the base would purchase a large fixed higher powered laser from Laser Strip to do all of the stripping. This fixed system, which has a nominal power of 6,000 watts, is currently being assembled by Laser Strip.

For the first scenario, the cost of leasing the lasers is $1 per square foot of surface area stripped per millimeter of paint removed. The paint stripped by the Base is between eight and 12 millimeters thick with an average thickness of 10 millimeters. The Base could not provide the square footage stripped in a year but did provide the number of large and small vehicles stripped each month and gave examples of small and large vehicle types. During one year, 144 large vehicles and 525 small vehicles were stripped. IRTA assumed the Light Armored Vehicle (LAV) was typical of the large vehicles stripped. Using the dimensions of the LAV (a length of 29.96 feet, a width of 8.20 feet and a height of 8.83 feet), the typical large vehicle has a surface area of about 859 square feet. Assuming there are 144 large vehicles stripped, the square footage of large vehicles stripped in a year is 123,696. IRTA assumed that the M105 1.5 ton cargo trailer was typical of the small vehicles stripped. This vehicle has a length of 9.17 feet, a width of 6.17 feet and a height to the top of the side panels of 1.5 feet. On this basis, taking into account that there are 525 small vehicles stripped, the square footage of small vehicles stripped annually amounts to 83,475 square feet. The base also strips pallets used to support the vehicles. An average of 400 pallets are stripped per month. Typical pallet dimensions are 48 inches by 40 inches. Assuming the base strips only the top of the pallets, the surface area square footage of the pallets amounts to 63,840. The total of the square footage stripped taking into account the small vehicles, the large vehicles and the pallets is 271,011.

Assuming the average coating thickness is 10 millimeters and using the square footage number for the vehicles and pallets, the cost of using the service would amount to $2,710,110 annually. This is substantially higher than the cost of using the garnet blasting operation which is a little less than $1 million per year.

The second option, purchasing a large fixed laser, is a more reasonable one for Barstow since they have such a large stripping operation. The fixed laser currently under construction by Laser Strip would have a sales price of $3 million. Assuming a four percent cost of capital and a 20 year useful life for the laser, the annualized capital cost of the laser is $156,000.

This laser was used for several years at Hill Air Force Base for stripping radomes which are made of composite. Laser Strip purchased the laser components from Hill and is modernizing some of the components and modifying it so it will be able to strip a range of different parts. The Hill Air Force Base personnel indicate that the strip rate of the laser is 162 square feet per hour for a five millimeter coating thickness. For the 10 millimeter average coating thickness routinely stripped at Barstow, the strip rate would be half the value or 81 square feet per hour. Assuming Barstow needs to strip 271,011 square feet per year, the laser would be operated for 3,346 hours annually. The labor hours used for stripping currently at Barstow amount to 12,480 annually, more than three times the laser stripping hours that would be required. Assuming three workers would be required during the hours of operation of the laser (half the number required for the garnet blasting operation) and that the labor rate is $30 per hour, the annual labor cost of using the laser would amount to $290,340.

The maintenance cost of the laser is likely to be high because it is a fairly new technology. IRTA estimates this cost at $50,000 per year.

The fixed 6 kW laser is used for 1,673 hours per year. The electricity use is 100,380 kilowatt hours per year. Again, assuming a cost for the electricity of 13 cents per kilowatt hour, the annual energy cost of using the large fixed laser is $13,049.

Summing up the capital cost of the laser, the labor cost, the maintenance cost and the energy cost, the total annualized cost of using the fixed laser amounts to $509,389. This cost is substantially lower than the cost of the current stripping operation.

Table 4-1 summarizes and compares the three different options. The first option is the garnet blasting used currently. The second option is leasing the service of laser stripping from Laser Strip. The third option is for the base to purchase the large fixed laser from Laser Strip.

Table 4-1
Annualized Cost of Stripping Options for Barstow Marine Base

	Garnet Blasting	Leasing Laser Stripping Service	Purchasing Fixed Laser
Capital Cost	-	-	$156,000
Media Cost	$41,846	-	-
Media Disposal Cost	$27,095	-	-
Maintenance Cost	$62,500	-	$50,000
Labor Cost	$374,400	-	$290,340
Electricity Cost	$422,076	-	$13,049
Total Cost	$927,917	$2,710,110	$509,389

The lowest cost option in Table 4-1 is purchasing the large fixed laser. The major reason this option is lower cost is that the hours of operation for the laser stripping are much lower than the hours of operation for the garnet blasting operation. The hours of operation influence the labor cost and the electricity cost. The electricity cost for the laser system is much less than the electricity cost of the garnet blasting operation.

The highest cost option is leasing the laser stripping service. This is a loaded cost that includes many variables and these same variables are not quantified in the garnet blasting operation or the option of purchasing the fixed laser. The variables include the cost of leasing or owning space and many indirect costs.

V. NAVY SHIP PARTS STRIPPING AT NAVY MAINTENANCE CENTER

This section describes the testing that was conducted at the San Diego Navy maintenance center on a common type of part the center strips and on panels brought to the site by another Navy group. The part is commonly stripped in a burn-off oven and with sand blasting. The ship hull coatings on the panels are commonly stripped with sand blasting. The section provides a discussion of the coatings and a cost analysis and comparison of the laser stripping process and the processes that are used today.

Background on Navy Parts and Panel Stripping

The Navy's maintenance center, located in San Diego, is responsible for stripping and recoating various types of navy ship parts. The operation processes 80,000 pieces per year. Currently the parts are stripped in a burn-off oven. They are then sand blasted to clean the surface and etch it for the coating application. The parts are coated first with thermal spray aluminum paint and then a polyester powdercoat. The coating used by the Center is polyester Triglycidyl Isocyanurate (TGIC). An MSDS for the powdercoat is shown in Appendix D.

Another Navy group brought panels containing several different types of ship hull coatings. This group did not know the exact types of coatings that were on the panels but some qualitative information on these paints is provided below.

Laser Stripping Demonstration

The laser was transported to San Diego to the Navy maintenance center for the stripping tests. This demonstration showed the portability of the laser for a long 2-hour driving trip. At the center, portions of powder coated ship parts and panels painted with ship hull coatings were stripped. A picture of the laser at the shipyard is shown in Figure 5-1.

Figure 5-1. Laser Stripping Device at Navy Maintenance Center

The Navy commonly paints a part called a stanchion that is a component of the railing on ships. A picture of two stanchions is shown in Figure 5-2. They are made of steel and contain a metallized aluminum coating and then a powder topcoat. Figure 5-3 shows one of the stanchions prior to stripping and Figure 5-4 shows a close-up view of a portion of the stanchion that was stripped.

Figure 5-2. View of Typical Stanchions

Figure 5-3. Stanchion Before Stripping


Figure 5-4. Close-up View of Stanchion after Stripping

The project team also stripped part of two panels that contained copper antifouling paint topcoat with a significant (50 to 75%) copper content and probably a high zinc oxide content as well. These panels also contained an epoxy primer. The coating thickness ranged from 23 millimeters to 27 millimeters which is very thick. One of the panels had a sprayed on coating and the other had a rolled coating. Figure 5-5 shows the laser stripping one of the copper panels. Figure 5-6 shows the stripped sections of the copper panel. Even though the coating is very thick and contains substantial quantities of metal, the laser did a reasonable job in stripping.


Figure 5-5. Laser Stripping Copper Paint Panel

Figure 5-6. Copper Coated Panel after Stripping

Sections of two other panels, one coated with a blue coating and the other coated with a yellow coating, were also stripped. The blue coating may be an epoxy foul release coating that has a thickness of 7 millimeters. The yellow coating, which has an oil layer, is almost certainly silicon based foul release coating; this coating was extremely thick, 27 millimeters. Figure 5-7 shows the blue panel during stripping and Figure 5-8 shows the blue panel after stripping. Figure 5-9 shows the yellow coating after stripping.

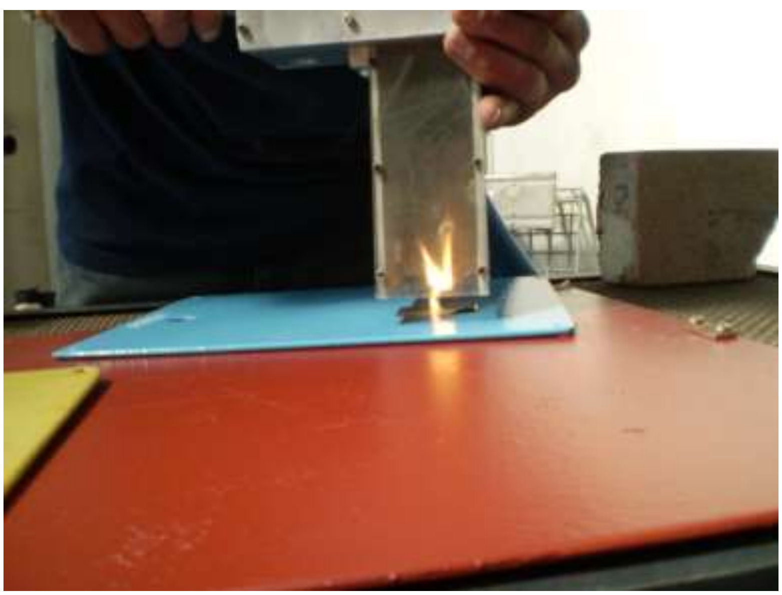

Figure 5-7. Laser Stripping Blue Coated Panel

Figure 5-8. Blue Coated Panel after Stripping

Figure 5-9. Yellow Coated Panel after Stripping

The laser also stripped the rust from a threaded part. The part after stripping is shown in Figure 5-10.

Figure 5-10. Threaded Rusted Part after Stripping

Cost Analysis for Stanchion Stripping

The stanchions are currently stripped and repainted at the Navy maintenance facility in San Diego. As discussed earlier, two coatings are used on the stanchions. The first coating that is applied is a metalized coating and the second coating is a powder coating. When the stanchions are repainted, the Navy only removes the powder coating which is about 7 millimeters thick.

The stanchions are 36 inches tall and 3.5 inches in diameter. Based on this information, the cylindrical surface area of each stanchion is 2.75 square feet. The Navy strips about 150 of the stanchions per day which leads to a coating surface area of 413 square feet. The operation involves using a burn off oven to remove the coatings. The manager of the operation estimates that the cost of stripping the stanchions is $178 per hour or $1,424 per day. This cost excludes the labor cost and does not take into account overhead.

Two people are responsible for the stripping operation. Using a labor rate of $21.60 per hour, the cost of stripping is $43.20 per hour or $346 per day assuming an eight hour day. The manager of the operation does not know what the overhead and indirect costs are for the operation. IRTA investigated this issue and used the results of a paper (Raffi and Swamidase) indicating that the overhead rate in an average U.S. manufacturing firm is about two and one-half times the direct labor cost. On this basis, adding in this overhead rate, the labor cost and the overhead cost of stripping at the Navy maintenance facility is $865 per day. Adding in the non-labor cost, the total cost of the stripping operation is $2,289 per day.

For the laser, the strip rate is assumed to be 500 square feet per hour per millimeter of paint stripped. The cost charged by Laser Strip is $500 per hour. On this basis, the laser would cost $1 per square foot per millimeter stripped. Taking into account the area of

413 square feet that needs to be stripped and a coating thickness of 7 millimeters, the total cost of stripping the stanchions with the laser amounts to $2,891.

Table 5-1 summarizes and compares the stripping options for the stanchions. The cost of stripping with the laser is 26 percent higher than the cost of using the burn off oven. The cost of the operation will vary depending on the cost of gas. As the cost of gas increases, the laser stripping process might be competitive with the current process.

Table 5-1
Cost of Stripping Options for San Diego Navy Maintenance Center

	Burn-Off Oven	Leasing Laser Stripping Service
Stripping Cost	$1,424	-
Labor Cost	$346	-
Overhead Cost	$865	-
Total Cost	$2,289	$2,891

VI. CONFERENCE AND DEMONSTRATION

On October 21, 2009, the project team held a conference at Southern California Edison's Customer Technology Applications Center (CTAC) in Irwindale, California. Attendees included representatives from commercial and military operations involved in aircraft maintenance. Personnel from commercial vehicle maintenance facilities, an electric motor rebuilder and representatives from several government agencies also attended.

At the conference, the project team presented the results of the project. The four demonstrations were described and the cost analysis results were presented and discussed. A demonstration of the 100 watt prototype laser used for the four applications was performed by Laser Strip. Videos of the larger 3,000 watt portable laser and the 6,000 watt fixed laser under development by Laser Strip were also presented. A picture of the Laser Strip owner demonstrating the prototype unit at the conference is shown in Figure 6-1 and a picture of several attendees in the demonstration room is shown in Figure 6-2.

Figure 6-1. Laser Strip Owner Joe Ermalovich Demonstrating Prototype Unit


Figure 6-2. Attendees in the Demonstration Room

VII. RESULTS AND CONCLUSIONS

This project involved performing tests and demonstrations of a portable hand-held laser paint stripping device developed by Laser Strip. The prototype device used for the demonstrations had a power of about 100 watts. Laser Strip is developing a larger 3,000 watt hand-held stripping laser that is much more powerful. The company is also developing a stationary laser stripping system with a power of about 6,000 watts.

Four demonstrations were conducted with the small 100 watt laser prototype in the course of the project. First, the small laser was used to strip paint from various components of an aircraft at Aero Pro, an aircraft maintenance facility. Second, it was used to strip a small portion of an industrial maintenance coating on a large water storage tank at the San Bernardino Airport. Third, it was used to strip paint from sections of a wide variety of ground vehicles at Barstow Marine Base. Fourth, it was used to strip portions of stanchions and panels containing marine coatings at a San Diego Navy maintenance facility. The analysis focused on these four diverse activities that span the range of paint stripping applications encountered today.

IRTA conducted a cost analysis which compares the cost of stripping the paints with the technology that is used currently in each case with the cost of stripping with the larger lasers under development by Laser Strip. The cost comparison is summarized in Table 7-1.

Table 7-1
Cost Comparison of Currently Used Technology and Laser Stripping Technology

Stripping Application	Current Stripping Technology	Cost of Stripping With Current Technology	Cost of Stripping With Laser
Aircraft	Chemical Stripping	$36,325	$25,920
Storage Tank	Sand Blasting	$54,906 to $57,796	$24,729
Ground Vehicles	Media Blasting	$927,917	$509,389
Navy Parts	Burn-Off Oven	$2,289	$2,891

Many aircraft maintenance facilities use chemical strippers for removing the primer and topcoat from aircraft and aircraft parts. These chemical strippers are often based on methylene chloride which is a carcinogen and is classified as a TAC in California. Other aircraft maintenance facilities use chemical strippers based on VOC solvents which contribute to photochemical smog. The values of Table 7-1 show that the cost of using the methylene chloride stripper at Aero Pro for stripping a large 727 aircraft is higher than the cost of using the larger portable laser under development by Laser Strip.

Water storage tanks and other large metal structures are often stripped using sand or other blasting media. These operations generate particulate matter emissions which can cause lung damage and will increasingly be regulated by EPA and air regulatory agencies in

California in the future. The cost of using sand blasting is higher than the cost of using the large portable laser that is being developed by Laser Strip for stripping the metal water storage tank as shown in Table 7-1.

Ground vehicles constructed of various metal substrates are commonly stripped with media blasting of various types. Again, these operations generate large quantities of particulate matter emissions. Table 7-1 shows that the cost of using the media blasting operation at the Barstow Marine Base is almost twice as costly as using the larger fixed laser under development at Laser Strip.

Stanchions used on Navy craft are currently stripped using a burn-off oven at the Navy maintenance facility in San Diego. Such ovens have high energy use and generate nitrogen oxide emissions. The values of Table 7-1 illustrate that the cost of using the burn off oven for stripping is somewhat lower than the cost of using the larger portable laser under development at Laser Strip for the stripping.

In the case of three of the four applications discussed in the document, the cost of using the laser technology for stripping is lower than the cost of using current technology. In a particular application, the cost of using the portable laser technology is heavily influenced by the area that requires stripping and the thickness of the coating. The higher the square footage that requires stripping and the thicker the coating that needs to be stripped, the higher the cost is of using the portable laser. Cases where a very thick coating needs to be stripped are likely to be very costly to strip with the portable laser. The Barstow Marine Base cost comparison demonstrates this point. It would be much more cost effective for the Base to purchase the larger fixed laser under development at Laser Strip than to use the service of stripping with the portable laser. That cost comparison shows that using the large fixed laser is actually much lower in cost than stripping with the current media blasting operation.

A notable advantage of using the laser for stripping is that the energy requirements of stripping with the laser are much lower than the energy requirements for stripping with the other technologies. In the case of the aircraft stripping case study analyzed here, the electricity requirement for using the methylene chloride stripping process for a 727 is 6039 kWh whereas the electricity requirement for the laser is only 147 kWh. In the case of the Barstow Marine Base case study, the annual electricity requirement for stripping with the garnet blasting is 3,246,750 kWh. The annual electricity requirement for stripping with the large fixed laser is 100,380 kWh which is substantially less.

Laser Strip is in the development phase of the higher power hand-held portable device. The company plans to commercialize the high power laser within the next few years. Laser Strip will offer a stripping service to potential customers or will sell the lasers to other companies that offer stripping services. Laser Strip is also developing a very large stationary laser stripping system. Potential customers for purchasing such stationary systems would include very large commercial operations that perform stripping and military operations that strip routinely.

The results of the project were presented at a conference held at Southern California Edison's CTAC facility in Irwindale, California. Parties interested in laser stripping as an alternative method attended. They included representatives from private companies, military bases and government.

VIII. REFERENCES

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