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An Investigation Into the Actual Transfer Efficiency of High Volume Low Pressure Spray Guns

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AN INVESTIGATION INTO THE ACTUAL TRANSFER EFFICIENCY OF HIGH VOLUME LOW PRESSURE SPRAY GUNS

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CHAPTER I

INTRODUCTION

Over the last few years staying in compliance with ever changing environmental regulations has been very difficult for industries using spray coatings, mainly paints. In 1984, when the U.S. Congress passed the Hazardous and Solid Wastes Amendments to the Resource Conservation and Recovery Act, waste minimization became a mandated policy (EPA, 1991). One way for the companies to minimize the waste that was being produced was to reduce the waste at the source, for the spray coatings area, this meant becoming more efficient. Companies were affected by more stringent environmental regulations when the Clean Air Act Amendments of 1990 were passed. These amendments required businesses to reduce the amount of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) they released, from among other sources, such as parts cleaning, de-greasing, and their coating operations. VOCs and HAPs are both chemical components of solvent based liquid coatings. The most commonly occurring VOCs and HAPs in coatings are; Methylethylketone (MEK), Methylisobutylketone (MIBK), Toluene, Xylene, 1,1,1 Trichloroethane (U.S. Environmental Protection Agency 1996).

With the demand from the consumer that products be visually pleasing, most items sold in today's marketplace are either painted, coated for decorative purpose, or surface protection. Unfortunately, painting and coating operations can be one of the largest contributors to the release of VOCs and HAPs. In the automotive refinishing industry, 55 percent of the VOCs emitted come from paint application processes (Iowa Waste Reduction Center, 1998). Many manufacturers have sought ways to decrease VOC emissions from their painting and coating processes. One solution has been to use higher transfer efficient equipment, such as high volume low pressure (HVLP) spray guns. These spray guns have the ability to decrease paint consumption by 20 to 30 percent over the conventional spray guns they had been using (Iowa Waste Reduction Center, 1998) and, thereby, reducing the VOC and HAP emissions.

To assist companies in determining the efficiency of their painting operations, paint spray gun manufacturers claim the transfer efficiency (TE) of their spray guns. TE is a measurement that can be used to determine the amount of paint consumption the company can expect. TE is the percent of material applied to the part and can be calculated by taking the amount of coating that is applied to the work piece divided by the amount of coating that is sprayed. This can be calculated using the following formulas:

$$\frac{\text{Mass of solids sprayed}}{\text{Mass of solids deposited}} = \%\ \text{TE} \quad \text{or} \quad \frac{\text{Volume of material sprayed}}{\text{Volume of material deposited}} = \%\ \text{TE}$$

(IWRC, 2000).

Spray gun manufacturers have made claims in their sales promotion literature that the new generation high volume low pressure (HVLP) spray guns could achieve 65 percent or greater transfer efficiency. Many end users of the guns believed these new generation HVLP spray guns were the solution to the problem of high paint and coatings consumption. Companies, prior to this time, were using conventional spray guns that would only achieve 35 - 40 percent transfer efficiency under ideal conditions. The EPA stated "of all the strategies available to minimize pollution in a paints and coatings facility, improving transfer efficiency is perhaps one of the most effective" (U.S. Environmental Protection Agency, 1996 p.74). However, what many manufacturers soon found was not the decrease of 20 to 30 percent in material consumption that was expected. The reasoning for this was, in reality, most HVLP spray guns deliver approximately 40 to 50 percent TE when used by spray technicians in common conditions. This indicates there is a difference between the stated and actual spray gun efficiency. Thus, there is a need to verify the actual TE for HVLP spray guns. If gun manufacturers' claims of TE were validated, gun users could trust the information stated in manufacturers specification sheets. For example, in one gun manufacturers information, there are TE claims of far over the HVLP standards of 65 percent. The knowledge that would be gained from the testing would also be beneficial for air emissions calculations, performed by local and regional government agencies, so that a true emission calculation could be preformed. This proves there is a need to validate gun manufacturers TE claims by an independent testing agency.

With the past research in pollution prevention for the painting and coatings industry the Iowa Waste Reduction Center has established a solid reputation of being unbiased and a leader in progressive thinking. At this point, no research has been preformed to specifically verify the TE of HVLP spray guns. The IWRC currently is preforming research and training to determine and improve spray technicians TE. In the past, research to verify other pollution prevention equipment has been performed. One example of such activity is the Environmental Technology Verification for the Laser Touch® Beta Model research project. This project verified that a specific piece of equipment could increase the efficiency of a manual spray system.

Problem Statement

The problem to be addressed in this study was to determine the actual transfer efficiencies of three high volume low pressure spray guns from three different manufacturers in a controlled setting. Once that was completed the next step was to compare the actual transfer efficiencies with the manufacturers' stated efficiencies.

Purpose Statement

The purpose of this study is twofold:

1. To determine actual transfer efficiencies of the three HVLP spray guns.

2. To compare the actual transfer efficiencies with the manufacturers' stated transfer efficiencies.

Need Statement

The need for this research stems from paint gun manufacturers claiming much higher TE than actually occur in coating facilities. With this research study the TE of HVLP spray guns would be validated, gun users could trust the information stated in manufacturers specification sheets as accurate. The knowledge that would be gained from the testing would also be beneficial for air emissions calculations so that a true emission calculation could be preformed.

Independent consultant Ron Joseph, stated in an article published in the February issue of Metal Finishing Journal, "Over the last several years I have visited numerous paint facilities in which neither the painter nor their supervisors have any idea as to whether or not they are in compliance with this requirement. In fact I venture to say that by far the majority of painters who use HVLP spray guns are out of compliance" (Joseph, 1999, p.96). The requirement that he was speaking of is keeping HVLP spray guns at or below 10 psig of atomizing air pressure. If a spray gun is out of compliance it is not spraying efficiently. If the spray gun is not spraying efficiently it will not be at the manufacturers stated TE. With the results of this research the actual TE of the three HVLP spray guns would be known and local and regional regulatory agencies would be able to accurately calculate and regulate air emissions from coating facilities utilizing the models of HVLP spray guns that were tested.

Furthermore, if the companies that are using the HVLP spray guns knew their actual TE, they would be able to regulate the release of harmful contaminants. This would allow less exposure to solvents like toluene, xylene, methyl ethyl ketone, and isocyanates (Enander, Gute, Missaghian. 1998). Decreasing the exposure to the solvents would lower the painters risk of contracting diseases that are linked to solvent exposure.

Thus there is a need to validate gun manufacturers TE claims by an independent testing agency. This information would be beneficial to both the EPA and manufacturing facilities performing spray painting operations.

Research Questions

I have trained more than 50 automotive spray technicians over the last 5 years and have never seen transfer efficiency's as high as any manufacturers' stated transfer efficiency prior to training. With this knowledge I chose to perform a formal research project to answer the follow questions:

1. What is the actual transfer efficiency (TE) of the three high volume low pressure spray guns?

2. How does the actual TE compare to that of the manufacturers' stated TE?

Assumptions

In pursuit of this study, the research was conducted using the following assumptions:

1. The subject spraying the HVLP spray guns will perform the spray process properly.
2. The final appearance of the finish will be of automotive quality.
3. The HVLP spray guns are operating consistently and according to manufacturers specifications throughout the testing.
4. The Ohaus Explorer E02140 and Ohaus Explorer E0L210 scales are calibrated and working properly throughout the testing.
5. The PPG base coat and clear coat paint will be mixed consistently and according to manufacturers specifications throughout the test.
6. The substrate being coated will not affect the TE.

Delimitations

This research only tested three different manufacturers' spray guns. The data that is collected will not be able to be used to generalize all HVLP spray guns. By using a human subject to spray the HVLP spray guns there is a variation in the TE that were achieved for test run of the spray gun.

Definition of Terms

The following terms were defined to clarify their use in the context of this research project:

1. ASTM. American Society for Testing and Materials provides standards that are globally accepted (*Annual Book of ASTM Standards 2001*).

2. EPA. Environmental Protection Agency the government organization that oversees regulations pertaining to air emissions on a national level (EPA, 2004).

3. HAP. Hazardous Air Pollutants are air pollutants that pose a significant threat to human health and the environment (EPA, 1998).

4. HVLP. High Volume Low Pressure is defined bye the Clean Air Act as any spray gun that uses 10 psi at the air cap and sprays 65 percent efficiency (EPA, 1998).

5. Laser Touch®. Laser Touch® is a distancing device used to keep a consistent distance and 50 percent overlap while painting (Laser Touch, 2004).

6. PPG. PPG is a chemical manufacturing company that produces paints and coatings (PPG, 2003).

7. VOC. Volatile Organic Compound is any organic compound that participates in atmospheric photochemical reactions that is not specifically exempt by U.S. EPA. (EPA, 1998)

8. Spray Gun. Equipment used to apply coatings by atomizing and directing (EPA, 1998).

9. TE. Transfer Efficiency is the amount of material that is applied to the part divided by the amount of material that was sprayed (IWRC, 2000).

CHAPTER II

LITERATURE REVIEW

The topics of this research project was, are the manufacturer's stated transfer efficiencies of high volume low pressure spay guns actually the efficiency of the spray gun in a real process. So the main topic that I reviewed for this research project was, what is the transfer efficiency of high volume low pressure spray painting guns. Other topics that I reviewed were directly related to the main topic, how to calculate transfer efficiency, what transfer efficiency is, and what spray gun manufactures state their high volume low pressure spray guns and spray for transfer efficiency.

The reasoning behind determining the actual transfer efficiency of high volume low pressure spray guns is to assist the end user of the spray gun in assessing the effectiveness of the spray gun that will be purchased. Also, with actual transfer efficiencies emission calculations that utilize them, when determining emissions, can become more accurate. Once a company knows the actual efficiency of a spray gun they can use that information to determine the materials savings and wether or not there is a benefit to changing out their existing equipment.

While researching the topic of spray gun transfer efficiency it was apparent that very little academic research had been preformed on this topic. So I look to trade journals and magazines for more information. The three that were most helpful were *Paint and Powder*, *Metal Finishing* and *Metal Finishing Journal*.

All spray gun manufacturers' claim at least 65 percent efficiency for their high volume low pressure spray guns, some even state efficiencies in the 70 percent and higher range. After reading 15 articles from trade magazines I was sure that the spray gun manufacturers' stated efficiencies were not actual, production setting, efficiencies. The title of one article says it all "HVLP Guns are Not Automatically Compliant", compliant meaning spraying 65 percent efficiency (Joseph, 1999).

Transfer efficiency, simple is the percentage of material that stays on the part compared to the amount of material that was used (IWRC, 1998). The efficiency of a spray gun can be calculated by taking the mass of the solids deposited on the part divided by the mass of the solids sprayed and multiplied by one hundred. Due to the fact the material that is being spray initially is liquid, the solids must be determined but removing all solvents from a sample of the coating to accurately calculate the transfer efficiency of the spray gun (EPA, 1996).

With the research that was preformed I came to the conclusion that very little work has been done on calculating actual transfer efficiencies of high volume low pressure spray guns. I found no academic research on the topic. The information that I did find came mostly from prior research at the Iowa Waster Reduction Center.

Further research needs to be to conducted on calculate transfer efficiency's for more spray guns. This would help companies purchasing spray guns make more informed decisions. Further research should also be preformed in the area of transfer efficiency testing procedures. With no national testing standard for testing high volume low pressure spray guns companies can modify their test procedures to achieve the desired results and not an accurate transfer efficiency. With a national testing standard consumers would be ensured that when they compare two spray guns, the guns were tested the same way using the same set of standards.

CHAPTER III

METHODOLOGY

This chapter will cover the parts and equipment used during this research project. The chapter will also cover the methodology behind performing the TE testing for the HVLP spray guns.

Spray Guns

The three spray guns were randomly selected out of seven HVLP spray guns that were available for testing. The Sata NR 2000, the Iwata 400 LPH and the Walcom FX Geo were the three guns that were selected.

Parts

Two different sized parts will be utilized in this project; a large solid aluminum part and a small solid aluminum part. By using two flat parts, one large and one being small I was able to achieve the highest TE possible on these parts. The large part will be 3 by 3 feet in dimension and .030 to .035 inches thick. The small part will be 1 by 1 foot in dimension and .030 to .035 inches thick.

The parts will be assigned an alpha numeric label which will be engraved on the back of each part. The parts will be labeled using the following template: AAaaNN. Where:

A = Spray technicians initials

a = Spray gun used

N = Test number

An example showing the numeric labeling that was used is BZsa01. This example would be for Bill Zimmerle spraying a SATA spray gun on test panel one.

All the parts were cleaned with a grease and wax remover. After the parts were cleaned they were only handled with latex gloves to prevent contamination from skin oils. Then the parts were coated with a PPG primer sealer and allowed to dry. The seal coat was applied to ensure all surfaces were identical. After the parts dried for a minimum of 48 hours, to ensure a proper cure had occurred, they were weighing.

Each part was weighed, using the Ohaus Explorer E0L210 scale, prior to testing. The parts were hung from the scale while being weighed. All sources of air movement were turned off as to not effect the scale. The weight of each part was recorded on the data tracking sheets along with the part identification number. A example of a data collection sheet can be found in Appendix A. This weight was later used to calculate the TE of the spray gun used to coat that part.

<u>Coatings Solid Pans</u>

The solid sample pans will also be labeled with an alpha numeric identification code. The label on the pans will match the following example: AANNn

Where A = Spray technicians initials

N = Test number

n = Pan number

An example showing the numeric labeling that was used is BZ011. This example would be for Bill Zimmerle on the first test set pan number 1. A minimum of five solids pans will be used for each batch of coating. The pans will be pre-treated in accordance with the ASTM standard for determining volatile content of coatings (ASTM D 2396 - 93). The procedure states that the pans must be heated to a temperature of 110 +/- 5 degrees C for 30 minutes and allowed to cool. This assures that the weight of the pan will not change when the coating is cured. Once this is done the pans will be weighed and entered onto the data sheet with their identification number. A solids data collection sheet can be found in Appendix B.

Coating

The base and clear coats was mixed according to the manufacturer's specifications. Base coat and clear coat manufacturer's specification sheets can be found in Appendix C. The temperature and viscosity of the mixed coating was measured before testing began. Viscosity was measured using a Gardco number 2 zahn cup, and the temperature was taken using a QuikSite® laser sited thermometer, and both were recorded on the data sheets.

The coatings were sampled for solids content using a modified ASTM standard ASTM D 2369-98. The pans that were described in the previous section had five drops of coating placed on a labeled and pre weighed sample pan. The pan was then weighed to determine the mass of coating in the pan. The pan remained at room temperature for 30 minutes. The pan was then placed in the spray booth with the parts to be heated to 140 degrees F for 30 minutes. The pans were then placed in a desiccator to cool. The pans were weighed 24 hours later and recorded on the data sheets.

The percent solids will be calculated using this equation:

$$N = [(W3-W1)/(W2-W1)]* 100$$

Where:

W1 = Empty pan weight

W2 = Pan weight immediately after placing coating

W3 = Pan weight after heating and 24 hour cool down period

Spray Gun Setup

The mixed coating will be placed in the chosen HVLP spray gun. The spray guns air pressure, fluid setting, fluid needle/tip and air cap will be set within the manufactures specifications for the coating being used. The fluid tips will be 1.3 to 1.4 mm and the corresponding air cap will be used. Air pressure will not be allowed to exceed 10 psi at the air cap, to comply with regulation for HVLP spray guns. The HVLP spray guns will also be equipped with a Laser Touch® distancing device to ensure the gun is sprayed at the proper distance at all times.

Testing

A Spray Technique Analysis and Research (STAR) certified spray trainer will spray the twenty large and twenty small parts with 3 different HVLP spray guns. The transfer efficiency for each part sprayed will be calculated. Once all the transfer efficiencies have been calculated the average for each gun will be compared to the manufacturers' stated transfer efficiency.

The procedure used to test the transfer efficiency of the HVLP spray guns will be the mass of material sprayed method. The spray guns will be weighed prior to coating each part, the weight will be logged on the data sheets. After coating each part the gun will again be weighed and the weight will be logged. Each part will be weighed prior to coating, and logged on the data sheets. After each coating (base coat and clear coat) has been cured, the parts will again be weighed and recorded on the data sheets.

Calculating TE

Once the part weights and solids weights have been collected the calculations will begin. A spread sheet will be designed to perform all calculations of transfer efficiency. The equations that were used to calculate the actual transfer efficiency for each gun were:

MMS = GWP-GWA

PSMS = [(W3-W1)/(W2-W1)]* 100

MSS = MMS * PSMS

MSD = PWAS - PWPS

% TE = (MSD/MSS) * 100

Where:

GWA = Gun weight after spraying

GWP = Gun weight prior to spraying

MMS = Mass of material sprayed

MSD = Mass of solids deposited

MSS = Mass of solids sprayed

PSMS = Percent solids of material sprayed

PWAS = Part weight after spraying

PWPS = Part weight prior to spraying

W1 = Empty pan weight

W2 = Pan weight immediately after placing coating

W3 = Pan weight after heating and 24 hour cool down period

Equipment

The equipment that was used for this project can be found listed in Table 1 below.

Equipment		
Type	Description	Specifications
Ohaus Explorer EOL210	Weigh below scale used to weigh parts and spray guns	Capacity of 22000 grams, readability of 0.1 grams, linearity of +/- 0.4 grams
Ohaus Explorer EO2140	Balance scale used for solid sample weighing	Capacity of 210 grams, readability of 0.1 miligrams, linearity of +/- 0.2 miligrams
Walcom Geo	Gravity feed HVLP spray gun	1.3 fluid tip
Anest Iwata LPH-400	Gravity feed HVLP spray gun	1.4 fluid tip
SATA Jet NR 2000	Gravity feed HVLP spray gun	1.3 fluid tip
6000 Positector	Mil thickness Gage	accuracy ± 0.1 mils
Laser Touch	Laser distancing devise	
Quik Site	Laser thermometer	
Number 2 Zahn Cup	Viscosity cup	
Digital Stop Watch	Digital stop watch	
Spray Booth	Down draft spray booth	
Quattro Pro 9	Spread sheet	

Table 1.

CHAPTER IV

DATA AND DATA ANALYSIS

The data was collected from all 40 parts that were sprayed for each of the three HVLP spray guns. The data consisted of spray gun mass before and after spraying each coating, part mass before and after spraying each coating, and mil thickness readings taken from nine places on the large test parts and five places on the small test parts prior to spraying each coating and after the final coating. Data was also collected to calculate the solids content of each coating batch that was sprayed. With the data that was collected transfer efficiencies were calculated for all test parts for each HVLP spray gun.

The first HVLP that was tested on the large test panels was the Geo spray gun. Spraying the base coat the gun had an average TE of 59.26 percent efficiency. While spraying the clear the gun achieved an average TE of 67.67 percent efficiency. This gave the gun an overall efficiency of 63.46 percent. TE's for all large panels sprayed with this gun can be seen in Table 2.

Geo Large Test Panel	TE Base	TE Clear	TE Both
WZgo01	61.61%	68.01%	64.81%
WZgo02	64.42%	72.52%	68.47%
WZgo03	64.79%	69.07%	66.93%
WZgo04	64.69%	69.28%	66.98%
WZgo05	63.29%	64.78%	64.04%
WZgo06	63.33%	69.05%	66.19%
WZgo07	64.04%	66.33%	65.18%
WZgo08	58.38%	64.90%	61.64%
WZgo09	55.81%	66.81%	61.31%
WZgo10	55.91%	66.15%	61.03%
WZgo11	58.46%	67.54%	63.00%
WZgo12	55.60%	68.26%	61.93%
WZgo13	55.02%	64.28%	59.65%
WZgo14	56.17%	68.28%	62.23%
WZgo15	54.95%	62.08%	58.52%
WZgo16	56.82%	66.31%	61.56%
WZgo17	58.88%	69.43%	64.15%
WZgo18	58.87%	70.69%	64.78%
WZgo19	57.11%	69.63%	63.37%
WZgo20	56.95%	69.90%	63.42%
Averages	**59.26%**	**67.67%**	**63.46%**

Table 2.

Then the Geo was tested on the small test panels. Spraying the base coat the gun had an average TE of 56.91 percent efficiency. And while spraying the clear the gun achieved an average TE of 55.56 percent efficiency. This gave the gun an overall efficiency of 56.23 percent. TE's for all small panels sprayed with this gun can be seen in Table 3.

Geo Small Test Panel	TE Base	TE Clear	TE Both
WZgo01	55.18%	50.13%	52.65%
WZgo02	53.70%	54.96%	54.33%
WZgo03	54.94%	57.03%	55.98%
WZgo04	51.24%	53.94%	52.59%
WZgo05	52.68%	54.59%	53.64%
WZgo06	58.29%	52.63%	55.46%
WZgo07	55.95%	50.69%	53.32%
WZgo08	60.10%	51.32%	55.71%
WZgo09	56.06%	52.50%	54.28%
WZgo10	56.97%	53.37%	55.17%
WZgo11	57.98%	59.54%	58.76%
WZgo12	57.58%	60.96%	59.27%
WZgo13	58.63%	57.87%	58.25%
WZgo14	56.68%	55.38%	56.03%
WZgo15	55.08%	58.26%	56.67%
WZgo16	58.89%	59.36%	59.13%
WZgo17	57.37%	60.37%	58.87%
WZgo18	59.34%	56.76%	58.05%
WZgo19	62.38%	58.08%	60.23%
WZgo20	59.12%	53.44%	56.28%
Averages	**56.91%**	**55.56%**	**56.23%**

Table 3.

The overall average efficiency of the Geo spray gun was 59.85 percent efficient while spraying twenty large and twenty small parts with an automotive base and clear coat.

The second HVLP spray gun that was tested was the Iwata. Coating the large parts with base coat the Iwata spray gun and an average TE of 53.48 percent. While spraying the clear coat the Iwata had and average TE of 63.85 percent. The overall efficiency of the Iwata for the large panels was 58.67 percent. TE's for all large panels sprayed with this gun can be seen in Table 4.

Iwata LPH400 Large Test Panel	TE Base	TE Clear	TE Both
WZiw01	55.76%	64.39%	60.07%
WZiw02	57.39%	65.91%	61.65%
WZiw03	55.65%	63.88%	59.77%
WZiw04	54.95%	64.52%	59.74%
WZiw05	54.11%	63.93%	59.02%
WZiw06	56.82%	65.84%	61.33%
WZiw07	54.85%	67.43%	61.14%
WZiw08	54.30%	64.98%	59.64%
WZiw09	56.64%	65.71%	61.17%
WZiw10	55.47%	67.88%	61.67%
WZiw11	52.41%	62.00%	57.20%
WZiw12	51.28%	62.39%	56.84%
WZiw13	52.01%	62.84%	57.43%
WZiw14	50.75%	63.08%	56.91%
WZiw15	49.07%	62.18%	55.63%
WZiw16	51.59%	62.69%	57.14%
WZiw17	50.13%	60.25%	55.19%
WZiw18	51.09%	62.22%	56.66%
WZiw19	53.23%	62.24%	57.74%
WZiw20	52.16%	62.72%	57.44%
Averages	**53.48%**	**63.85%**	**58.67%**

Table 4.

Then the Iwata was tested on the small test panels. Spraying the base coat the gun had an average TE of 44.46 percent efficiency. And while spraying the clear the gun achieved an average TE of 49.13 percent efficiency. This gave the gun an overall efficiency of 47.79 percent. TE's for all small panels sprayed with this gun can be seen in Table 5.

Iwata LPH400 Small Test Panel	TE Base	TE Clear	TE Both
WZiw01	48.44%	49.02%	48.73%
WZiw2	49.08%	49.83%	49.46%
WZiw3	46.63%	50.12%	48.37%
WZiw4	44.75%	46.24%	45.49%
WZiw5	43.68%	47.35%	45.52%
WZiw6	46.79%	50.85%	48.82%
WZiw7	48.07%	49.58%	48.83%
WZiw8	46.05%	46.06%	46.05%
WZiw9	44.85%	47.00%	45.92%
WZiw10	45.61%	49.12%	47.36%
WZiw11	44.56%	50.61%	47.59%
WZiw12	49.27%	52.02%	50.65%
WZiw13	48.82%	49.15%	48.99%
WZiw14	45.33%	47.67%	46.50%
WZiw15	46.72%	49.31%	48.02%
WZiw16	45.75%	50.23%	47.99%
WZiw17	44.91%	50.03%	47.47%
WZiw18	46.39%	47.89%	47.14%
WZiw19	43.92%	51.33%	47.62%
WZiw20	49.27%	49.15%	49.21%
Averages	**46.44%**	**49.13%**	**47.79%**

Table 5.

The overall average efficiency of the Iwata spray gun was 53.23 percent efficient while spraying twenty large and twenty small parts with an automotive base and clear coat.

The final HVLP that was tested was the Sata NR 2000 spray gun.. Spraying the base coat on the large panels the Sata had an average TE of 54.25 percent efficiency. And while spraying the clear the gun achieved an average TE of 60.16 percent efficiency. This gave the gun an overall efficiency of 57.21 percent. TE's for all large panels sprayed with this gun can be seen in Table 6.

Sata NR 2000 Large Test Panel	TE Base	TE Clear	TE Both
WZsa01	52.27%	59.81%	56.04%
WZsa02	53.35%	60.32%	56.84%
WZsa03	50.86%	59.67%	55.27%
WZsa04	52.97%	60.05%	56.51%
WZsa05	55.61%	60.20%	57.91%
WZsa06	52.82%	58.04%	55.43%
WZsa07	53.69%	57.97%	55.83%
WZsa08	52.86%	55.16%	54.01%
WZsa09	51.00%	56.69%	53.85%
WZsa10	50.38%	59.00%	54.69%
WZsa11	54.90%	60.92%	57.91%
WZsa12	57.16%	61.72%	59.44%
WZsa13	54.68%	61.39%	58.03%
WZsa14	56.61%	62.40%	59.50%
WZsa15	56.79%	62.43%	59.61%
WZsa16	58.20%	61.59%	59.90%
WZsa17	56.58%	61.76%	59.17%
WZsa18	53.41%	61.24%	57.33%
WZsa19	56.40%	62.18%	59.29%
WZsa20	54.39%	60.75%	57.57%
Averages	**54.25%**	**60.16%**	**57.21%**

Table 6.

Then the Sata was tested on the small test panels. Spraying the base coat the gun had an average TE of 45.21 percent efficiency. And while spraying the clear the gun achieved an average TE of 49.01 percent efficiency. This gave the gun an overall efficiency of 47.11 percent. TE's for all small panels sprayed with this gun can be seen in Table 7.

Sata NR 2000 Small Test Panel	TE Base	TE Clear	TE Both
WZsa01	42.83%	49.36%	46.10%
WZsa02	45.79%	48.08%	46.93%
WZsa03	46.31%	48.52%	47.41%
WZsa04	46.07%	47.86%	46.96%
WZsa05	43.66%	46.98%	45.32%
WZsa06	48.15%	47.46%	47.80%
WZsa07	45.84%	46.81%	46.33%
WZsa08	47.32%	50.01%	48.67%
WZsa09	43.89%	46.92%	45.40%
WZsa10	43.66%	44.38%	44.02%
WZsa11	40.97%	52.96%	46.97%
WZsa12	46.80%	49.90%	48.35%
WZsa13	47.83%	50.48%	49.15%
WZsa14	45.95%	46.69%	46.32%
WZsa15	41.71%	49.34%	45.53%
WZsa16	46.71%	52.47%	49.59%
WZsa17	46.50%	50.95%	48.72%
WZsa18	46.03%	48.61%	47.32%
WZsa19	41.96%	49.96%	45.96%
WZsa20	46.22%	52.40%	49.31%
Averages	**45.21%**	**49.01%**	**47.11%**

Table 7.

The overall average efficiency of the Sata spray gun was 52.16 percent efficient while spraying twenty large and twenty small parts with an automotive base and clear coat.

Figure 1 shows the average TE of the three HVLP spray guns for the large panels that were coated. Figure 2 shows the average TE for the HVLP spray guns for the small panels. And figure 3 shows the average TE for the HVLP spray guns on both parts.

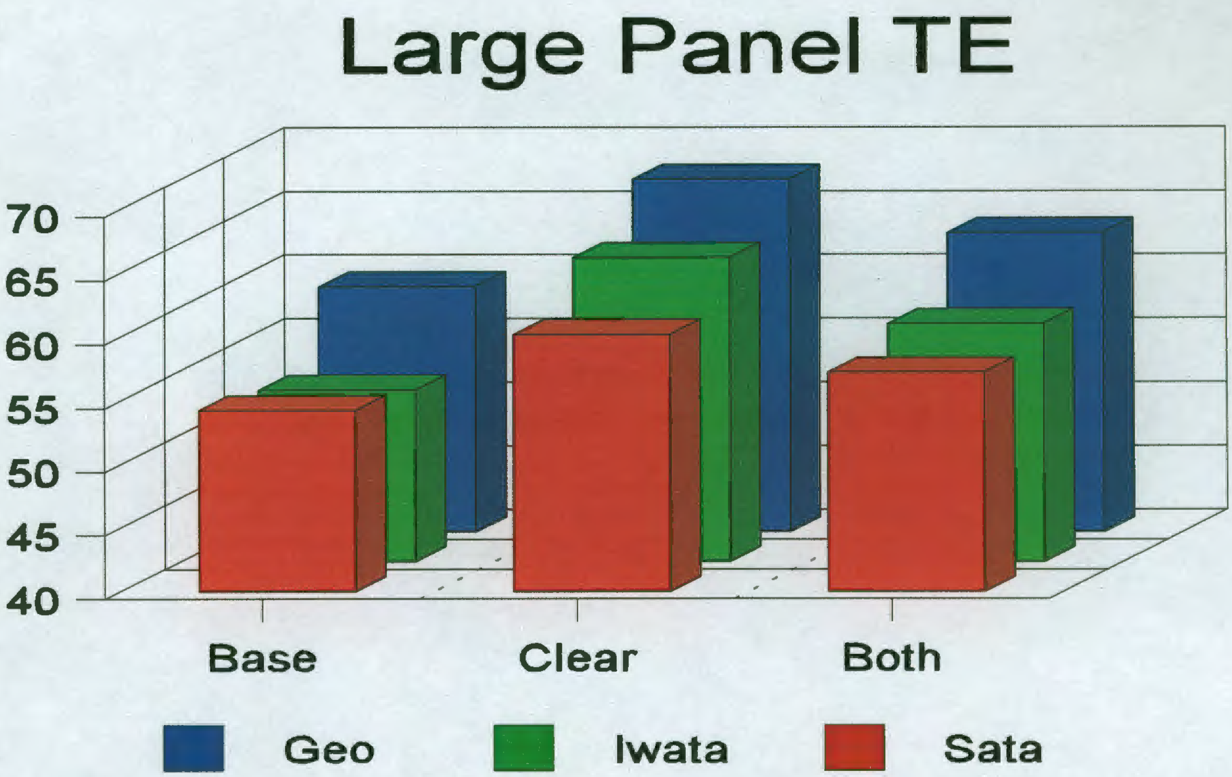

Figure 1.

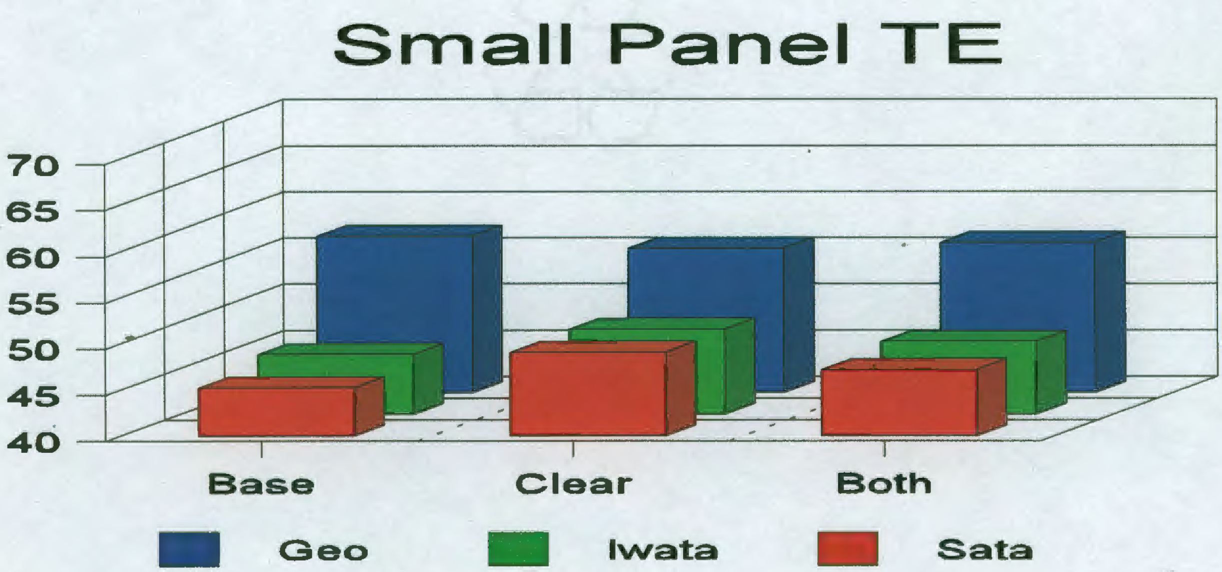

Figure 2.

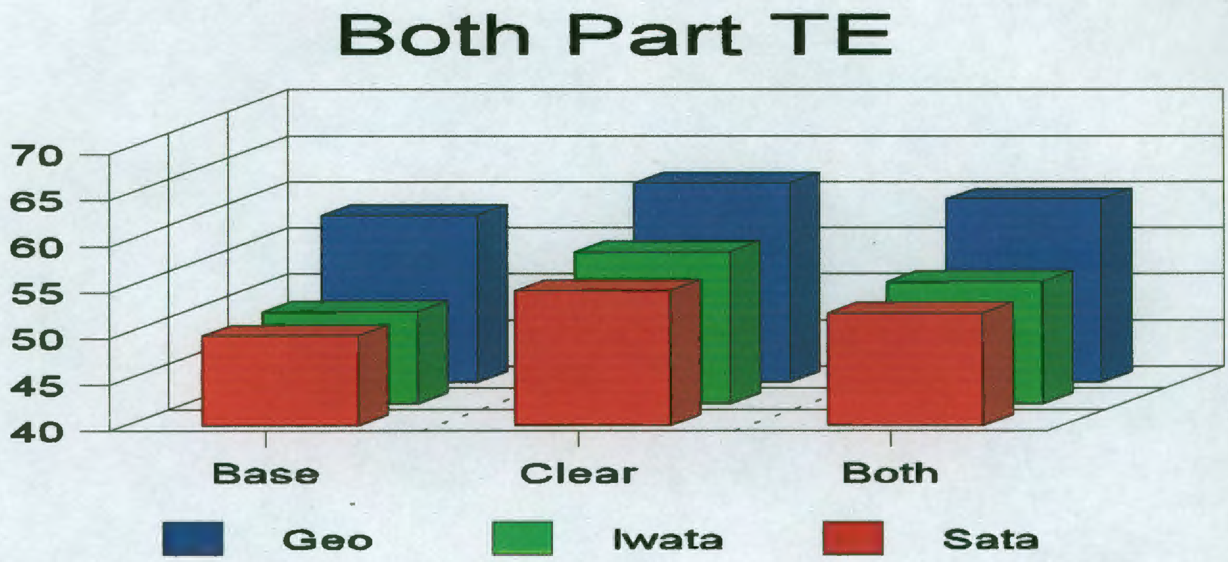

Figure 3.

CHAPTER V

SUMMARY, CONCLUSION AND RECOMMENDATIONS

The questions were; what is the actual TE's of HVLP spray guns, and how the actual TE compared to the manufacturers' stated TE? The data that was collect shows that the average actual TE for the three HVLP spray guns tested was dependent on the size of the part being coated and the coating that was being used. This research project revealed that there is a difference in the manufacturers stated TE's and the calculated TE's of the spray guns that were tested. The actual TE's for the guns that were tested were well below the TE's that the manufacturers have stated for their guns. The overall TE's of the spray guns ranged from 5.15 to 12.84 percent below the 65 percent efficiency that is set for the standard for HVLP spray guns.

By coating twenty large and twenty small parts with an automotive quality finish the research was able to show an average TE well below the manufacturers stated TE for each gun. This does not mean that all HVLP spray guns will have an average TE below the manufacturers stated TE only that these three guns do not perform at the manufacturers stated efficiency when being spray on flat panels by a trained spray technician. The results also show that there needs to be a formal test procedure for testing the TE of HVLP spray guns.

Future research need to be conducted on more models of HVLP spray guns, this would allow generalized statements for the TE of HVLP spray guns. The same test should be preformed using the same spray guns, but utilizing a automated spray applicator to eliminate the human variable from this research.

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Appendix A
Data Collection Sheet

SPRAY GUN DATA SHEET/ Small Part

Spray Tech			Spray Gun	
DATE			Fluid tip and air cap size	
Temperature Start and Finish			Spray distance	
	Small PART		Presure inlet	
PART AREA	1 x 1		Fluid Turns	
			Air Turns	
Solids for Base Coat	ERR		Coating Type	
Cure Time			Viscosity	
			Coating Temp.	

Weight (Grams)

Small Part WEIGHT		Before spraying

Mil Build Measurements (Prior to Spraying Base Coat)

BUILD TEST	Small PART
P1	
P2	
P3	
P4	
P5	

After Gun setup

GUN MASS (grams)		
BEFORE		
AFTER		

Weight (Grams)

Small Part WEIGHT		after spraying and drying

Mil Build Measurements (Base Coat Applied)

BUILD TEST	
P1	
P2	
P3	
P4	
P5	

SPRAY GUN DATA SHEET/ Small Part

Spray Tech			Spray Gun	
DATE			Fluid tip and air cap size	
Temperature Start and Finish			Spray distance	
	Small PART		Presure inlet	
PART AREA	1 X 1		Fluid Turns	
			Air Turns	
Solids for Coating	ERR		Coating Type	
Cure Time			Viscosity	
			Coating Temp.	

Weight (Grams)

Small PART WEIGHT	0	Before spraying

Mil Build Measurements (Prior to Spraying Clear Coat)

BUILD TEST	Small PART
P1	0
P2	0
P3	0
P4	0
P5	0

After Gun setup

GUN MASS (grams)		
BEFORE		
AFTER		

Weight (Grams)

Small Part WEIGHT		after spraying and drying

Mil Build Measurements (Clear Coat Applied)

BUILD TEST		Gloss
P1		1
P2		
P3		
P4		
P5		

SPRAY GUN DATA SHEET/ Large Part

Spray Tech	BZ		Spray Gun	
DATE			Fluid tip and air cap size	
Temperature Start and Finish			Spray distance	
	LARGE PART		Presure inlet	
PART AREA	3 X 3		Fluid Turns	
			Air Turns	
Solids for Base Coat	ERR		Coating Type	base Silver
Cure time			Viscosity	
			Coating Temp.	

Weight (Grams)

LARGE PART WEIGHT		Before spraying

Mil Build Measurements (Prior to Spraying Base Coat)

BUILD TEST	LARGE PART
P1	
P2	
P3	
P4	
P5	
P6	
P7	
P8	
P9	

After Gun setup

GUN MASS (grams)		
BEFORE		Primer
AFTER		

Weight (Grams)

Large Part WEIGHT		after spraying and drying

Mil Build Measurements (Base Coat Applied)

BUILD TEST Primer	Large Part
P1 -	
P2	
P3	
P4	
P5	
P6	
P7	
P8	
P9	

SPRAY GUN DATA SHEET/ Large Part

Spray Tech	BZ		Spray Gun	
DATE			Fluid tip and air cap size	
Temperature Start and Finish			Spray distance	
	LARGE PART	0	Presure inlet	
PART AREA	3 X 3		Fluid Turns	
			Air Turns	
Solids for Clear Coat	ERR		Coating Type	
Cure time			Viscosity	
			Coating Temp.	

Weight (Grams)

LARGE PART WEIGHT	0	With Base Coat

Mil Build Measurements (Prior to Spraying Clear Coat)

BUILD TEST	LARGE PART
P1	0
P2	0
P3	0
P4	0
P5	0
P6	0
P7	0
P8	0
P9	0

After Gun setup

GUN MASS (grams)		
BEFORE		
AFTER		

Weight (Grams)

Large Part WEIGHT		after spraying and drying

Mil Build Measurements (Clear Coat Applied)

BUILD TEST Primer	Large Part
P1	
P2	
P3	
P4	
P5	
P6	
P7	
P8	
P9	

Gloss	
1	
2	
3	

Appendix B
Solids Data Collection Sheet

SOLIDS SAMPLES TEST

Solid Samples for Part Size   Parts Numbers

PAN # BASE	Empty PAN Wt.	Wet PAN & COATING Wt	PAN & SOLIDS Wt.	% SOLIDS BY Wt.
B1				**ERR**
B2				**ERR**
B3				**ERR**
B4				**ERR**
B5				**ERR**
Average	0.000	0.000	0.000	**ERR**
Pan # Clear				
C1				**ERR**
C2				**ERR**
C3				**ERR**
C4				**ERR**
C5				**ERR**
Average	0.000	0.000	0.000	**ERR**

Appendix C
Manufacturers' Coat Specification Sheet

DELTRON® 2000 Basecoat **Form P-175 (3/93)**

DBC

IDENTITY	CODE
DELTRON 2000 Basecoat	DBC
DT Reducers	
Cool Temperature	DT 860
Moderate Temperature	DT 870
Warm Temperature	DT 885
Hot Temperature	DT 895

BACKGROUND

DELTRON 2000 Basecoat is a state-of-the-art premium quality basecoat/clearcoat system designed to reproduce the hi-tech finishes found on today's luxury import and domestic vehicles.

DIRECTIONS FOR USE

Preparation:

- Wash areas to be refinished with soap and water.
- Wipe down with DX 330 ACRYLI-CLEAN® Wax and Grease Remover or DX 380 Low VOC Cleaner.
- Sand areas to be refinished to remove gloss and/or remove rust.
- Reclean with (#)DX 220, DX 330 or DX 380.
- Clean and treat bare metal areas with the appropriate PPG Metal Cleaning and Conditioning System.
- Prime the cleaned and conditioned bare metal areas with DP Epoxy Primers, (#)DCP 21, or DX 1791/1792 Self Etching Primer. If DX 1791/1792 is selected, a primer surfacer or sealer must be used before basecoat is applied. When using DCP 21 Primer over the bare metal, sanding with 80 - 180 grit sandpaper is necessary with or without metal treatments.

(#) Not currently available in Canada

- If filling is required, prime the surface with K 36/K 201 PRIMA™, K 200/201 Acrylic Urethane Primer Surfacer, or NCP 250/NCX 255 NCT® Primer Surfacer.
  Final sand with:
    DA/Machine : 400 grit
    Hand Sand Dry : 400 grit
    Hand Sand Wet : 500 grit

- For best results seal with either KTS 2K Sealers, NCS 2K Sealers, or K 36 reduced as a sealer. It is not necessary to seal DCP 21.

Mixing:

Reduce DBC color 100 - 150% with DT Reducer (one part DBC Color to 1-1½ parts DT Reducer). Use the appropriate DT Reducer best suited to shop temperatures, and the size of the job. **Thoroughly mix before using.**

Example:

DBC Color		DT Reducer
1 part		1 - 1½ parts
or	to	or
1 pint		1 - 1½ pints

Note: There is no pot life for this mixture.
However, thorough mixing is necessary before reusing.

Application and Dry Times:

- Adjust air pressure to 35-45 PSI at the gun for siphon feed gun or a maximum of 10 PSI for a HVLP gun setup.
- Apply 2-3 medium coats or until hiding is achieved.
- Apply each coat as soon as the previous coat dries flat, approximately 5 minutes.
- Allow the final coat of color to dry 10 to 15 minutes, but no longer than 24 hours before clearcoating. After 24 hours the DBC Color must be sanded and additional color applied.

Blending:

In most cases, simply extend each successive coat of DBC Color a little beyond the previous coat. No additional reduction necessary. However, the following option is available if needed:

Option:

- After achieving hiding of the DBC color on the repair additional DT Reducer may be added to the remaining DBC color and applied to the blend edge overlapping the previous coat until the desired blend is achieved.
- Melt in the overspray at the repair edge using a two gun method with the second gun containing DX 830 Universal Blender, DT 885, or DT 895. Apply a mist coat to the blend edge working the gun back towards the repair area. Avoid over wetting the blend edge.

Tinting:

DBC Basecoat colors may be tinted with DMD mixing bases. The maximum allowable amount of DMD is 5% by weight, (i.e. for every 100 parts of DBC up to 5 parts of DMD may be added). Do not use DMD 663, DMD 664, DBX 695, or any mixing base used exclusively for DBU Color.

Clearcoating:

DELTRON 2000 (DBC) Basecoat Color may be clearcoated with one of the following clears:

- DCU 8200 CONCEPT™ Medium Solids Acrylic Urethane Clear
- DCU 2001 CONCEPT High Solids Polyurethane Clear
- DCU 2020 CONCEPT Urethane Clear
- DCU 8300 FLORITRON™ Fluorinated Urethane Clear
- (#)DCD 35 DELTA™ Clear 3.5 VOC Compliant Clear
- DU 1000 DURETHANE® Polyurethane Clear

Repair or Recoating:

- DBC Color may be recoated with itself after a 15 minute dry time, or up to 24 hours without sanding. It may be sanded after 30 minutes, if necessary, but more DBC color must be applied. After 24 hours, it must be sanded and more DBC Color applied prior to clearcoating. Avoid excessive film build of DBC Color.

Painting of Flexible Parts:

- Properly prepare and prime the flexible part with the appropriate flexible primer or flexibilized primer surfacer.
- Sand and seal when necessary and recommended.
- Apply 2 - 3 medium coats of DBC Color or until hiding is achieved.
- Allow the DBC Color to dry 15 minutes and then apply the recommended properly flexibilized clearcoats.
- **Do not** add DX 369 FLEXATIVE® to the DBC Color.

Additives (Fisheye Eliminators):

Surfaces to be painted must be thoroughly cleaned and prepared. The use of DX 77 is not recommended unless absolutely necessary. Flow out is decreased in direct proportion to the amount of preventer used. When necessary, DX 77 can be used in a ratio of 1 to 2 screw capfuls per sprayable quart of DBC Color.

Note: <u>Do not use</u> DX 817 Fisheye Preventer in DBC Color.

Equipment Cleaning:

Spray guns, gun cups, storage pots, etc., should be cleaned thoroughly after each use with (#)DX 590 All Purpose Clean Up Solvent, DTL Thinners or DT Reducers.

(#) Not currently available in Canada.

Cautions:

Do not sand the basecoat color. If any damage occurs that necessitates sanding, additional color must be applied.

Do not use DX 369 FLEXATIVE or DC 950 NCT Flexibilizer in the basecoat color.

Do not overload the basecoat color or clearcoat as this will cause the finish to dry slow and stay soft for an extended period of time. Overloading the basecoat may also cause die-back in the clearcoat and poor repairability.

Do not add any hardeners or reactive reducers (DAU's, DU's, or DRR's) to the DBC Basecoat Color.

Do not use DBU 500 Color Blender with DBC Color.

COMPATIBLE SURFACES: DBC Basecoat Color **may be** used over the following:

DP Epoxy Primers
DX 1791/1792 Self Etching Primer (a)
K 36/201 PRIMA™ Acrylic Urethane Primer Surfacer (b)
NCP 250 NCT Primer Surfacer (b)
NCS NCT® 2K Sealers
K 200/201 Acrylic Urethane Primer Surfacer (b)
DZ KONDAR® Acrylic Primer Surfacers (a)
KTS 2K Sealers
DAS DEL-SEAL® Acrylic Sealers
(#)DCP 21 Urethane 2"N"1 Primer
DPX 844 Flexible Primer
DPX 800 Polypropylene Primer
DX 54 ROADGUARD® Chip Resistant Coating
(#)DPW Low VOC Waterborne Primers

(a) Must be sealed or primed
(b) Best if sealed

(#) Not currently available in Canada

INCOMPATIBLE SURFACES: DBC Basecoat Color **may not** be used over:

DPE 1538 Zinc Chromate Primer
DZL Primer Surfacers
DL 1970 SEALER 70™ Primer Sealer
DPE Primer Sealers
DFL Putties
DSX 1900 Bonding Clear

TEST PROPERTIES

Application Viscosity (#2 Zahn)	14-17 seconds
Flash Point (DBC only)	27°F
VOC (DBC only)	5.1 to 6.2 lbs/U.S. Gal
VOC (a)	6.0 to 6.6 lbs/U.S. Gal
Weight Solids (a)	12 - 27%
Volume Solids (a)	9 - 14%
Sq Ft Coverage/US Gal (100% Transfer Efficiency)	144 to 225 sq ft
Recommended Film Build	.5 to 1.5 mils
Dry Time	
Dust Free Time	5 to 10 minutes
Tack Free Time	10 to 20 minutes
Tape Free Time	20 to 40 minutes
Recoat Sensitivity @ 24 hours dry (normal film builds)	None

(a) Ready to Spray (1 part DBC Color to 1 part DT 870, 1:1)

IMPORTANT: The contents of this package must be blended with other components before the product can be used. Before opening the packages, be sure you understand the warning messages on the labels of all components, since the mixture will have the hazards of all its parts. Improper spray technique may result in a hazardous condition. Follow spray equipment manufacturer's instructions to prevent personal injury or fire. Follow directions for respirator use. Wear eye and skin protection. Observe all applicable precautions.

See Material Safety Data Sheet and Labels for additional safety information and handling instructions.

EMERGENCY MEDICAL OR SPILL CONTROL INFORMATION (304) 843-1300.
IN CANADA (514) 645-1320

PPG INDUSTRIES
19699 PROGRESS DRIVE
STRONGSVILLE, OH 44136

PPG CANADA INC.
880 AVONHEAD ROAD
MISSISSAUGA, ONTARIO L5J 2Z5

DCU 2042
Low VOC Speed Clear

DCU 2042

DCU 2042 Low VOC Speed Clear is the newest clear to join the PPG family of clearcoats. This amazing new clearcoat is the fastest, most productive baking clear on the market today. This clear cuts your bake time in half. DCU 2042 can be polished within minutes after cooling down.

Features	Advantages	Benefits
• Fastest Baking Clear	• Double Your Booth Production	• Increased Revenue
• Polish Shortly After Bake	• Repairs Completed Quickly	• Fast Delivery Times
• Low 4.2 VOC	• Complies With Current Regulations	• No Need To Switch Products In The Future

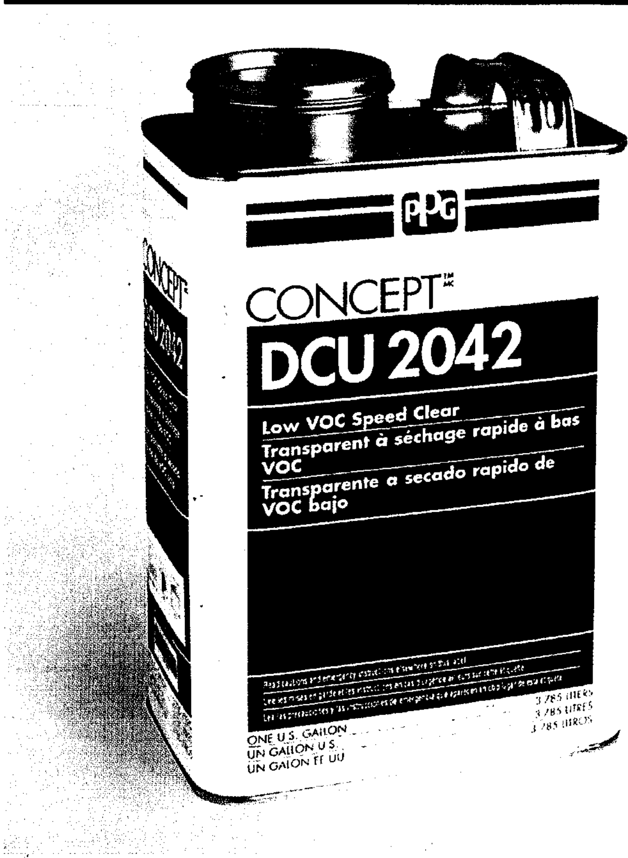
Compatible Surfaces

DCU 2042 may be applied over:

- DELTRON® (DBU) Universal Basecoat
- DELTRON® 2000 (DBC) Basecoat
- CONCEPT® (DCC) Acrylic Urethane

	DT Reducer
Cool Temperature (60°-70°F)	DT 860
Medium Temperature (65°-80°F)	DT 870
Warm Temperature (75°-90°F)	DT 885
Hot Temperatures (85°F and above)	DT 895
Hot Temperatures (85°F and above)	DT 898

	Hardeners
Hot Temperature/Force Dry	DCX 9
General Purpose	DCX 61



PPG Industries, Inc., 19699 Progress Dr., Strongsville, OH 44136

P-216 Effective 4/98

Directions for Use

DCU 2042

Preparation

Where VOC limits allow a maximum of 5.0 #/US Gal. for multi-stage systems, reduce DBU Color 150% with DRR Reducer or DBC Color 100% with DT Reducer. Refer to the Product Information Bulletin of the color system for its application and dry times.

Mixing Ratio

DCU 2042		DT Reducer		DCX 9 or DCX 61
4	:	1	:	1

! *Pot life of mixture is 1-1½ hours at 70°F (21 °C)*

Application and Dry Times

Apply	2 wet coats
Fluid Tip	1.3 - 1.5 mm or equivalent
Air Pressure	10 PSI at the cap for HVLP guns 45 - 50 PSI at the gun for conventional guns
Between Coats	5 - 10 minutes
Air Dry	8 hours at 70°F (21°C)
Purge Time	0 - 5 minutes at 70°F (21°C)
Force Dry	15 - 20 minutes at 140°F (60°C)

Polishing

Air Dry	After 12 hours at 70°F (21°C)
Force Dry	After cool down

Repair and Recoat

After the force dry / cooling cycle plus 2 additional hours or 8 hours air dry at 70°F (21°C). After 3 days, DCU 2042 must be sanded before recoating with primer, color or clear.

Painting of Flexible Parts

Full panel only when part is off vehicle*. Mix DCU 2042 with DX 814 Universal Flexibilizer in the following ratio:

DCU 2042		DT Reducer		DCX 9 or DCX 61		DX 814
4	:	1	:	2	:	2

! Pot life of flexibilized DCU 2042 is 1-2 hours at 70°F (21 °C)

DCU 2042/DCX 9 may be used on flexible parts without DX 814

DCU 2042		DT Reducer		DCX 9	DX 814
4	:	1	:	1	–

Pot life of mixture is 1-1½ hours at 70°F (21°C)

! *It is not necessary to add DX 814 to DCU 2042 when the part is already mounted on the vehicle.

Tinting and Additives

DCU 2042 cannot be tinted.
DX 84 ENHANCER™, DX 87 Extender or DXR 81 Accelerator may be added to DCU 2042 up to 1/2 OZ. per RTS quart.

Technical Data

Properties	**(a)**	**(b)**
VOC (Pkg) #/US Gal	4.0	4.0
VOC (RTS) #/US Gal	4.1	4.1
Total Solids by Volume (RTS)	41.4%	40.9%
Sq Ft Coverage / US Gal (1 mil at 100% Transfer Efficiency)	664	655
Film build per coat	1.2 - 1.4 mils	1.2 - 1.4 mils
Recommended Dry Film	2 - 2.5 mils	2 - 2.5 mils
Dry Time at 70°F (21°C)		
Dust Free Time	20 - 25 min	30 - 35 min
Tack Free Time	60 - 70 min	70 - 80 min
Tape Time	5 - 6 hrs	5 - 6 hrs

(a) Ready to Spray (4:1:1 DCU 2042 : DT 870 : DCX 61)
(b) Ready to Spray (4:1:1 DCU 2042 : DT 870 : DCX 9)