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Application of Industrial Engineering Techniques to Reduce Workers' Compensation and Environmental Costs - Deliverable D

U.S. DEPARTMENT OF THE NAVY
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DELIVERABLE D

BLAST AND PAINT DEPARTMENT ENVIRONMENTALLY COMPLIANT SPRAY EQUIPMENT

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SUMMARY

The research with environmentally compliant spray equipment is to reduce airborne emissions (VOC's) from the coating application process (spray painting). The process is designed to identify, test and streamline spray equipment to reduce paint usage, reduce smog causing voc emissions, improve transfer efficiency, and reduce paint wastes in U.S. shipyards. Most U.S. shipyards and foreign shipyards currently use traditional air-atomized spray painting guns for their coating applications. Some facilities utilize the Powder coating or Flame spray process to apply specialized coatings, but on the average the preferred process is the air-atomized gun. Over the years, this process has become expensive and time consuming as companies strive for compliance to mandated EPA, OSHA and local district air quality regulations.

Under pressure from environmental authorities and upper management to reduce voc emissions, coating manufactures are producing coatings that are low in voc emissions, which by the way are increasing in cost as new formulations are developed due to the complexities of certain marine coatings for tanks, underwater hulls, bilges, fresh water tanks and Cht tanks (waste tanks). Because of rising costs, it is wise for U.S. shipyards to take a proactive approach to minimizing coating, man-hour and equipment expenditures.

BACKGROUND

The traditional air spray gun, such as airless and conventional is not about to disappear from the industrial scene any time soon, because there are more of them in production activities than any other type of device for spraying liquid coatings. Most spray equipment manufacturers and environmental agencies predict that this staple of our industry will be essentially eliminated in the next ten years and replaced by spray guns that offer higher transfer efficiency. Transfer efficiency rates the ability of spray painting equipment to put paint on the parts being painted rather than allowing it to escape as overspray or in other forms of paint waste. If you use conventional spray equipment for example to apply ten pounds of paint to an uncoated surface and that surface gain two pounds as a result of being coated, you've achieved twenty percent transfer efficiency, i.e. twenty percent of the paint ended up on the part and the rest landed on booths, walls, containment, hangers and clothing (80% loss).

Paint is not the only cost associated with poor transfer efficiency. Open air spraying, as performed in most shipyards, requires purchasing and setting up of spray containment equipment which often equals the cost of the paint. Plus the generated waste is either difficult or very expensive to dispose of. Despite all the pressure to eliminate voc's, coatings thinned with organic solvents will continue to be used in the shipbuilding industry because of customer specifications or individual yard specifications.

It is quite evident that in the shipbuilding industry, requirements make it difficult or expensive to change overnight from "tried and true" air applied conventional-solvent thinned coatings and configurations of vessels make it difficult to coat with certain types of equipment that lessen voc's and improve transfer efficiency.

U.S. shipyards spend an enormous amount of money on coatings and coating applications. As environmental regulations tighten and finishers continue to search for ways to cut cost, the trend is clearly towards higher transfer equipment and alternative coatings.

TYPES OF ENVIRONMENTALLY COMPLIANT SPRAY EQUIPMENT

Most of the alternatives to conventional air spray guns would never have been invented had it not been for the relatively poor transfer efficiency of air-atomized spray. Two of the most common replacements, electrostatic application and airless spray, were commercialized long before the advent of the Environmental Protection Agency (EPA). The driving force was to reduce overspray (and cost of paint). There was certainly room for improvement, since conventional air-spray guns can waste 60-80 pct of the paint purchased.

The major types of spray equipment in use today are as follows:

- Conventional Spray Guns
- Airless
- Air-Assisted Airless Spray gun
- High-Volume Low-Pressure Spray gun
- Electrostatic Spray gun
- Plural-Component Spray gun
- Air-Assisted Electrostatic Spray Gun

In this section several types of spray gun used to apply liquid coatings will be identified, noting advantages and disadvantages. In order to properly examine, test and evaluate spray equipment, you must first identify coating requirements and specifications. The research provided in this section gives baseline data for evaluating the spray equipment.

1. Conventional Spray Guns: These are "conventional" because they have been around since the early part of this century. They were widely used before any of the others. Basically they emit a stream of paint from a small opening in a fluid nozzle. The paint is broken up into tiny droplets by compressed air emerging from jets adjacent to the fluid nozzle. Relatively high air pressures at low volumes will quickly atomize large amounts of paint.

Despite their tendency to spray more paint into the air, on containment, clothing, and onto other parts, they remain an important tool in most painting facilities. They are versatile and can spray a class A finish on almost any surface. So even if you have one of the more efficient types of spray apparatus, you probably need a few conventional air-atomizing guns to do what the more advanced equipment will not.

a. Advantages:

-In the hands of a skilled operator, produces a smooth, reflective finish.
-Can be used to coat almost any shape. Using a variety of fluid and air nozzles, an operator can spray narrow bands or wide fan patterns.
-Can apply paint at high production rates on parts hanging from fast-moving conveyors.
-Are "user friendly" and most spray painters are experienced in using them.

b. Disadvantages

-Very poor transfer efficiency.
-Wastes paint, increases cleanup costs, emits more VOC's.

2. Airless Spray Guns: When you think of airless spray, think of a garden hose. It sprays water under high pressure through a nozzle. When the water emerges from the nozzle its velocity causes the stream to disintegrate into droplets as it encounters resistance from the atmosphere. The airless gun is similar in that it pressurizes paint to 3,000 psi (or higher) and forces it through a nozzle. Unlike conventional air spray, there are no jets of atomizing air to break up the paint and propel it to the surface. Atomization is dependent upon high fluid pressure.

a. Advantages:

-In the absence of atomizing air, less overspray and better transfer efficiency.
-Can apply paint at a high flow rate, resulting in ability to meet high-production speeds.

b. Disadvantages:

-Inability to break up paint into very fine droplets, thus producing a coarser spray and rougher finish.
-Nozzle wear. High velocities cause abrasive pigments in paint to wear nozzle openings as they travel through the nozzle.
-Danger of air-less injection injury. The paint emerges at such force that it can penetrate skin exposed to the spray at close range.

3. Air-Assisted Airless Spray Equipment: A hybrid of airless spray and conventional air-atomized spray, this kind of gun uses fluid pressures higher than those used in conventional air-atomized guns but lower than those employed in normal airless spray. Unlike normal airless guns, these guns do have compressed air jets that supply atomizing air, but the air pressure is far lower than that used in conventional air-atomize guns. The result is that the coarse spray provided by the airless atomization is further broken up into a finer spray by the compressed air.

In operation, air-assisted airless guns provide atomization much better than is normal with airless spray. The finish quality and production equals that of air-atomized spray. Danger of airless injection is lessened, as is wear of fluid nozzles.

a. Advantages:

-The main reason for considering use of air-assisted airless spray, however, is its much better transfer efficiency. The softer spray also makes it easier to spray into recesses. Both air-assisted and pure airless spray operate at high fluid pressures and thus can use smaller-diameter fluid lines. This translates into paint and solvent savings because it takes less solvent to flush smaller-diameter lines.
-Lower pressures required to pump High Solid coatings.

b. Disadvantages:

-An extra airline required for spray gun.
-Getting the operator of an airless gun used to lower pressure requirement of air-assisted airless.

4. High-Volume Low-Pressure (HVLP) Spray Equipment

HVLP is a variation of conventional air-atomize spray. The difference is that these guns are designed to atomize paint using a high volume of air delivered at low pressure. The lower pressure results in far less overspray and "bounce back."

a. Advantages:

-Better transfer efficiency results in less paint waste and lower cleanup costs. The exact transfer efficiency depends upon the circumstances in your installation , the part design, spray techniques, the mix of parts, etc. But most experts agree that HVLP offers significant improvement.
-Operators used to conventional guns generally find it easy to learn how to use HVLP.

b. Disadvantages:

-Atomization may be insufficient to meet the strictest requirements for smooth, fine finishes.

-May be difficult to atomize paint at sufficiently high rates to meet very high-production requirements. HVLP atomization capability has improved markedly in recent years, however, with better ability to break up low-VOC coatings being sprayed at high fluid-flow rates.

Some problems in achieving proper atomization with HVLP may be caused by "starving" the spray gun for air. Causes of this problem include use of air hoses that are too long or too small in diameter; use of too many "quick disconnect" fittings; and use of low-performance air compressors and air regulators. Any one of these factors may result in too little air being delivered to the air cap, causing poor atomization from the gun. Some of these guns use air compressors to deliver the atomizing air, while others use a turbine. The turbine is a series of fans mounted inside a housing, designed to produce pressurized air for one or more guns. In the process of forcing the air through the turbine the fans create friction and warm the air. This helps to heat the paint and in turn lowers its viscosity, thus making it easier to atomize.

5. Electrostatic Spray Equipment

Electrostatic painting begins with a spray gun or other device (discs or bells) to atomize paint. The atomizing principle could be any of those previously discussed, conventional air-atomize, HVLP, or airless.

The difference is that an electrostatic application device is equipped with a means of electrically charging the particles of paint. A common method is to build in an electrode near the point where paint is atomized. This electrode electrostatically charges the particles positively. Parts are grounded, usually by hanging or using a grounding strap securely connected to the ground. The grounded parts attract the positively charged paint particles (opposite attract).

The result is that fewer of the paint particles are propelled into space as overspray and more are electrostatically guided to the surfaces of the parts being painted. Sprayed particles will even turn the corner and be attracted to the back side of a part if the velocity of the particles causes them to initially travel past the parts being painted. This is called "wraparound".

Transfer efficiency is greatly improved. The amount of improvement depends upon the parts being painted, the design, etc. Electrostatic spray is particularly beneficial in improving transfer efficiency when parts with lots of open areas, (lacy patterns, for example) are being sprayed.

a. Advantages:

-Higher transfer efficiency.
-Coverage of edges (electrostaticly guided paint is attracted to high points and edges first).
-Uniformity of film thickness. As paint builds up on surfaces with the highest electrostatic attraction, it insulates them. Then electrical attraction increases in the uninsulated, uncoated areas, and these receive more of the paint.
-Productivity. Electrostatic guns mounted on reciprocators are widely used to paint long runs of parts in high-production installations. Labor costs are lower.

b. Disadvantages

-Faraday-Cage Effect. As mentioned previously, electrostatically charged particles seek out the nearest grounded surface. If that happens to be the ridge area of a sculptured part, the valley may be difficult to reach. For this reason, manual touchup with non-electrostatic guns may be necessary.
-Changes appearance of metallics. Many paints, especially those used in automotive finishing, contain metallic flakes that give the finish metallic sparkle. The visual effect is different if the particles are applied electrostatically, since they are conductive and tend to stand on edge rather then lie flat in the coating.
-Fire Hazard. If an electrostatic installation is not properly set-up, there is a danger that a spark can occur, igniting paints containing flammable solvents.
-Safety. If operators are not careful in following set-up directions, they can be electrostatically shocked.
-Ergonomics. Electrostatic guns traditionally have been longer and some heavier than conventional guns. Some have a bulky cable connected to them to carry the electrical current. The newer models have built in turbines that produces an electric charge once connected to air. This eliminates bulky cables and cords. Operators may find some guns more difficult and more tiring to handle, but suppliers have been working to improve ergonomics of electrostatic guns. In considering this equipment (and indeed any spray equipment) you should look not only at size and weight of the gun, but evaluate ease of trigger pull and maneuverability of the tool (with hoses) as well.
-Cleanliness. It's always a good idea to keep conveyors, spray equipment and spray booth areas clean. But in electrostatic painting it is not just a good idea; it's mandatory in order to achieve the benefits of electrostatic application. Parts must be securely grounded as they travel through the booth. This means that if they are hanging from paint-laden racks or the conveyor has picked up paint and

is becoming insulated, electrostatic attraction is lessened.
-Some coatings may require reformulation. Since the process depends upon electrical conductivity or lack thereof, solvent selection becomes more important. Some solvents are more conductive than others. In a like manner, application of waterborne coatings requires special equipment to deal with the conductivity of water. High humidity in the paint area can cause conductivity problems.

6. Plural-Component Spray Equipment

Some coatings, principally urethanes, are supplied as two components. After being mixed, the components chemically react with one another to form a solid coating. They are often referred to as "catalyzed" since the "catalyst" causes a reaction that leads to curing of the coating. An advantage is that low temperatures are sufficient to cure the coating and thus plastic parts that cannot tolerate high temperatures can be coated. The coatings also exhibit unusual durability in certain applications and require less solvent for thinning, thus improving VOC control.

If the two components are mixed before entering a paint pump or pressure pot, the mixed material must be sprayed promptly or the reaction of the two components increases viscosity to the point where the coating is no longer sprayable. It is said to have limited "pot life".

The components mix just prior to application. This remedies the "pot life" problem, since mixing occurs only at the moment before application.

Two-component application equipment is used in some very high-production applications, but not to the extent of the more conventional technologies. The reason is obvious, the equipment is more costly, as are the coating materials.

a. Advantages:

-Manpower reduction for replenishing paint units
-55 gallon drums or paint totes
-60% reduction in solvent usage
-50-70% more efficient usage
-Reduction of paint usage from batch mixing
-Reduction in solid waste disposal costs

b. Disadvantages:

-High initial cost for purchase
-Some restriction on location and placement

7. Air-Assisted Electrostatic Spray Guns

In the shipbuilding and repair industries, most areas of a ship will require different coatings applications due to different coating requirements and location of application. The gun to meet those various applications is the air-assisted electrostatic gun. This gun provides ease of usage with the convenience of applying coatings using an air-assisted or electrostatic method. Due to the Faraday-cage effect on electrostatic application, air-assisted airless application would suffice to coat hard to reach areas.

The air-assisted airless electrostatic gun increases transfer efficiency, reduces waste, reduces touchup after application, eliminates "bounce back", reduces overspray and provides ease of application with the flip a finger from one application to the other. Underwater hulls requires the use of various anti-fouling paints which cannot be applied using electrostatic, but that same gun can be used to apply that coating with a air-assisted airless application. This is an excellent gun when you are spraying various coating in succession(such as from an epoxy primer to a urethane). Multi-coat application can be accomplished easily if needed.

a. Advantages:

-Highest transfer efficiency available
-Operator versatility between applications (air-assisted airless or electrostatic)
-Excellent for coating corners and some crevices

b. Disadvantages:

-Lengthy operator training
-Operator fatigue (hand gripping)
-Larger spray gun
-Restrictions in area usage (such as using in tight or confined area radius)

EQUIPMENT EVALUATION

In order to help reduce VOC emissions, paint usage, paint waste and cost associated with spray equipment, two Air-assisted spray guns and a Electro-static gun was purchased for testing. This equipment was purchased from

Graco Inc. Graco has over the years, become a leader in research and development of Air-assisted and Electro-static technology. The guns utilized for testing were the AA Plus and the Pro A4500 Electro-static gun. Both guns will operate at higher pressures in the 3,000 to 5,000 psi range and can be used with existing equipment.

Due to NASSCO's coating requirements, I realized there would be problems with the transfer of the High Solids Low Voc Coatings to the spray guns. In order to spray this material, a Graco 41:1 Bulldog pump was purchased. The 41:1 pump is stronger than a 30:1 pump and therefore able to pump the heavier material from the paint container. A few problems associated with high solid coatings are high viscosity and density. Because of this, larger pumps, heaters and longer mixing times are required for effective transfer of the coating. The idea behind using a larger pump is quite simple; if you are able to pump the coating, you can atomize it at the spray tip without clogging and damage to pump cylinders.

1. AA Plus Air-Assisted Spray Gun

The AA Plus has been designed to atomize high solids coatings at higher pressures while providing an excellent finish for air-assisted applications. The AA Plus is readily adaptable to your existing airless or air-assisted finishing equipment without major changes to your operation. When changing from competitive air-assisted or airless guns, the painters will appreciate the light trigger pull and comfort of the AA Plus.

The AA Plus is available with the new Reverse-A-Clean tip, air cap and housing for difficult applications that require the benefits of air-assisted airless. The AA Plus delivers less bounceback, lower overspray, better film control and higher transfer efficiency than conventional airless spray guns.

The AA Plus has improved air caps and tips which has enhanced atomization and consistency for production needs. The gun requires minimal force to pull the trigger, due to an improved design. If you need to improve transfer efficiency and are using high solid coatings, this air-assisted gun will give satisfactory results.

2. Pro 4500 Electro-static Spray Gun

This gun combines the convenience of Air-assisted airless power with the versatility of selective voltage control of electrostatic spray. For coatings that are low in electro-static charge, this gun can be adjusted to 85KV for compensation of electrical charge. You can deliver up to 85KV of electrostatic charge (or adjust to a preset lower voltage) by simply flipping a switch. All essential controls are located right at the back of the gun.

Other electrostatic systems require constant pacing between the power supply and the gun to alter the voltage setting. But the Pro 4500 uses factory air to generate its electrostatic charge inside the gun. No external power supplies or power cables are required.

The voltage setting of this gun can be monitored up to distances of ten feet. The Pro 4500 reports actual spraying voltage to the hand held spraying voltage readout (svr, optional equipment) remote monitor. This gun is a self-generating electrostatic gun, equipped for versatility of voltage control. Voltage control is important because it allows the user to maximize its high transfer efficiency capabilities in applying low charged coatings.

Compliance: This gun meets the most stringent air quality equipment rules, including South Coast Air Quality Management District Rules 1124, 1136 and 1151. In addition, the optional SVR remote monitor allows you to verify compliant electrostatic operation at any time.

Simplicity: The Pro4500 can be installed on your finishing line in only a few minutes with no special equipment. (Knowledge and practice of electrostatic painting and safety techniques are required.)

Efficiency: The transfer efficiency of the Pro4500 matches or exceeds the capabilities of other electrostatic guns in critical performance tests.

Versatility: The Pro 4500 voltage control enables the operator to adjust voltage up or down to maximize electrostatic efficiency. In constricted part areas where Faraday-Cage effect is present, electrostatic voltage can be reduced or turned off right at the gun to perform complete paint coverage.

Maneuverability: This is an excellent painters' gun, expressly built to handle the rigors of industrial finishing, while providing the balance and feel that minimizes operator fatigue over long duty cycles.

Control: This user-friendly gun brings electrostatic control back to the gun. With a simple flick of the thumb, an operator can activate electrostatic power and also adjust the level of electrostatic effect. Fan pattern and fluid control are also conveniently located at the back of the gun for maximum control.

CONCLUSION

Painters who are used to conventional and airless spray will experience difficulty in converting to the new equipment, but changeover can be achieved with a proper amount of training. Electrostatic spray is still currently a source of fear for painters that are conditioned to air or airless spray. With proper indoctrination on safety, spray techniques and education on electrostatic spray technology, operator fears will ease. Most painters will associate intense electrical shock with liquid coatings and refuse to use the equipment.

The majority of NASSCO's painters who used the equipment were receptive for the most part, but again, most were very hesitant. Their comments included such statements as, the electrostatic guns are too delicate, productivity is decreased with electrostatic use, and it takes too long to set-up equipment. The use of electrostatic equipment leads to a decrease in production painting speed, but the decrease in overspray, better mil thickness adherence, decrease in solvent usage and increased coating coverage outweighs production speed.

The airless spray gun is much higher in production speed and rate. Most painters have been trained with this particular gun and the learning curve required for re-training on an electrostatic gun is tremendous. This gun will apply paint at a much faster rate in less time than any gun on the market. Even though production rates for application is much better for airless guns, overspray, over millage of paint (build up of paint on a surface that causes exceeding mil thickness), coarser and rougher finishes and less operator control for applying fine finishes makes this gun inefficient for quality finishes. Runs, sages, and orange peel (coating separation) are common occurrences with airless guns especially in tight and confined spaces. Due to today's cost's for epoxies (from $7.00 to $19.00 per gallon) which is used in all shipyards to some exodic finishes up to or exceeding $45.00 per gallon; It makes good dollars and sense to use application equipment with a higher transfer efficiency. **(Figure 1)**

Air-assisted airless spray was more acceptable to seasoned painters because it provided a combination of airless and conventional spray familiarity. The air-assisted airless guns tested eliminated complaints that the spray tips weren't easily changeable. The current guns are equipped with a reversible tip to meet the most stringent production requirements. The painters discovered that these guns could be effectively used from the same paint pump without a changeover to another pump. Changeover of spray equipment is time consuming during a spray operation and therefore any equipment that will blend into your current process will effect employee buy-in.

Air-assisted airless guns can be utilized on shipboard areas where airless equipment is currently used. The application of high solid primers and topcoats by air-assisted

airless can effortlessly be accomplished using the same processes and procedures used for airless application. Electrostatic guns provide opportunities for exterior application of topcoats such as urethanes, acrylics, alkyds and epoxies. Most shipbuilding companies accomplish paint activities outside. This is an ideal application method to reduce airborne contaminants and lessen overspray damage to machinery, automobiles and other structures. **(Figure 2)**

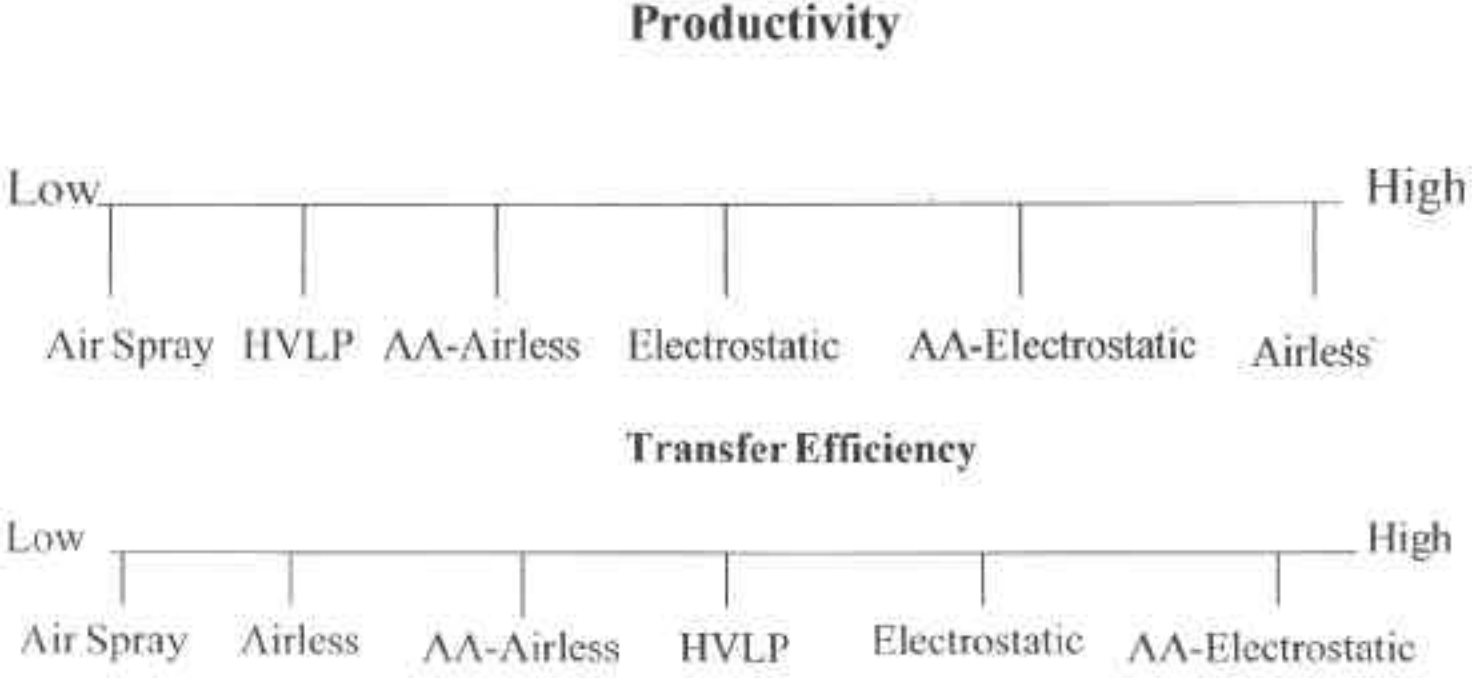
Air-assisted airless electrostatic provides the highest in transfer efficiency because of versatility and user choice of application. This equipment will apply coatings to adherent mil thickness with a smoother finish. Overspray is reduced primarily because of electrostatic technology and Faraday-cage effect is significantly reduced because an operator can use the air-assisted airless function to spray tight or confined spaces. With today's rising costs for coatings, solvent and disposal, it makes sense to use application equipment that apply's paint to the manufactures coverage specifications. **(Figure 1)**

Transfer efficiency should be a driving factor in spray equipment purchases. Care must be taken in examining the equipment manufacters claims in transfer efficiency by extensive testing and training. The transfer efficiency rates given below are approximate rates achieved in testing in a marine environment and will vary according to conditions and environment of actual application. **(Figure 3)**

There is much trial and error associated with the use of environmentally compliant spray equipment. Company management is hesitant to purchase this equipment because of cost factors, training and time requirements needed to familiarize their painters with the new technology. **(Figure 4)** Equipment cost are high initially, but long term benefits outweigh the initial costs. With any type of new equipment or procedure, time and effort are needed to ensure success.

Figure 1

Productivity and Transfer Efficiency Rankings



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Compliant Spray Equipment

- **Electrostatic usage areas**
  Exterior surfaces; bulkheads, decks, side shells, interior storage spaces, cargo areas, etc.

- **Air-assisted airless usage areas**
  In all areas where current usage of airless guns are used

Figure 2

Paint and Blast Department
Compliant Spray Equipment

- **High volume low pressure guns**
  Can be used in areas where current usage of conventional spray is used

- **Air-assisted airless electrostatic guns**
  More versatility than regular electrostatic guns to spray areas where Farady cage effect is of concern

Figure 2

Paint and Blast Department

- **Transfer efficiency rates:**

- Electrostatic	45 -- 75%
- AA-Airless	70%
- Airless	20 -- 40%
- Conventional	15 – 30%
- HVLP	50 – 75%
- AA-Electrostatic	70 – 90%

Figure 3

Cost Comparisons for Spray Equipment

• Electrostatic	• $1,800 - $2,500
• AA-Airless	• $300 - $450
• Airless	• $35 - $65
• Conventional	• $17 - $28
• HVLP	• $175 - $230
• AA-Electrostatic	• $3,500 - $4,500

Figure 4