September 1999

Environmental Technology Verification Report

HVLP Coating Equipment
ITW Industrial Finishing, Binks·DeVilbiss
DeVilbiss JGHV-531-46FF HVLP Spray Gun

Prepared by

National Defense Center for Environmental Excellence

Operated by

Concurrent Technologies Corporation

for the

U.S. Environmental Protection Agency

Under Contract No. DAAE30-98-C-1050 with the U.S. Army (TACOM-ARDEC)

via EPA Interagency Agreement No. DW97936814

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ITW Industrial Finishing, Binks·DeVilbiss DeVilbiss JGHV-531-46FF HVLP Spray Gun

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Under Contract No. DAAE30-98-C-1050 (Task 208, SOW Task 4)
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Foreword

The Environmental Technology Verification (ETV) Program has been established by the U.S. Environmental Protection Agency (EPA) to evaluate the performance characteristics of innovative environmental technologies across all media and to report this objective information to the states, buyers, and users of environmental technology. EPA's Office of Research and Development (ORD) has established a 5-year pilot program to evaluate alternative operating parameters and determine the overall feasibility of a technology verification program. ETV began in October 1995 and will be evaluated through October 2000, at which time EPA will prepare a report to Congress containing the results of the pilot program and recommendations for its future operation.

EPA's ETV Program, through the National Risk Management Research Laboratory (NRMRL), Air Pollution Prevention and Control Division (APPCD) has partnered with Concurrent Technologies Corporation (*CTC*) under an ETV Pilot Project to verify innovative coatings and coating equipment techniques for reducing air emissions from coating operations. Pollutant releases to other media are considered in less detail.

The following report describes the verification of the performance of the ITW Industrial Finishing, Binks·DeVilbiss DeVilbiss JGHV-531-46FF high-volume, low-pressure spray gun.

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UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
Office of Research and Development
Washington, D.C. 20460

ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAM VERIFICATION STATEMENT

TECHNOLOGY TYPE:	**HIGH VOLUME, LOW PRESSURE (HVLP) LIQUID COATING SPRAY APPLICATION EQUIPMENT**
APPLICATION:	**LIQUID ORGANIC COATINGS APPLICATION IN AEROSPACE INDUSTRY**
TECHNOLOGY NAME:	**DeVilbiss JGHV-531-46FF**

COMPANY: **ITW Industrial Finishing, Binks·Devilbiss**
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The United States Environmental Protection Agency (EPA) has created the Environmental Technology Verification Program (ETV) to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved, cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, stakeholder groups, which consist of buyers, vendor organizations, and states, and with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The ETV Coatings and Coating Equipment Program (CCEP), 1 of 12 technology areas under ETV, is operated by Concurrent Technologies Corporation (*CTC*), in cooperation with EPA's National Risk Management Research Laboratory. The ETV CCEP has recently evaluated the performance of high-volume, low-pressure (HVLP) spray guns for painting metal and plastic parts. This verification statement provides a summary of the test results for the DeVilbiss JGHV-531-46FF HVLP spray gun, manufactured by ITW Industrial Finishing, Binks·DeVilbiss.

VERIFICATION TEST DESCRIPTION

The ETV CCEP evaluated the pollution prevention capabilities of HVLP liquid spray equipment. The test was conducted under representative factory conditions at *CTC*. It was designed to verify the environmental benefit of the HVLP spray gun with specific quality requirements for the resulting finish. The operational pressure of the HVLP gun at the air cap was verified to be $\leq$10 psig per the definition of HVLP application equipment. The finish quality applied under HVLP conditions was verified to match that of the paint manufacturer's reference panel. If an HVLP spray gun cannot provide an acceptable finish while operating under HVLP conditions, the end users may have a tendency to raise the input air pressure to meet their finishing requirements. However, these adjustments eliminate the environmental benefits of HVLP. These environmental benefits include a significant drop in paint usage and subsequent reduction of VOC/HAP emissions and solid waste disposal.

In this test, the DeVilbiss JGHV-531-46FF HVLP spray gun was tested under conditions recommended by ITW Industrial Finishing, Binks·DeVilbiss, the gun's manufacturer. Flat cold-rolled steel panels, measuring 10.2 cm x 30.5 cm (4 in. x 12 in.), were coated with an aerospace polyurethane selected by ITW Industrial Finishing, Binks·DeVilbiss. The HVLP gun was mounted on a robotic translator to increase accuracy and repeatability of the test. The translator can move the spray gun horizontally and/or vertically. The panels were sprayed in a single row of eight per rack, with three racks coated per run, and a total of five runs per test. Coated test panels were used for transfer efficiency (TE) and finish quality analyses. The TE improvement of the HVLP spray gun over a conventional air spray (CAS) gun baseline was verified using American Society for Testing and Materials (ASTM) method D 5286. The CAS baseline guns were pressure-feed, non-HVLP spray guns. The HVLP panels' finish quality was compared to a reference panel prepared by the coating manufacturer using CAS equipment. The CAS baseline panels' finish quality validated the comparison of the HVLP and CAS baseline TE data.

The details of the test, including a summary of the data and a discussion of results, may be found in Chapters 4 and 5 of "Environmental Technology Verification Report – HVLP Coating Equipment: ITW Industrial Finishing, Binks·DeVilbiss - DeVilbiss JGHV-531-46FF HVLP Spray Gun," which was published by *CTC*. Contact Robert J. Fisher of *CTC* at (814) 269-2702 to obtain copies of this statement, the Verification Report, or the Data Notebook.

TECHNOLOGY DESCRIPTION

The DeVilbiss JGHV-531-46FF HVLP liquid spray gun was tested, as received from ITW Industrial Finishing, Binks·DeVilbiss, to assess its capabilities. The spray gun was equipped with a #46MP air cap, a FF needle, and a 1.4 mm (0.055 in.) fluid tip, and was set to obtain a fan pattern of 27.94 cm (11 in.). This HVLP spray gun is marketed to industrial applications, including aerospace. ITW Industrial Finishing, Binks·DeVilbiss chose an exterior coating used on aircraft and aerospace equipment. The coating was a Deft, two-component, polyurethane topcoat (Deft Product Code 03-GY-292) that meets MIL-PRF-85285C, Type I, Amendment 2.

The DeVilbiss JGHV-531-46FF HVLP liquid spray gun is a DeVilbiss Standard-Size Maximum Performer manual spray gun. The spray gun tested was a pressure-feed gun with an aluminum body and 400-grade stainless steel fluid passages (300 grade stainless is optional). More information on the spray gun, including recommended air caps and fluid tips for various coatings, is available in the DeVilbiss Technical Bulletin I-2155-B, dated April 1997. At the time of this test, the list price of the DeVilbiss JGHV-531-46FF HVLP spray gun was $395.

VERIFICATION OF PERFORMANCE

The performance characteristics of the DeVilbiss JGHV-531-46FF HVLP liquid spray gun include the following:

Environmental Factors

- Relative Transfer Efficiency (TE): The DeVilbiss JGHV-531-46FF HVLP spray gun provided an 18.9% relative improvement in absolute TE when compared to the CAS baseline. Absolute TE for this test is defined as the actual, unadjusted TE obtained. The DeVilbiss JGHV-531-46FF HVLP spray gun provided a 37.9% relative improvement in applied TE over the CAS baseline. Applied TE for this test is the absolute TE adjusted to discount the dead space between the panels and outside the racks. The applied TE represents what would be expected if the eight panels on a rack were one contiguous, 81.3 cm x 30.5 cm (32 in. x 12 in.) panel. The standard deviation of the DeVilbiss JGHV-531-46FF test was 0.3% for the absolute TE data.

- Emissions Reduction: The absolute TE improvement equates to a reduction of volatile emissions of 0.5 kg per kg of solids applied when compared to CAS guns. The applied TE improvement equates to a volatile emissions reduction of 0.3 kg per kg of solids applied when compared to CAS guns. The specific quantitative reduction in paint usage, volatile organic compound (VOC) or hazardous air pollutant (HAP) emissions, solid waste, and cost due to increased TE depends on numerous factors such as paint formulation, process line and paint booth design, and the products being coated.

- Cost Savings: The increased TE of the HVLP spray gun provides an economic advantage in terms of reduced paint usage and solid waste generation. In this verification test, the absolute TE improvement equates to a reduction of 1.2 L of paint used and 0.9 kg of solid waste generated per kg of solids applied when compared to CAS guns. Also, the applied TE improvement equates to a reduction of 0.8 L of paint used and 0.6 kg of solid waste generated per kg of solids applied when compared to CAS guns.

- Output Air Pressure: The output air pressure is a function of the spray gun design and depends on the coating being sprayed. In this verification test, the output air pressure was measured with the DeVilbiss KK-5033-46-MP Air Cap Test Kit. The dynamic air pressure at the cap was set at 8 psig by adjusting the input air pressure.

Marketability Factors

- Dry Film Thickness (DFT): ITW Industrial Finishing, Binks·DeVilbiss recommended that the target DFT be 1.7–2.3 mils. The DFTs for all tests were determined from nine points measured on 25 random panels (i.e., 5 panels from each run). The DFT of the HVLP test averaged 1.8 mils with a standard deviation of 0.2 mil. The reference panel was found to have an average DFT of 1.5 mils. The average DFT for the CAS baseline was 1.8 mils.

- Distinctness-of-Image (DOI): The DOI was measured per ASTM D 5767 Test Method B (exception: an eight-bladed rotating disc was used rather than a sliding combed shutter) at three points on five panels per run. The target value, based on the results of the reference panel, was determined by ACT Laboratories to be 1 DOI unit with a standard deviation of 0. The average DOI for the HVLP test was 2 DOI units with a standard deviation of 1 DOI unit. This test method has a range of 0–100 DOI units; therefore, the difference between the HVLP panels and the reference panel is 1% of full scale. DOI was not measured on the CAS baseline panels because they were not used as the finish quality reference panels.

- Gloss: The gloss was measured per ASTM D 523 Test Method at three points on five panels per run. The test method has a range of 0–100 gloss units. For military purposes, the maximum allowable gloss value for the coating is 9.0 gloss units at an 85° angle. Deft recommended that the coating should have a target gloss value of 2.4 gloss units. The reference panel had a gloss of 1.6 gloss units. The HVLP test had an average of 2.8 gloss units with a standard deviation of 0.3 gloss unit. The average gloss of the CAS baseline was 2.9 gloss units.

- Visual Appearance: *CTC* personnel assessed the visual appearance of all 120 panels sprayed. The intent of this analysis was to identify any obvious coating abnormalities that could be attributed to the application equipment. The visual appearance of the coating was found to be acceptable with no obvious visual abnormalities that would render the coating unacceptable for its intended application

SUMMARY

The test results show that the DeVilbiss JGHV-531-46FF HVLP spray gun provides significant environmental benefit by reducing VOC/HAP emissions, paint usage rates, and solid waste generated and by producing a comparable finish to conventional paint spray guns when applying an organic coating under HVLP conditions. As with any technology selection, the end user must select appropriate paint spray equipment for a process that can meet the associated environmental restrictions, productivity, and coating quality requirements.

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CTC acknowledges the support of all those who helped plan and implement the verification activities and prepare this report. In particular, a special thanks to Michael Kosusko, EPA ETV CCEP Project Manager, and Shirley Wasson, EPA ETV CCEP Quality Assurance Manager, both of EPA's National Risk Management Research Laboratory in Research Triangle Park, North Carolina.

CTC also expresses sincere gratitude to ITW Industrial Finishing, Binks·DeVilbiss, the manufacturer of the DeVilbiss JGHV-531-46FF HVLP spray gun, for their participation in, and support of, this program and their ongoing commitment to improve organic finishing operations. In particular, *CTC* would like to thank Raymond P. Swiatecki, Mark D. Miller, and Alan H. Fritz. ITW Industrial Finishing, Binks·DeVilbiss is based in Maumee, Ohio.

SI to English Conversions

SI Unit	English Unit	Multiply SI by factor to obtain English
°C	°F	3.380 E + 01
L	gal. (U.S.)	2.642 E - 01
m	ft	3.281 E + 00
kg	lbm	2.205 E + 00
kPa	psi	1.4504 E - 01
cm	in.	3.937 E - 01
mm	mil (1 mil = 1/1000th in.)	3.937 E + 02
m/s	ft/min	1.969 E + 02
kg/L	lbm/gal. (U.S.)	8.345 E + 00

List of Abbreviations and Acronyms

ABB	Asea Brown Boveri
ASTM	American Society for Testing and Materials
CAS	conventional air spray
CCEP	Coatings and Coating Equipment Program
CTC	Concurrent Technologies Corporation
DEP	Department of Environmental Protection
DFT	dry film thickness
DOI	distinctness-of-image
EPA	Environmental Protection Agency
ETV	Environmental Technology Verification
HAP	hazardous air pollutant
HVLP	high-volume, low-pressure
ID	identification
NDCEE	National Defense Center for Environmental Excellence
NIST	National Institute for Standards and Technology
P2	pollution prevention
PEA	performance evaluation audit
PLC	programmable logic controller
QA/QC	quality assurance/quality control
RTI	Research Triangle Institute
SAE	Society of Automotive Engineers
SCAQMD	South Coast Air Quality Management District
TE	transfer efficiency
TNRCC	Texas Natural Resources Conservation Commission
TQAPP	Testing and Quality Assurance Project Plan
TSA	technical system audit
VOC	volatile organic compound

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Section 1
Introduction

1.1 ETV Overview

Through the Environmental Technology Verification (ETV) Pollution Prevention (P2) Innovative Coatings & Coating Equipment Program (CCEP) pilot, the United States Environmental Protection Agency (EPA) is assisting manufacturers in selecting more environmentally acceptable coatings and equipment to apply coating materials. The ETV program, established by EPA as a result of the President's environmental technology strategy, *Bridge to a Sustainable Future*, was developed to accelerate environmental technology development and commercialization through third party verification and reporting of performance. Specifically, this pilot targets coating technologies that are capable of improving organic finishing operations, while reducing the quantity of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) generated by coating applications. The overall objective of the ETV CCEP is to verify pollution prevention and performance characteristics of coatings and coating equipment technologies and to make the results of the verification tests available to prospective technology end users. The ETV CCEP is managed by Concurrent Technologies Corporation (*CTC*), located in Johnstown, Pennsylvania. *CTC*, under the National Defense Center for Environmental Excellence (NDCEE) program, was directed to establish a demonstration factory of prototype manufacturing processes, capable of reducing or eliminating materials harmful to the environment. The demonstration factory finishing equipment was made available for this project.

The ETV CCEP is a program of partnerships among the EPA, *CTC*, the vendors of the technologies being verified, and a stakeholders group. The stakeholders group comprises representatives of end users, vendors, industry associations, consultants, and regulatory permitters.

The purpose of this report is to present the results of the verification test of the DeVilbiss JGHV-531-46FF high-volume, low-pressure (HVLP) pressure-feed spray gun, hereafter referred to as the DeVilbiss JGHV, which is designed for use in industrial finishing. The test coating chosen by ITW Industrial Finishing, Binks·DeVilbiss was Deft 03-GY-292 aerospace polyurethane coating. Where possible, analyses performed during these tests followed American Society for Testing and Materials (ASTM) methods, or other standard test methods.

1.2 Potential Environmental Impacts

VOCs are emitted to the atmosphere from many industrial processes, as well as through natural biological reactions. VOCs are mobile in the vapor phase, enabling them to travel rapidly to the troposphere where they combine with nitrogen oxides in the presence of sunlight to form photochemical oxidants. These photochemical oxidants are precursors to ground-level ozone or photochemical smog.[1] Many VOCs, HAPs, or the subsequent reaction products, are mutagenic, carcinogenic, or teratogenic, i.e., cause gene mutation, cancer, or abnormal fetal development.[2] Because of these detrimental effects, Titles I and III of the Clean Air Act Amendments of 1990 were established to control ozone precursor and HAP emissions.[2,3]

Painting operations contribute approximately 20% of the total VOCs being generated. These operations also contribute to HAP emissions, liquid wastes, and solid wastes. End users and permitters often overlook these multimedia environmental effects of coating operations. New technologies are needed and are being developed, to reduce the total generation of pollutants from coating operations. However, the emerging technologies must not compromise equipment performance and finish quality.

CTC is serving as the verification organization for the CCEP because of their commitment to environmental excellence and helping the U.S. industrial base achieving world class agility and competitiveness. *CTC*'s equipment is located in a demonstration factory that was established under the NDCEE Program. This equipment includes full-scale, state-of-the-art organic finishing equipment, as well as the laboratory equipment required to test and evaluate organic coatings. The equipment and facilities have been made available for this program for the purpose of testing and verifying the abilities of finishing technologies.

1.3 HVLP Technology Description

HVLP spray application equipment was developed to reduce air pollution that typically results from organic finishing operations by improving transfer efficiency (TE). Legislation requiring the use of spray equipment that is at least as efficient as HVLP spray guns has been adopted throughout the nation, with the intention of reducing VOC and HAP emissions. For example, Rule 1511 of California's South Coast Air Quality Management District (SCAQMD) established the following definition of HVLP spray equipment on June 13, 1997:

> *Equipment used to apply coatings by means of a spray gun which is designed to be operated and which is operated between 0.1 and 10 pounds per square inch gauge (psig) air pressure measured dynamically at the center of the air cap and at the air horns.*

The low air pressure of HVLP spray equipment results in a low velocity air stream that leads to a larger average paint droplet size and reduced paint particle momentum, which creates less overspray and bounceback, improving TE. Improved TE leads to a reduction in paint usage, VOC and HAP emissions, solid waste disposal, and spray booth maintenance costs. Reduced overspray and bounceback provide a cleaner work environment with improved visibility for the operator.

1.4 Technology Testing Process

Technology focus areas were selected based on input from the ETV CCEP stakeholders group and market research. Upon initiating agreements with interested vendors, a Generic Test Protocol for HVLP equipment was developed by *CTC*. *CTC* then developed a technology specific Testing and Quality Assurance Project Plan (TQAPP) for each piece of equipment being verified, with significant input from the vendors. After the vendor concurred with, and the EPA and *CTC* approved, the TQAPP, *CTC* personnel performed the verification test. The Verification Statement, which is produced as a result of this test, may be used by the technology vendor for marketing purposes or by end users selecting HVLP equipment. The Verification Statement for this product is included on pages v–viii of this report.

1.4.1 Technology Selection

Organic finishing technologies that demonstrated the ability to provide environmental advantages were reviewed and prioritized by the ETV CCEP stakeholders group. The stakeholders group is composed of coating industry end user and vendor association representatives, end users, vendors, industry consultants, and state and regional technical representatives. The stakeholders group reviewed the pollution prevention potential of each candidate technology and considered the interests of industry. HVLP spray equipment was found to have one of the greatest pollution prevention potentials, was being widely considered by industry in organic finishing replacement activities, and is being mandated for use by many regulating agencies and government specifications. As a result, HVLP received the highest ranking and, thus, was the first technology selected for verification.

1.5 Test Objectives and Approach

The testing was performed according to the DeVilbiss JGHV-531-46FF HVLP Spray Gun TQAPP. This project was designed to verify that the DeVilbiss JGHV is capable of providing the end user with a pollution prevention benefit and an acceptable quality finish, while operating under the current definition of HVLP spray equipment. It can be argued that nearly all spray guns are designed to operate at low output pressures when the input air pressure is sufficiently low. A spray gun operated under the definition of HVLP solely by decreasing the input air pressure (with the exception of turbine spray guns), will most likely provide an unacceptable coating finish under those conditions; therefore, the operator may be inclined to increase the input air pressure to those spray guns to meet their finish requirements, subsequently raising the output air pressure above the 10-psig limit. This project supplies the end users with the best available, unbiased technical data to assist them in deciding if the DeVilbiss JGHV meets their needs.

The quantitative pollution prevention benefit, in terms of improved TE, depends on innumerable factors that are often unique to each coating production line. Attempting to verify every possible combination of these factors is unrealistic. For this verification test, a specific combination of these factors was selected by *CTC*, EPA, ITW Industrial Finishing, Binks·DeVilbiss, and the ETV CCEP Stakeholders. The data presented in this report are representative only of the specific conditions tested; however, the test design represents an independent, repeatable evaluation of the pollution prevention benefits and performance of the technology. To determine the environmental benefit of the DeVilbiss

JGHV, the HVLP TE is quantitatively and qualitatively compared to a conventional air spray (CAS), or non-HVLP, baseline (see Section 4). The CAS guns used for this verification test were pressure-feed.

All processing and laboratory analyses, with the exception of the distinctness-of-image (DOI) analyses, were performed at *CTC* facilities. ACT Laboratories, Inc. in Hillsdale, Michigan, performed the DOI analyses. TE was calculated to determine the relative pollution prevention benefit of the technology. DOI, gloss, and visual appearance were evaluated to verify finish quality. The finish quality of the HVLP panels was compared to a reference panel prepared by the coating manufacturer using CAS equipment. The finish quality of the CAS baseline panels was also evaluated to validate the comparability of the TE data.

1.6 Performance and Cost Summary

This verification test has quantitatively shown that the DeVilbiss JGHV is capable of providing an environmental benefit over CAS guns (see Table 1). This environmental benefit was quantified through the ability of the DeVilbiss JGHV to apply a coating at a higher TE. This verification test has also shown that the DeVilbiss JGHV does not require output pressures greater than 10 psig to provide the end user with an acceptable quality finish. The increased TE reduces paint usage and solid waste generation. The reduction in paint usage translates into a reduction in VOC and HAP emissions. The extent that emissions and wastes are reduced depends on each individual application, which must be determined on a case-by-case basis.

Table 1. Verification Factors for the DeVilbiss JGHV HLVP Spray Gun

	Target	**Result**
Relative Transfer Efficiency Improvement[a] (%)	Improvement over CAS baseline	Absolute 18.9 Applied 37.9
Output Air Pressure (psig)	$\leq$10 (per definition)	8
Dry Film Thickness (mils)	1.7 to 2.3 (per Deft)	Average of 1.8
Distinctness-of-Image (DOI units)	1 out of 100 (per Reference Panel)	2
Gloss (gloss units at an 85° angle)	1.6 out of 100 (per Reference Panel)	2.8
Visual Appearance	Acceptable for target industry application	Acceptable for industry applications and military aerospace use.

[a] Reported in terms of the absolute TE improvement of the test (including the coating sprayed into dead space) and applied TE improvement (which factors into the equation only when the spray gun is directly in front of a panel).

Absolute TE is defined for this test as the actual, unadjusted TE obtained from this verification test. Absolute TE includes the coating that was sprayed between panels and when the gun was traveling towards or away from the racks.

Applied TE takes into account only the coating that was sprayed while the gun was directly in front of a panel. Applied TE estimates the results that would be obtained if each rack consisted of a single panel, 81.3 cm x 30.5 cm (32 in. x 12 in.), and that the gun begins, or stops, spraying as the vertical axis of the spray gun crosses the leading, or trailing, edge of the panel.

The capital costs of HVLP spray guns are generally higher than for comparable CAS guns. At the time of this verification test, the list price of the DeVilbiss JGHV was $395, and the CAS guns used for the baseline testing ranged in price from $125 to $260. Although no modifications were necessary to perform this verification test, changing from CAS guns to HVLP spray guns sometimes requires a modification to the existing air delivery system to ensure that the increased volume of air is available to operate the HVLP spray gun. However, the operating costs of the HVLP and CAS guns are very similar. The economic advantage of the HVLP spray gun is realized when reduced paint usage and solid waste generation are considered.

Table 2 summarizes the emission and usage reductions resulting from the relative TE improvement.

Table 2. Benefits Realized from Relative TE Improvement

	Absolute			**Applied**		
	JGHV	**CAS**	**Difference**	**JGHV**	**CAS**	**Difference**
Coating Density (kg/L)	1.171	1.178	[b]	1.171	1.178	[b]
Wt. % Solids (%)	63.86	64.74	[b]	63.86	64.74	[b]
VOC Content (kg/L)	0.423	0.415	[b]	0.423	0.415	[b]
TE (%)	21.4	18.0	[b]	62.9	45.6	[b]
Solids Sprayed (kg)[a]	4.7	5.6	0.9	1.6	2.2	0.6
Paint Usage (L)[a]	6.1	7.3	1.2	2.1	2.9	0.8
VOC Emissions (kg)[a]	2.5	3.0	0.5	0.9	1.2	0.3

[a] Per kg of solids applied to a product.
[b] Not applicable.

Section 2
Description of the Technology

2.1 Technology Performance, Evaluation, and Verification

The overall objectives of this verification study are to verify pollution prevention characteristics and performance of HVLP coating equipment technologies and to make the results of the verification tests available to the technology vendor for marketing to prospective technology end users. The DeVilbiss JGHV is designed for use in industrial finishing operations, which includes aerospace applications. The DeVilbiss JGHV is fabricated from drop-forged aluminum and 400-grade stainless steel. The FF needle and a 1.4 mm fluid tip used in this test were both fabricated from 400-grade stainless steel. The combination of the fluid tip and air cap determines the quality of the finish and the productivity potential. For this verification study, the gun used a pressure-feed system. The fluid adjustment determines the distance that the needle retracts from the fluid tip, which determines how much coating passes through the gun. The farther the needle retracts, the greater the paint flow. The Deft 03GY292 aerospace polyurethane coating was chosen by ITW Industrial Finishing, Binks·DeVilbiss as the test coating. The test coating was also sprayed with CAS guns under nearly identical process conditions to establish the relative pollution prevention benefit in terms of improved TE.

CTC, the independent, third party evaluator, worked with the vendor of the technology and EPA throughout verification testing. *CTC* prepared this verification report and was responsible for performing the testing associated with this verification.

2.2 The HVLP Tests

This verification test is based on the ETV CCEP HVLP Coating Equipment - Generic Testing and Quality Assurance Protocol, which was reviewed by the ETV CCEP stakeholders. ITW Industrial Finishing, Binks·DeVilbiss, the manufacturer of the DeVilbiss JGHV, worked with *CTC* to identify the optimum performance settings for the gun. ITW Industrial Finishing, Binks·DeVilbiss had determined the parameters through tests their personnel conducted at their facility. A preliminary TQAPP was generated using the vendor-supplied information and was submitted to EPA for review of content. Following the initial EPA review and incorporation of their comments, the vendor was given the opportunity to comment on the specifics of the TQAPP. Any information pertinent to maintaining the quality of the study was incorporated into the TQAPP. A final draft of the TQAPP was reviewed by the vendor and technical peer reviewers then approved by the EPA and *CTC* prior to the start of verification testing.

Testing was conducted under the direction of *CTC* personnel, with ITW Industrial Finishing, Binks·DeVilbiss personnel present during testing. The ITW Industrial Finishing, Binks·DeVilbiss personnel aided in air cap pressure measurement and setting the gun-to-target distance. All information gathered during verification testing was analyzed, reduced, and documented in this report. TE and finish quality measurements of the DeVilbiss JGHV and the relative TE improvement over a CAS baseline were the primary objectives of this report. The data comparison highlights the pollution prevention benefit of the HVLP spray gun, as well as its ability to provide the required finish quality. A portion of the test data has been quality audited by EPA and the *CTC* Quality Assurance Officer to ensure the validity of the data.

2.3 HVLP Spray Application Equipment

This section contains information on the HVLP spray equipment, its current applications in industry, the advantages and benefits of the technology, and information on technology deployment.

HVLP spray equipment is divided into two main categories: turbine and conversion. The turbine HVLP spray guns use a turbine compressor to generate large volumes of low-pressure air that is fed to the spray gun. The turbines are designed so that the input air pressure is consistently below 10 psig. The HVLP turbine compressor intrinsically transfers heat to the atomizing air that is supplied to the spray gun, which helps atomize paints that have a high viscosity. Turbine guns primarily use pressure, or force, feed systems to deliver the paint to the gun. Conversion HVLP spray guns use the existing high-pressure air supply that non-HVLP spray guns use. Conversion guns convert the low volume of air supplied at high pressure to a larger volume of air at lower pressure. Conversion HVLP spray guns use three types of paint delivery systems. First, pressure, or force, feed systems consist of a pressure pot that contains a drawtube that travels from the bottom of the pressure pot to the connection that leads to the spray gun. Air pressure above the coating forces the paint up through the drawtube, through the supply lines, and to the spray gun. A constant paint flow rate is achieved by maintaining constant air pressure to the delivery system. The DeVilbiss JGHV uses a pressure-feed paint delivery system, as does each of the three CAS guns used in this verification test. Second, gravity-feed systems consist of a cup mounted on top of the spray gun. Hydrostatic pressure, as a result of gravitational forces, is the driving force behind the paint flow rate to the spray gun. As the volume of paint in the gravity cup decreases, the paint flow rate decreases. Third, a siphon, or suction, feed system consists of a cup attached to the bottom of the spray gun, near the air cap. The siphon cup contains a drawtube that travels from the spray gun connection to the bottom of the cup. The air pressure passing through the spray gun creates a negative pressure in the drawtube, drawing the paint up towards the spray gun. Paints with a higher viscosity require increased air pressure through the spray gun to induce paint flow.

2.3.1 Technology Applications

HVLP spray equipment is relatively universal in its applications, with some applications obtaining better results. The DeVilbiss JGHV can be used for many applications; however, an aerospace industry application was the subject of this verification test. Aerospace companies utilize the DeVilbiss JGHV because it is a drop-in substitute for CAS guns, it is capable of high production rates, and its maintainability is comparable to and interchangeable with other DeVilbiss HVLP and CAS guns.

2.3.2 Advantages of Technology

HVLP spray application equipment is designed to reduce VOC emissions that typically result from spray painting operations by increasing paint TE. HVLP equipment use is legislated as a requirement in many states, such as, California SCAQMD's Rules 1151 and 1145, the Texas Natural Resources Conservation Commission's (TNRCC) Title 30, Section 115.422, and the Pennsylvania Department of Environmental Protection's (DEP) Title 25, Section 129.52. Similar requirements have been adopted in legislation throughout the U.S.

A low velocity air stream is used to atomize the coating, which leads to larger paint droplets and reduced paint particle momentum, resulting in less overspray and bounceback of the coating. Less overspray and bounceback lead to improved TE and sustain a cleaner environment for the operator. Improved TE leads to lessened VOC emissions, paint consumption, waste disposal, material costs, and spray booth maintenance.

2.3.3 Limitations of Technology

For some applications, HVLP spray guns may experience difficulties in spraying paints with very high solids content or high viscosity. The restriction on atomizing air input places a theoretical limit on the types of coatings that can be sprayed with acceptable results. However, one of the largest criticisms that has prevented wide-scale acceptance by all industries is the claim that HVLP spray guns cannot maintain high production rates. Based on this verification test, the DeVilbiss JGHV applied the target film thickness at an average horizontal gun speed that was faster than the CAS baseline tests, provided an improvement in TE over the CAS baseline, and maintained a finish quality comparable to the coating reference panel.

2.3.4 Technology Deployment and Costs

HVLP spray equipment has many applications, with few limitations on its distribution throughout the various finishing industries. One area of concern is the efficient application of high viscosity coatings, which are harder to atomize at lower air pressures. Although the equipment is not significantly different from CAS guns in its operation, ITW Industrial Finishing, Binks·DeVilbiss offers training sessions, as do most trade schools. The equipment is cost effective, because it is similar in capital and operating costs to CAS guns. However, economic benefits are displayed through reduced paint usage, as a result of improved TE, and reduced solid waste, as a result of less frequent dry filter replacements or a lower volume of wash water entrapment.

Section 3
Description and Rationale for the Test Design

3.1 Description of Test Site

The testing of the DeVilbiss JGHV was conducted at the Organic Finishing Line, in *CTC*'s Environmental Technology Facility Demonstration Factory. The layout of the Organic Finishing Line is shown in Figure 1.

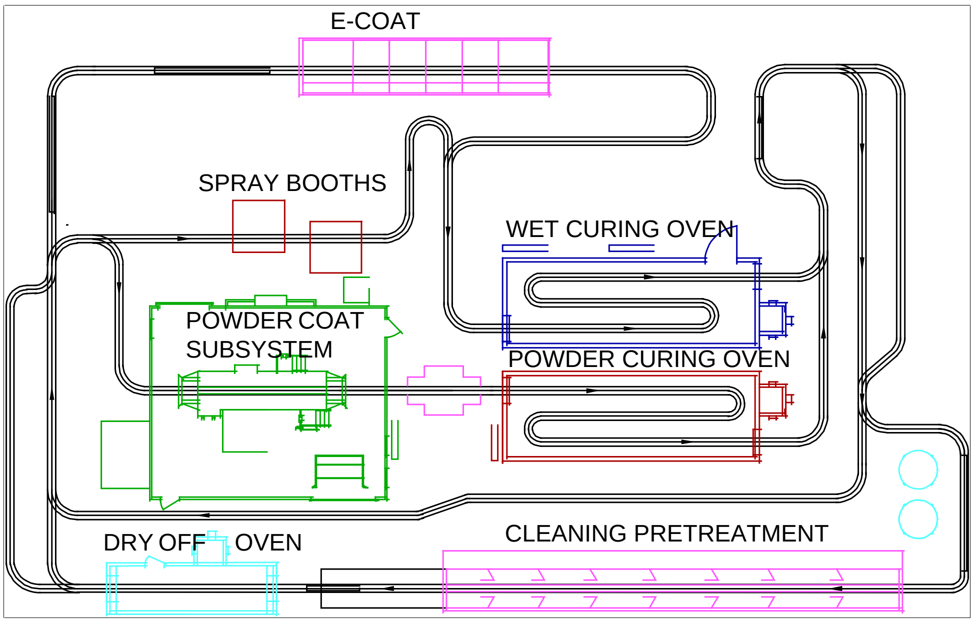

Figure 1. Organic Finishing Line at *CTC*

Coating application involves transporting test panels through the Organic Finishing Line using an automatic conveyor. The test panels were pretreated in the seven-stage pretreatment process of the Organic Finishing Line, weighed, stored until needed for testing, placed back on the racks, and then transported through the Organic Finishing Line to the wet spray booth. The spray booths are capable of producing air velocities up to 0.63 m/s (125 ft/min). The three stages of dry filters are equipped with a gauge that monitors the pressure drop across the filter bank. Air supply lines for operating the guns and gauge readouts are located at the spray booths and were used for this test. A linear translator was procured to move the spray guns vertically and horizontally when applying the coating. The translator, operated through a programmable logic controller (PLC), was used to remove any operator bias. A drawing of the rack setup is shown in Figure 2. Figure 2 shows the location of the two support bars that were behind the test panels. These support bars helped to minimize the motion of the test panels during the application of the test coating.

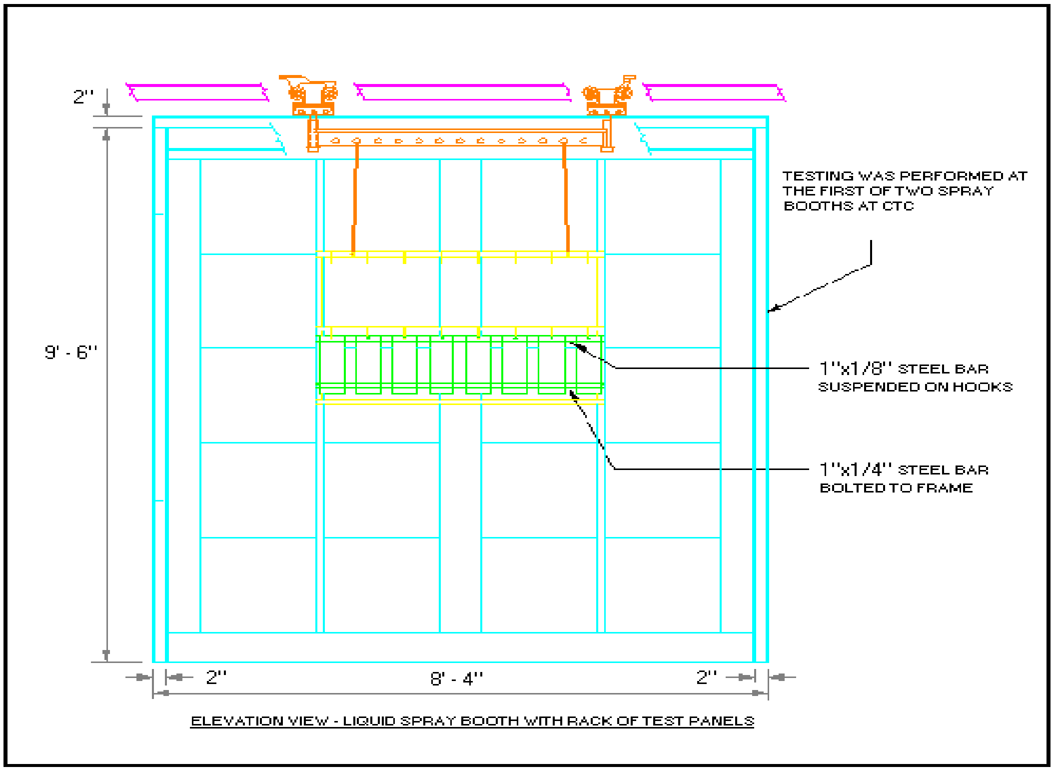

Figure 2. Rack Setup Diagram

CTC's Environmental Laboratory maintains extensive state-of-the-art facilities that are dedicated to coating technology evaluations, and can also measure and characterize products, processes, and waste specimens resulting from factory activities.

3.2 DeVilbiss JGHV Setup

The fluid delivery system consisted of a 2-L paint pot and a 20-L, high-pressure pot. The 2-L pot that held the test coating was placed inside the 20-L pot. The 20-L pot was pressurized to 70 psig, to force the coating through the drawtube that was immersed in the coating. Once the coating was in the draw tube, it passed through a ball valve, a T-joint, and another ball valve before travelling to a 1.6 mm orifice on the mass flow meter. The coating exited the mass flow meter as it passed through a second 1.6 mm orifice en route to the fluid connection of the spray gun. A 9.5 mm inside diameter fluid hose carried the coating from the pressure pot to the mass flow meter and then to the gun. The setup during this verification test had to overcome a large pressure drop in the fluid line. The large pressure drop was due to the instrumentation and controls necessary for this verification test, which are not necessarily used under production conditions. The pressure drop was primarily caused by the Asea Brown Boveri (ABB) K2 mass flow meter that was in-line between the paint pot and the gun. Figure 3 details the fluid path from the paint pot to the spray gun.

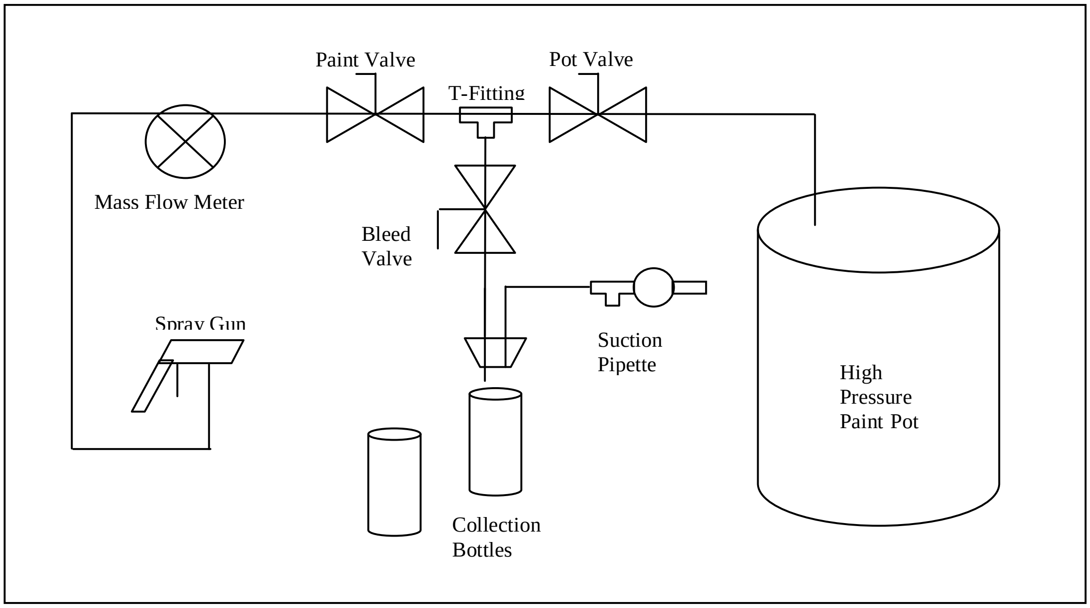

Figure 3. Pressure-feed Paint Delivery System

3.3 Evaluation of HVLP Performance

The overall objectives of the verification study were to establish the pollution prevention benefit of the DeVilbiss JGHV, relative to the TE of CAS spray guns, and to determine the effectiveness of the DeVilbiss JGHV at providing an acceptable coating finish. Section 4 discusses the details of the CAS baseline. Finish quality cannot be compromised in most applications, despite the environmental benefit that may be achieved. Therefore, this study has evaluated both of these crucial factors. Results from the HVLP spray gun verification testing will benefit prospective end users by enabling them to better determine if the DeVilbiss JGHV will provide them with a pollution prevention benefit while meeting the finish quality requirements for their application.

3.3.1 Test Operations at CTC

The TQAPPs for the DeVilbiss JGHV and CAS baseline guns identified that testing would consist of coating eight panels per rack, with three racks per run, and five runs per verification test. This enabled both total and run-to-run variation to be determined for each response factor. The statistical analyses for certain response factors were performed using a statistical software package.

The standard test panels used for verification testing were flat, cold-rolled 22-gauge steel with a 0.6-cm (1/4-in.) hole in one end that meets Society of Automotive Engineers (SAE) 1008 specifications. The panel dimensions were 30.5 cm by 10.2 cm (12 in. x 4 in.). The panels were received untreated because *CTC*'s pretreatment line provides more precise and consistent pretreatment weights than the panel supplier could guarantee. All panels were subjected to an alkaline cleaning, followed by a deionized water rinse. Zinc phosphate was subsequently applied, followed by a non-chromate sealer and deionized water rinse. A dry-off stage completed the pretreatment. One random test panel was removed per run for pretreatment analysis. To fill in the empty spaces left by the panels removed for pretreatment analysis and to provide panels for setup testing, an additional four racks of panels were pretreated. All panels were suspended on the rack by placing the panels on hooks attached to the rack. Two bars were fixed to the rack, one near the top of the panels and one near the bottom of the panels. The bars were used to minimize movement during paint application.

The test coating chosen by ITW Industrial Finishing, Binks·DeVilbiss was a two-component, Deft aerospace polyurethane (03GY292) that is designed to contain less than 419 g/L VOC, as applied. The VOC content was determined by assuming that all volatiles in the coating were regulated compounds. The coating was within the VOC content limit of its target industry, a requirement identified by the ETV CCEP. For the HVLP test, the VOC content exceeded the TQAPP target limit during four of the runs by less than 2% each. For the CAS baseline, the VOC content exceeded the limit during two runs by less than 0.5%. The test coating was chosen because it is a common coating used in the aerospace industry. The coating data sheet is shown in Appendix B of the DeVilbiss JGHV-531-46FF Data Notebook. Prior to each run, the test coating was prepared in the laboratory according to the manufacturer's instructions. The exact coating preparation procedures were recorded and are listed in Appendix C of the DeVilbiss JGHV-531-46FF Data Notebook. To ensure comparability among tests, the test coating was prepared using the same procedures for the HVLP test and all CAS tests. The amount of coating mixed for each run varied from 1 to 3 L, depending on the amount of paint required for the setup. Samples were taken from each coating preparation for viscosity, weight % solids, density, and volatile content measurements. Viscosity and temperature measurements were taken before and after each run. The coating was then transferred to the paint pot, and the initial weight was recorded.

Upon completion of pretreatment, panels were weighed and stored until they were needed for testing. The panels were then placed back on the racks and transferred to the spray booth area by an overhead conveyor. A mechanical stop mechanism aligned the racks of test panels in the proper position relative to the spraying mechanism. The rack of panels remained stationary during spraying. The DeVilbiss JGHV was mounted on a nylon arm extending from the carrier plate of the robotic translator, which was controlled by a remote PLC. The PLC also controlled the pneumatic valves for atomizing air and the pneumatic cylinder that triggered the gun. A 1.4 mm fluid tip, a 1.4 mm fluid needle, and a #46MP air cap were used on the DeVilbiss JGHV. The product data sheets for the DeVilbiss JGHV can be found in Appendix A of the DeVilbiss JGHV-531-46FF Data Notebook. The fan and fluid adjustments were set at full open, and the dynamic output pressure at the air cap was set at 8 psig. The paint was applied in two coats, with a different translator speed for each coat, as recommended by ITW Industrial Finishing, Binks·DeVilbiss. The horizontal traverse speed of the gun/translator system was set so that the gun traveled at 98.6 cm/s (38.8 in./s) while in front of the panels for the first coat and 48.7 cm/s (19.2 in./s) while in front of the panels for the second coat. Due to the acceleration and deceleration for each pass, the average speed measured for the entire range of motion will be lower. Each coat required four passes of the gun. The vertical drop between passes was set at 10.2 cm (4.0 in.) for both coats, and the gun-to-target distance was set at 20.3 cm. (8 in.). The parameters for traverse speed, number of passes, vertical drop, and gun-to-target distance were established by ITW Industrial Finishing, Binks·DeVilbiss. These parameters were verified with ITW Industrial Finishing, Binks·DeVilbiss representatives present, prior to testing.

New, clean, spray booth filters were installed before testing the HVLP and each of the CAS spray guns. The spray booth air filters were changed prior to setting up the standard apparatus for each gun to minimize the difference in the initial booth air velocity between the guns. The booth air velocity was measured in close proximity to the panels. The air velocity through the booth was expected to be between 0.2 and 0.5 m/s (40 and 100 ft/min). The velocity measured near the panels may vary greatly because of the disruption of the air currents by the rack and panels. The pressure drop across the filters also was checked prior to each run and at the end of the test. To ensure that the filter bank system was functioning properly, a pressure drop across the filter bank greater than 1.0 cm of water indicated that the system required service.

The input atomizing air pressure at the air trigger was set during the setup phase to obtain the desired output air pressure. A dynamic input air pressure of 70 psig at the air trigger was used to maintain the 8-psig output air pressure for the DeVilbiss JGHV. The air traveled from a quick disconnect at the shop line to a quick disconnect at an elbow. The elbow was connected to the pneumatic air trigger, which was connected to another quick disconnect. The air then traveled to a quick disconnect located at the air inlet to the spray gun. All air hoses had a 9.5-mm (3/8-in.) inside diameter.

Once the racks were in position, all pertinent measurements taken, and equipment adjustments made, the PLC activated the motors that drove the linear motion translators and the pneumatic cylinder that triggered the gun. The translator traveled 142.2 cm (56 in.) horizontally and dropped 30.5 cm (12 in.) vertically during the four passes on each rack. The panels were automatically sprayed using vertical overlap of the fan pattern. The target dry film thickness (DFT) requirement was 1.7-2.3 mils. Four passes and two coats were recommended by ITW Industrial Finishing, Binks·DeVilbiss to achieve the required thickness. During the dwell time between passes, paint flow was interrupted to minimize paint usage. The first coat was applied to all three racks in a run before applying the second coat. The flash time between coats was 20 minutes. Once the painting was complete, the PLC released the mechanical stop maintaining the position of the rack on the overhead conveyor. The processed rack was moved to the cure oven to air-dry and the next rack was moved into position within the spray booth. The cure oven was maintained at ambient temperature and was used solely for the purpose of minimizing contact with foreign objects or contaminants. The panels were air-dried at ambient temperature in the cure oven for at least 12 hours.

Twenty-four panels were coated during each run. One pretreated panel from each group of 24 panels was removed for zinc phosphate coating weight determination. Each of the panels removed for this measurement was replaced with another panel that was pretreated at the same time as all other panels used for each test. TE was determined using the average weight gain of the 24 coated panels, per the ASTM standard. Coated standard test panels were also analyzed for DFT, DOI, gloss, and visual appearance.

The final weight of the pressure pot was recorded after each run, so that the amount of paint sprayed could be determined. To ensure that little to no paint was lost when disconnecting the pressure-feed gun, the following procedure was used for both the HVLP verification test and the CAS baseline:

> The paint supply line to the gun contained a T-fitting, a paint valve that was normally open, a bleed valve that was normally closed, two collection bottles that were weighed before and after each disconnection, and a pipette bulb to control the paint in the line. First, the paint valve was closed, isolating the paint pot and bleeder system from the gun. The air supply to the pot was then closed, and the pressure relief valve was opened slowly to release the pressure on the paint pot. Once the pressure was released, the bleed valve was opened, and the paint below the paint valve was forced back into the paint pot using the pipette bulb. The paint pot was removed, and the paint drawtube was allowed to drip into the pot. One of the collection bottles was used to capture any additional paint lost from the paint drawtube. The paint pot was sent to the laboratory for weight measurement, removal of the spent coating, and addition of the fresh coating. The paint pot was reweighed and sent back to the factory floor for reconnection. The pipette bulb was used to draw the freshly prepared paint into the paint line, through the bleed valve, and into the second collection bottle. The bleed valve was then closed. The pressure relief valve that was opened to allow weighing of the paint must be closed again to repressurize the paint pot before painting can continue.

3.3.2 Test Sampling Operations at CTC

Standard test panels were used in this project, and each panel was stamped with a unique alphanumeric identifier. The experimental design used 120 samples for the TE test (5 runs with 3 racks per run and 8 panels per rack).

The laboratory analyst recorded the date and time of each run and the time at which each measurement was taken. Upon removing processed panels from the racks, they were stacked, each being separated by a layer of packing material, and transported to the laboratory.

3.3.3 Sample Handling and QA/QC Procedures

Prior to performing the required analyses, the laboratory analyst logged panels, giving each a unique laboratory identification (ID) number. The analyst that delivered the test panels to the laboratory completed a custody log that indicated the sampling point IDs, sample material IDs, quantity of samples, time and date of testing, and the analyst's initials. The product evaluation tests also were noted on the custody log, and the laboratory's sample custodian verified this information. The analyst and the sample custodian both signed the custody log, indicating the transfer of the samples from the processing area to the laboratory analysis area. The laboratory sample custodian logged the test panels into a bound record book; stored the test panels under the appropriate conditions (ambient room temperature and humidity); and created a work order to initiate testing. Testing began within 24 hours of coating application.

Other analytical measurements were performed on pretreatment solutions at the Organic Finishing Line. In such instances, the laboratory analyst titrated the solutions to ensure that chemical concentrations were within the specified ranges. Upon completing the titration, the analyst recorded the data in the Zinc Phosphate Process Log. The log was reviewed and initialed by a member of laboratory management. Where necessary, chemicals were added to the solutions to maintain proper concentrations. After the panels were pretreated, one random panel per run was taken to the laboratory for weight analysis of the zinc phosphate coating and log-in commenced as was previously mentioned.

The test coating components were mixed in the laboratory where samples were removed from the pressure pot. The temperature, viscosity, density, VOC content, and percent solids analyses were performed. Data were logged on bench data sheets, precision and accuracy data were evaluated, and results were recorded on the ETV CCEP QA/QC Data forms. Another member of the laboratory staff reviewed the data sheets for QA.

Each apparatus used to assess the quality of a coating on a test panel is set up and maintained according to the manufacturer's instructions, and/or the appropriate reference methods. Actual sample analysis was performed only after setup was verified per the appropriate instructions. As available, samples of known materials, with established product quality, were used to verify that a system was working properly.

3.4 Data Reporting, Reduction, and Verification Steps

3.4.1 Data Reporting

Raw data were generated and collected manually and electronically by the analysts at the bench and/or process level. Process data were recorded on process log sheets during factory operations. The recorded data included original observations, printouts, and readouts from equipment for sample, standard, and reference QC analyses. The analyst processed raw data, and was responsible for reviewing the data according to specified precision, accuracy, and completeness policies. Raw data bench sheets, calculations, and data summary sheets for each sample batch were kept together.

3.4.2 Data Reduction and Verification

A preliminary data package was assembled by the primary analyst(s). The data package was reviewed by a different analyst to ensure that tracking, sample treatment, and calculations were correct. A preliminary data report was prepared and submitted to the Laboratory Manager, who then reviewed all final results for adequacy to project QA objectives. After the EPA reviewed the results and conclusions from the Technical Project Manager, the Verification Statement/Verification Report was written, sent to the vendor for comment, passed through technical peer review, and submitted to EPA for approval. The Verification Statement was disseminated only after agreement by the vendor.

Section 4
Reference Data

4.1 Coating Reference Panel

The reference panel for the test coating was supplied by Deft, the coating manufacturer. DEFT applied the 03GY292 aerospace polyurethane to the reference panel using CAS equipment. The panel shows what characteristics Deft intended the coating finish to have. Deft coated a 30.5 cm x 30.5 cm (12 in. x 12 in.) flat aluminum sheet as the reference panel. The DFT was checked at nine points on the panel, and the average DFT was found to be 1.5 mils, which was below what Deft recommended for this coating. The gloss was checked at three points on the panel, and the average gloss was found to be 1.6 gloss units, on a scale of 0–100. Finally, the reference panel was sent to ACT Laboratories, Inc. for DOI analysis. DOI was found to be 1 DOI unit, on a scale of 0 to 100. The reference panel is the finish quality benchmark for the DeVilbiss JGHV panels.

4.2 CAS Parameter Development

Three pressure-feed CAS guns were used to establish a TE baseline. The operating parameters were developed from gun manufacturers' literature and through experimental trials conducted by ETV CCEP personnel. The manufacturers' literature was used to determine the spray gun components appropriate for the Deft 03GY292 test coating and also served as a starting point for determining the input air pressure required to atomize the coating.

Each of the CAS guns was set up in the same apparatus as the DeVilbiss JGHV. The paint pot pressure was set so that the fluid flow rate was approximately the same as the flow rate used during the DeVilbiss JGHV test. The guns were set at 25.4 cm (10 in.) from the panel surface, compared to 20.3 cm (8 in.) for the DeVilbiss JGHV. This increase in distance-to-target is consistent with normal production operating conditions, in which it is recommended that the HVLP spray guns be held closer to the product. The fluid and fan adjustments, along with the input air pressure, were set to produce fan patterns that were very similar to the DeVilbiss JGHV conditions.

The CAS fan patterns were similar in visual appearance to the DeVilbiss JGHV fan pattern in terms of size, particle distribution, and atomization effects. Several three-panel sets were coated using the same pattern (2 coats, 4 passes per coat), vertical drop [10.2 cm (4 in.)], and flash times (20 minutes), as the DeVilbiss JGHV test, except that the CAS guns applied both coats at the same speed. Each three-panel set was coated using different horizontal gun speeds. The trial-and-error method was used to achieve a dry film thickness comparable to the DeVilbiss JGHV test. The panel sets were allowed to air-dry for at least 12 hours. After they were cured, the average DFT of each set of panels was determined. If none of the average DFTs for the panel sets were within the target range, the range of application speeds was adjusted and additional sets of panels were coated. This process was repeated until a speed was identified that provided a DFT similar to that obtained from the DeVilbiss JGHV test. Once the appropriate speed was identified, that speed was entered into the CAS TQAPP and used for the baseline test. The operating parameters for each of the three CAS guns were determined in the same manner. Table 3 lists the configuration and setup conditions for each of the three CAS guns.

Table 3. CAS Gun Configuration and Setup

	CAS Gun #1	CAS Gun #2	CAS Gun #3
Air Cap	Medium – high solids	Pressure-feed	High solids
Fluid Tip (mm)	1.3	1.2	1.4
Fluid Needle (mm)	1.3	1.2	1.4
Fluid Adjustment	Full open	Full open	Full open
Fan Adjustment	2 turns out	2 turns out	1-¼ turns out
Distance to Target (cm)	25.4	25.4	25.4
Horizontal Gun Speed (cm/s)	55.9	49.5	53.3
Average Dynamic Input Air Pressure (psig)	72	54	63

4.3 CAS Results

The finish quality data in Table 4 show the operational characteristics obtained for each of the three CAS guns. The data indicate that the TE was maximized, but not at the expense of finish quality. Therefore, the comparison of the TE data from the CAS baseline and the DeVilbiss JGHV is valid. Table 4 lists the test results for the three CAS baseline guns.

Table 4. CAS Baseline Response Factor Results

	CAS Gun #1	CAS Gun #2	CAS Gun #3
Average Paint Flow Rate (g/s)	5.2	5.2	5.3
Average Total Paint Flow (g)	502	498	488
Average DFT (mil)	1.6	2.0	1.8
Average Gloss (units)	2.4	3.0	3.1
Average Absolute TE (%)	16.8	19.3	17.9
Average Applied TE (%)	43.4	47.8	45.5

Section 5
Results and Discussion

This section presents an overview of the verification test results, including an analysis of environmental benefits of the DeVilbiss JGHV HVLP spray gun and a summary of data quality. HVLP data generated during this test are being compared to CAS baseline data to establish the relative environmental benefit of the product, and to data obtained from the coating manufacturer's reference panel to determine the acceptability of the applied coating's finish quality. An explanation of the manner in which the data were compared is provided. Subsequently, the actual tabulation, assessment, and evaluation of the data are presented. The accuracy, precision, and completeness data, the process and laboratory bench sheets, the raw data tables, and calculated data tables are included in Section 5 of the DeVilbiss JGHV-531-46FF Data Notebook.

5.1 Potential Environmental Benefits and Vendor Claims

The primary purpose of this test is to verify that the DeVilbiss JGHV HVLP spray gun operates at HVLP conditions (≤10 psig output pressure) with high finish quality. ITW Industrial Finishing, Binks·DeVilbiss makes no claims on the absolute TE obtainable by the DeVilbiss JGHV. ITW Industrial Finishing, Binks·DeVilbiss has stated that use of HVLP equipment results in improvement in TE when compared to CAS guns, while maintaining finish quality and productivity. ITW Industrial Finishing, Binks·DeVilbiss proposes that the finish quality provided by the DeVilbiss JGHV is similar to, or better than, the reference panel prepared by the coating supplier using CAS equipment. The secondary purpose of this verification study was to confirm that HVLP spray guns are capable of improving TE over CAS guns, thereby reducing VOC and HAP emissions, while providing an acceptable finish.

5.2 Selection of Test Methods and Parameters Monitored

CTC, the ETV CCEP partner organization, performed most of the laboratory testing required for this verification test. *CTC* possesses the skills, experience, and most of the laboratory equipment required by this verification study. The ETV CCEP selected test procedures, process conditions, and parameters to be monitored based on their correlation to, or impact on, TE or finish quality.

5.2.1 Process Conditions Monitored

The conditions listed below were documented to ensure that there were no significant fluctuations in conditions during the HVLP verification test and the CAS baseline tests. No significant differences were recorded. A more detailed discussion of the data is presented in Section 3 of the DeVilbiss JGHV-531-46FF Data Notebook.

- Factory relative humidity ranged from 9.7 to 18.6 %
- Spray booth relative humidity ranged from 9.6 to 18.4 %
- Factory temperature ranged from 21.2 to 23.0 °C
- Spray booth temperature ranged from 21.1 to 23.0 °C
- Spray booth air velocity ranged from 0.3 to 0.5 m/s
- Panel temperature ranged from 21.1 to 22.8 °C
- Zinc phosphate weight ranged from 2.3 to 3.0 g/m^2

5.2.2 Operational Parameters

A number of operational parameters were also monitored because they often vary from gun to gun. These parameters were documented to explain TE and finish quality improvements over CAS guns, and to identify parameters that are likely to change when replacing CAS guns with HVLP spray guns. The dynamic input air pressures varied from gun to gun. The DeVilbiss JGHV was operated at approximately 70 psig and the CAS baseline guns averaged 62 psig. Also, the recommended distance to target is different for the two types of spray guns, such that the DeVilbiss JGHV was operated at 20.3 cm from the panel surface, and all three CAS guns were operated at 25.4 cm from the panel surface. A more detailed discussion of the data is presented in Section 3 of the DeVilbiss JGHV-531-46FF Data Notebook.

5.2.3 Parameters/Conditions Monitored

Other parameters and conditions were monitored to ensure that they remained relatively constant throughout HVLP verification testing and CAS baseline testing. Constancy was desired in order to reduce the number of factors that could significantly influence TE calculations and evaluation of finish quality. Most of these parameters were relatively constant within each test and from gun to gun. Although the traverse speeds were constant for each test, the speed varied from gun to gun in order to obtain the desired DFT. The DeVilbiss JGHV was operated at 98.6 cm/s while the gun was in front of the panels for the first coat and 48.7 cm/s while the gun was in front of the panels for the second coat. The CAS baseline guns were operated at an average speed of 52.9 cm/s while the gun was in front of the panels for both coats. A more detailed discussion of the CAS setup data is presented in Table 3 of this report and in Section 3 of the DeVilbiss JGHV-531-46FF Data Notebook.

5.3 Overall Performance Evaluation of HVLP

The DFT, gloss, and DOI obtained using the DeVilbiss JGHV are comparable to the finish quality of the reference panel provided by the coating manufacturer. Therefore, it was determined that the DeVilbiss JGHV was able to meet the finish quality requirements of the test coating, and that the TE values obtained for the DeVilbiss JGHV test are representative of the actual operation of the equipment. The DFT and gloss of the CAS baseline panels are considered to be representative of the actual operation of the equipment, and the TE values obtained from the CAS baseline are determined to be representative of the CAS guns tested. The DFT and gloss values obtained for the CAS baseline are similar to those for the panels from the DeVilbiss JGHV test; therefore, the comparison of the TE data from the DeVilbiss JGHV and the CAS baseline is valid.

The test results indicate that the DeVilbiss JGHV was able to provide an environmental benefit over a CAS baseline, while maintaining the required finish quality of the applied coating.

5.3.1 Response Factors

Responses to the process conditions and parameters were considered to be important due to their effect on, or ability to evaluate, TE and finish quality; therefore, these responses were documented, and the appropriate tests required to identify these characteristics were performed. Any response that was characterized using laboratory equipment followed accepted industrial and ASTM standards. Table 5 presents the average results for the response factors. A more detailed discussion of the data is presented in Section 3 of the DeVilbiss JGHV-531-46FF Data Notebook.

Table 5. DeVilbiss JGHV HVLP Response Factor Results

	Reference Panel	**DeVilbiss JGHV**	**CAS Baseline Average**
Average Output Pressure (psig)	N/A	8	N/A
Average Paint Flow Rate (g/s)*	N/A	5.2	5.2
Average Total Paint Flow (g)	N/A	426	496
Average DFT (mil)	1.5	1.8	1.8
Average DOI (units)	1	2	N/A
Average Gloss (units)	1.6	2.8	2.9
Average Absolute TE (%)	N/A	21.4	18.0
Average Applied TE (%)	N/A	62.9	45.6

***Based on the ABB K2 mass flow meter data.**
N/A - Not Available.

The average DFT for each test met the coating manufacturer's recommended target range. Although the average DFT varied between the HVLP and each of the CAS guns, no corresponding variation in the associated TE was shown in the verification tests. If a direct correlation between these parameters does exist, detailed testing is required to establish that correlation, an activity that is beyond the scope of this project. It should be noted that a low DFT bias was found to exist at one location on the reference panel, the DeVilbiss JGHV panels, and the CAS baseline panels. The consistently low DFT reading at the bottom of the panels may be caused by increased air velocity at the bottom of the racks or a process condition related to the spray pattern overlap. The low bias at the bottom of the panels was consistent for all panels.

The lower gloss and DOI readings for the reference panel may be a function of the lower DFT. All values for gloss were below the maximum 9-gloss unit level established for military purposes. Even though the gloss and DOI obtained from the DeVilbiss JGHV test are higher than the results of the reference panel, the coating finish is well within acceptable limits for its intended purpose.

The absolute TE for each gun is a representation of the exact verification test conditions, which includes the paint that was sprayed while the guns were between the panels and outside the boundaries of the racks. The calculation of the absolute TE uses the total amount of paint sprayed and the weight gain of the coated panels, both determined through gravimetric weight measurements. The relative improvement of the absolute TE was calculated as 18.9% over the CAS baseline.

The applied TE for each gun is a normalization of the verification test conditions. The applied TE includes only that amount of coating that was sprayed while each gun was directly in front of any portion of a standard test panel. Applied TE adjusts the absolute TE by removing the amount of coating sprayed while the gun was in front of the dead space between the panels or outside the racks. The applied TE represents what would be expected if the eight panels on a rack were one contiguous, 81.3 cm x 30.5 cm panel. The relative improvement of the applied TE was calculated as 37.9% over the CAS baseline.

5.3.2 Assessment of Laboratory Data Quality

The DeVilbiss JGHV TE results were compared to the CAS baseline data. The DeVilbiss JGHV results for DFT, DOI, and gloss were compared to the paint manufacturer's (Deft) reference panel. The information gathered was considered to be statistically valid and significant such that the advantages and limitations of HVLP, per these test conditions, could be identified with a high degree of confidence. It can be stated with greater than 95% confidence that the DeVilbiss JGHV provided a higher TE than the CAS baseline.

5.4 Technology Data Quality Assessment

Accuracy, precision, and completeness goals were established for each process parameter and condition of interest, as well as each test method used. The goals are outlined in the TQAPP.

All laboratory analyses and monitored process conditions/parameters met the accuracy, precision, and completeness requirements specified in the TQAPP, except for the deviations listed in Section 2 of the DeVilbiss JGHV-531-46FF Data Notebook. The definition of accuracy, precision, and completeness, as well as the methodology used to maintain the limits placed on each in the TQAPP, are presented below. The actual accuracy, precision, and completeness values, where applicable, are presented in Section 5 of the DeVilbiss JGHV-531-46FF Data Notebook.

5.4.1 Accuracy, Precision, and Completeness

Accuracy is defined as exactness of a measurement; i.e., the degree to which a measured value corresponds with that of the actual value. To ensure that measurements were accurate, standard reference materials, traceable to the National Institute of Standards and Technology (NIST), were used for instrument calibration and periodic calibration verification. Accuracy results are located in Table 31 of the DeVilbiss JGHV-531-46FF Data Notebook.

Precision is defined as the agreement of two or more measurements that have been performed in exactly the same manner. Ensuring that measurements are performed with precision is an important aspect of verification testing. The exact number of test panels coated is identified in the TQAPP, and the analysis of replicate test panels for each coating property at each of the experimental conditions occurred by design. All precision data are listed in Tables 33, 34, 35, and 36 of the DeVilbiss JGHV-531-46FF Data Notebook.

Completeness is defined as the number of valid determinations and expressed as a percentage of the total number of analyses conducted, by analysis type. *CTC*'s laboratory strives for at least 90% completeness. Completeness is ensured by evaluating precision and accuracy data during analysis. All laboratory results for finish quality were 100% complete. Testing of the coating for percent solids gave 90% completeness. The TE for Run #2 of the DeVilbiss JGHV was flagged because it is based on a single analysis for percent solids rather than duplicate analysis. The result is usable and close to the average TE result. All results were reviewed and considered usable for statistical analysis. Completeness results are located in Table 32 of the DeVilbiss JGHV-531-46FF Data Notebook.

5.4.2 Audits

Prior to any comparison studies, a portion of the data generated during HVLP and CAS baseline testing was audited for quality by *CTC*, the EPA ETV CCEP QA Manager, and the EPA contractors, *ARCADIS Geraghty and Miller* and Research Triangle Institute (RTI).

CTC conducted internal technical systems audits (TSAs) of both the DeVilbiss JGHV test and the CAS baseline tests. The EPA, with their contractor, *ARCADIS Geraghty and Miller*, performed a TSA and a performance evaluation audit (PEA) of the DeVilbiss JGHV test. The EPA, with their contractor, RTI, performed TSAs and PEAs of the CAS baseline tests.

The TSAs verified that *CTC* personnel were adequately trained and prepared to perform their assigned duties, and that routine procedures were adequately documented. EPA auditors examined copies of test data sheets that recorded information such as process conditions, spray booth conditions, equipment setup, and coating preparation. Auditors also reviewed laboratory bench sheets showing data for coating pretreatment weights, densities, and percent nonvolatile matter.

The EPA audits found that the HVLP spray gun testing and CAS gun baseline testing were conducted in a manner that provides data that support this Verification Statement/Report. Several deviations from the original TQAPP were identified by the EPA audit and are discussed in Section 2 of the DeVilbiss JGHV-531-46FF Data Notebook.

Section 6
Vendor Forum

[ITW Industrial Finishing, Binks·DeVilbiss has been offered the opportunity to comment on the findings of this report. Their comments are presented in this section of the report and reflect their opinions. *CTC* and EPA do not necessarily agree or disagree with the vendor's comments and opinions.]

An evaluation of TE without considering the finish quality of the applied coating provides little value to the equipment manufacturer or the end user. TE is a function of many parameters, including the coating being tested. In many cases, the finish quality of the applied coating must meet tough requirements so that the products are appealing to the consumers.

The TE tests used in this program were chosen because they were the only known tests on record traceable to any standards in the U.S., not necessarily the best way to test for an exact TE. To participate in this program, we agreed for testing to be conducted to these known standards.

We were given the opportunity, within parameters, to choose any industrial coating for this program. We had the option of choosing a simpler industrial coating just to drive up TE percentages. ITW Industrial Finishing, Binks·DeVilbiss choose a very difficult material to apply which required us to meet rigid military and aerospace specifications to display the versatility of the Maximum Performer HLVP spray gun – JGHV-531-46FF. TE percentages could easily have been driven higher into the 65-70% range by changing gun speed, distance, and atomization at the cap. We chose to prove that industrial production quality could be achieved at a normal production speed resulting in a TE percentage much greater than CAS, while providing excellent finish quality. This has been accomplished, meeting the objectives of this testing.

The reader should consider the fact that these tests were performed automatically with a manual HVLP spray gun, and that the same front end of the gun can be obtained in our Mid-Size HVLP (MSV manual), Ergonomic HVLP (MAX manual), and our automatic HVLP (AGXV) spray guns with the same results.

Be aware that 50 psig inlet pressure is normally required to operate this gun, not 70 psig as used in this test. A pressure of 70 psig was required because of restrictions in the established air piping located at the *CTC* facility. These restrictions require 70 psig through the restrictions to get to our recommended 8 psig atomization at the cap for this test. These restrictions are not normally present in an industrial manufacturer's paint facility

There is a more precise method to measure TE. However, it is not traceable to any recognized standard. Information as to how to conduct these tests is available by contacting ITW Industrial Finishing, Binks·DeVilbiss.

Section 7
References

1. Curran, T., et al., National Air Quality and Emissions Trends Report, 1990, EPA-450/4-91-023, NTIS PB92-141555, U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina, November 1991.

2. Clean Air Act Amendments of 1990, Title III - Hazardous Air Pollutants, November 15, 1990.

3. Clean Air Act Amendments of 1990, Title I - Attainment/Maintenance of National Ambient Air Quality Standards (NAAQS), November 15, 1990.