WASH SOLVENT REUSE IN PAINT PRODUCTION

by

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of materials that, if improperly dealt with, can threaten both public health and the environment. The U.S. Environmental Protection Agency (EPA) is charged by Congress with protecting the Nation's land, air, and water resources. Under a mandate of national environmental laws, the agency strives to formulate and implement actions leading to a compatible balance between human activities and the ability of natural systems to support and nurture life. These laws direct the EPA to perform research to define our environmental problems, measure the impacts, and search for solutions.

The Risk Reduction Engineering Laboratory is responsible for planning, implementing, and managing research, development, and demonstration programs to provide an authoritative, defensible engineering basis in support of the policies, programs, and regulations of the EPA with respect to drinking water, wastewater, pesticides, toxic substances, solid and hazardous wastes, Superfund-related activities, and pollution prevention. This publication is one of the products of that research and provides a vital communication link between the researcher and the user community.

Passage of the Pollution Prevention Act of 1990 marked a significant change in U.S. policies concerning the generation of hazardous and nonhazardous wastes. This bill implements the national objective of pollution prevention by establishing a source reduction program at the EPA and by assisting States in providing information and technical assistance regarding source reduction. In support of the emphasis on pollution prevention, the Clean Technology Demonstration (CTD) program has been designed to identify, evaluate, and/or demonstrate new ideas and technologies that lead to waste reduction. It continues the efforts of the Waste Reduction Innovative Technology Evaluation (WRITE) Program. CTD focuses on evaluating and demonstrating technologies available to a particular industry to minimize pollution at the source. These methods reduce or eliminate transportation, handling, treatment, and disposal of hazardous materials in the environment. The technology evaluation project discussed in this report emphasizes the study and development of methods to reduce waste and prevent pollution.

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ABSTRACT

This study evaluates technology for reducing solvent waste by reusing wash solvent in the manufacture of solvent-borne paint. Solvent used to clean equipment at the end of a production run is stored for use in subsequent batches of the same or compatible formulations. Three areas were considered: product quality, pollution prevention, and economics. The benchmark for the evaluation was solvent-borne alkyd paint manufactured with 100%-new solvent.

The wash-solvent recovery technology as it is practiced at Vanex Color, Inc., Mt. Vernon, Illinois, produces a product that meets company specifications. Nearly 80% of the wash solvent used in equipment cleaning is diverted from the wastestream and used in product formulation. On-site observation, sampling, and laboratory analysis in this study confirm that the physical properties of one batch of an alkyd house paint manufactured with 80%-wash solvent (mineral spirits) were comparable to the physical properties of one batch of the same formulation made with 100%-new solvent. The payback period for this technology was estimated to be about one month, due in part to the low capital and operating costs. Savings are generated by decreased raw material purchases and reduced volume of hazardous solvent waste for disposal.

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SECTION 1

PROJECT DESCRIPTION

This study, conducted by Battelle for the Pollution Prevention Research Branch (PPRB) of the U.S. Environmental Protection Agency, evaluates a technology for reducing solvent waste by reusing wash solvent in the manufacture of paint. Solvent used to clean equipment at the end of a production run is stored for use in the next formulation of the same type of paint.

The Pollution Prevention Research Branch (PPRB) of the U.S. Environmental Protection Agency is evaluating and demonstrating pollution prevention technologies through the Pollution Prevention Clean Technology Demonstration (CTD) Program. The goal is to promote the use of clean technologies that minimize the source of pollution problems in a particular industry. The CTD program is a continuation of efforts of the Process Engineering Section (PES) of PPRB, which directed the efforts of the Waste Reduction Innovative Technology Evaluation (WRITE) Program. The CTD program focuses on the evaluation and demonstration of technologies that can be used within a particular industry to minimize the source of pollution problems.

To assess this candidate technology for reduction of solvent waste in paint manufacture three aspects were evaluated: product quality, pollution prevention, and economics. The technology must produce a quality product and reduce waste or prevent pollution. The economics of the technology must be quantified and compared with the economics of the existing technology. However, reduction of operating costs is not an absolute criterion for the use of the prototype technology. There may be justifications other than saving money that would encourage adoption of new operating approaches.

PROJECT OBJECTIVES

This study evaluates a technology for reducing solvent waste by reusing wash solvent in the manufacture of paint. Solvent used to clean equipment at the end of a production run is stored for use in the next formulation of the same type of paint. This study has the following critical objectives:

- Product Quality: Evaluate the quality of the paint formulated with wash solvent to ensure that product quality has not been compromised.
- Pollution Prevention Potential: Evaluate the amount of solvent diverted from the wastestream by this technology.
- Economics: Evaluate the costs and cost savings of this pollution prevention project.

DESCRIPTION OF THE SITE

The site selected for evaluating this technology was Vanex Color, Inc., located in Mt. Vernon, Illinois. Vanex is a national and international manufacturer of consumer and specialty coatings; its primary market interests are in the U.S. and Europe. Vanex's primary business and production operations are staffed by a 32-member team operating out of a 70,000-ft^2 manufacturing and warehouse facility. Annual coatings production volume is approximately 500,000 gal. Vanex focuses on developing and producing environmentally compatible product lines, including trade sale architectural paints for interior and exterior surfaces and wood finishing products. Because Vanex wishes to concentrate on environmentally safe products, the majority (85 to 90%) of the coatings are based on waterborne technology. However, because some markets continue to rely on solvent-based formulations, Vanex still produces such products. In the production of solvent-based systems, Vanex maintains an environmentally conscious stance by following practices it has developed to reduce the volume of solvent used during manufacture. Wash solvent used to clean production equipment is categorized and saved. The company reuses wash solvents in the production of subsequent batches of solvent-based paint formulations.

Solvent reuse technology is one part of a company-wide pollution prevention program instituted by Vanex to review every wastestream in the office and the production plant with the objective of minimizing waste. Vanex's strategies include source reduction, raw material substitution, reuse and recycling of wash solvents where possible, reduction of packaging wastes, recycling of motor oil from company vehicles, and reuse and recycling of office wastepaper products.

Vanex reports that 80% of all wash solvent generated during solvent-borne paint manufacture is recycled in house, resulting in an annual cost savings of $15,000. Wash solvent that cannot be reused (e.g., solvent used to clean equipment after the production of dark custom colors) is shipped to a fuel blender for use as supplemental fuel in cement kilns.

DESCRIPTION OF THE TECHNOLOGY

Vanex uses a simple tracking and storage system to handle reuse of the wash solvent. Small amounts of solvent are used to clean the batch tanks and the dispensing equipment. This solvent is stored in labeled 55-gal drums for addition back into the same or very similar paint formulations within 90 days.

Only certain coatings are formulated using the stored wash solvents. Product lines selected for the solvent reuse program were primarily those that could be easily formulated to meet final color requirements. When these coatings are being formulated, any available wash solvent that can be used in that particular formulation is blended into the coating formulation during mixing. Fresh solvent is used for the remaining solvent make-up. The percentage of reused solvent varies from batch to batch, depending on the amount of stored solvent available at the time of production and the type of paint being formulated. From 0 to 100% wash solvent may be used.

In the storage area, used solvents are marked as Group 1, Group 2, or Group 3. Mineral spirits is the primary solvent in solvent-borne coatings produced by Vanex and is the only solvent currently used in the cleaning process. Group 1 is mineral spirits wash solvent from white, tint, or pastel paint. Group 2 is mineral spirits wash solvent from clear paint. Group 3 is mineral spirits wash solvent from gray and light-colored paint. Charts posted for the use of batchmen (formulators) and cleanup workers list which wash solvent group can be used in the formulation of which paint. The general principal is that used solvent is added back into the same or very similar formulations. One exception is that of wash solvent from oil-modified urethanes; it can be used in alkyd formulations, resulting in a tougher product. The other exception is that no wash solvent is added to the tint bases or pastels because the titanium dioxide pigment level is critical to later tinting for color matching at the point of sale.

In the past, when Vanex made a variety of colors in the solvent-borne paint and used more than two solvents, the wash solvent from each formulation was stored separately for reuse. All colors but white could be added into black batches. The solvent reuse system currently is used for whites, grays, and clear. Vanex no longer makes enough colored solvent-borne paints such as red, yellows, or black to justify saving the solvent for reuse. Solvents not selected for reuse are collected in drums, stored in a waste storage area, and shipped to a solvent blender who processes and sells the mixed solvent to a cement kiln as a fuel additive.

There is no filtration of the used solvent. During the first 24 hours of storage, pigment settles out of the wash solvent and collects at the bottom of the drum. When the used solvent is poured from the storage drums, care is taken to ensure that none of the sediment (mostly pigments) in the bottom of the drum is added to the formulation. Once the wash solvent has been poured from the drum, the drum is reused as a wash-solvent storage container until the sediment in the bottom of the drum becomes so thick that there is little useable storage space in the drum. At this point, waste solvent for disposal is added to fill the remainder of the drum, and the drum and its contents are shipped for disposal. This waste solvent can be generated by equipment cleanup after color batches other than whites, grays, and clears.

A schematic of the paint manufacturing process is presented in Figure 1. All raw materials are added to the mixing tank and dispersed using a high-speed dispersion blade that is lowered into the tank. After all components of the formulation have been added and properly blended, the product is ready for quality-control testing.

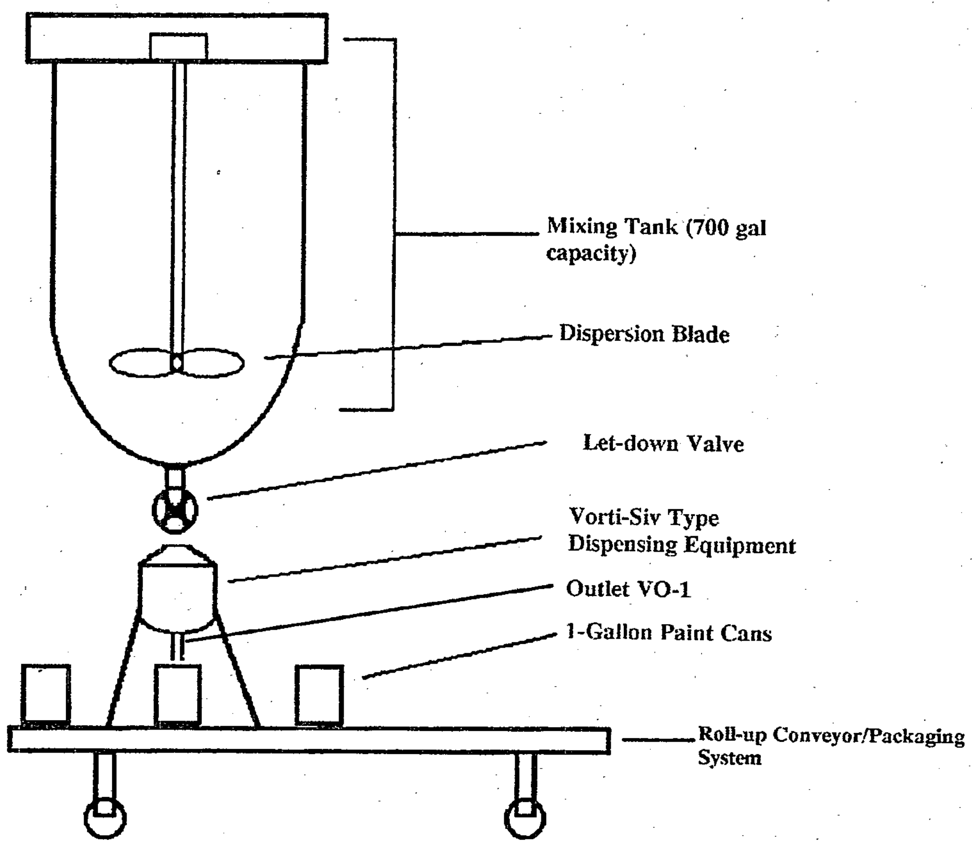

Figure 1. Paint manufacture schematic/packaging system.

Vanex has a small, efficient on-site laboratory for quality assurance testing, problem solving, and development of new formulations needed by customers. After mixing, each batch of paint is tested at 25°C for viscosity, weight per gallon, gloss, color, and linear flow. Test results are used to indicate needed adjustments to bring the paint to company specifications. Batches are held for at least 16 hours before final testing and filling.

SUMMARY OF THE APPROACH

The Quality Assurance Project Plan (QAPP), prepared at the beginning of this study, describes the detailed approach and scientific rationale used to evaluate the reuse of some percentage of wash solvent to formulate paint (Battelle, 1993). The evaluation covered product quality testing, waste reduction estimation, and economic analysis. Table 1 summarizes the critical and noncritical measurements and data collected from company records for this technology assessment.

TABLE 1. SUMMARY OF MEASUREMENTS AND COMPANY HISTORICAL INFORMATION

Objective of Evaluation	Sample Type	Property	Criteria	Critical
Product Quality	Coating samples from new solvent batch and wash-solvent batch	viscosity	measurement*	yes—Battelle
		density	measurement*	yes—Battelle
		grind	measurement*	yes—Battelle
		percent solids	measurement†	yes—Battelle
	wet drawdown test panel	wet color	measurement‡	yes—Vanex
	dry film test panel	color	measurement*	no—Battelle
		gloss	measurement*	yes—Battelle
Pollution Prevention	solvent waste	volume disposed	company records	yes
	solid waste	volume disposed	company records	no
	solvent-based coatings	annual production	company records	no
	solvent purchased	annual usage	company records	yes
Economics	wash-solvent reuse program	capital costs	company records	no
		operating costs	company records	no
		waste disposal costs	company records	no

* Vanex and Battelle measurements.
† Battelle measurement.
‡ Vanex measurement.

Product Quality Evaluation

The objective of the product quality testing is to determine whether or not the use of retained wash solvent to formulate subsequent batches of solvent-based coatings affects the quality of the final product. The paint formulated with wash solvent should meet the product specifications established by Vanex for the same paint formulated with 100%-new solvent. The evaluation was accomplished by running the same series of standard analytical tests on a batch of paint formulated with new solvent and on a batch of paint formulated with 80%-wash solvent. Two batches of a solvent-borne alkyd house paint were prepared at Vanex, under the observation of the Battelle Laboratory Manager conducting this study and sampled for laboratory analysis at Battelle as specified in the QAPP.

Pollution Prevention Potential

The second objective of this evaluation is to show that solvent is diverted from the wastestream by implementation of the solvent reuse program. The pollution prevention potential of this system is based on the reuse of wash solvent that formerly was disposed of. The use of wash solvent in the subsequent formulation of coating products would (1) reduce the amount of wash solvent that must be disposed of as waste and (2) reduce the amount of solvent that must be obtained for use in the paint formulations. Data were collected from company records and interviews with key personnel at Vanex.

Estimation of Economics

The objective of the economic estimation is to determine a payback period or cost reduction associated with the switch to this technology for reducing the solvent wastestream. The economic analysis included assessing the amount of solvent diverted from the wastestream and the cost associated with the disposal of the excess waste solvent if it were not reused in subsequent paint formulations. Data from company records and from interviews with key personnel were the bases for the economic calculations.

SECTION 2

PRODUCT QUALITY EVALUATION

Vanex stores mineral spirits used to clean mixing and dispensing equipment after manufacture of solvent-borne paint and reuses this wash solvent as part or all of the solvent needed in the manufacture of subsequent batches of paint. Wash solvent is separated carefully into groups based on colors and material types that have been identified as compatible. The paint formulated with wash solvent meets the product specifications established by Vanex for the same paint formulated with 100%-new solvent.

Two batches of a proprietary solvent-borne alkyd house paint were prepared at Vanex under the observation of the Battelle Laboratory Project Manager, and samples were taken to be analyzed at Battelle. Batch #46481-7 was formulated with 100 gal new mineral spirits and no wash solvent (0% wash solvent); Batch #46481-4, with 20 gal new mineral spirits and 80 gal wash solvent (80% wash solvent).

Samples of each batch were collected for laboratory analysis. The same series of standard analytical tests was run on both batches. If the measured properties of the batch manufactured with 80%-wash solvent closely match the measured properties of the batch manufactured with 100%-new solvent, the product quality objective will be met.

ON-SITE SAMPLE COLLECTION AND TESTING

Four 2-qt field samples (Table 2) from each coating batch were collected from the Vorti-Siv outlet at point VO-1 (shown in Figure 1). These samples, representative of Vanex's final commercial product, were collected in the retail gallon paint cans that are used to package and ship to the purchaser. For each batch, one sample was collected at the beginning of the dispensing process (4-1 and 7-1), two samples in the middle of the dispensing process (4-2, 4-3, 7-2, and 7-3), and one sample at the end of the process (4-4, and 7-4). Sample size was approximate. Samples were assigned sample ID numbers and labeled as defined in the QAPP.

TABLE 2. SUMMARY TABLE OF FIELD SAMPLES FOR PRODUCT QUALITY ASSESSMENT AND CRITICAL ANALYTICAL MEASUREMENTS

Field Sample Type	Number of Field Samples	Field Sample Number*
Product Quality:		
1) batch formulated with 100%-new solvent	4 (2 qt each)†	7-1 7-2 7-3 7-4
2) batch formulated with 80% wash solvent	4 (2 qt each)†	4-1 4-2 4-3 4-4
3) Wet film sample — side-by-side drawdown of formulation batch with color standard	1 panel for each coating batch evaluated	4 drawdown 7 drawdown

* The 46481- prefix for the Battelle designation for this study is omitted in test references to samples.

† Three 2-qt samples were tested. Samples 4-3 and 7-3 were held in reserve.

Samples were evaluated in the field by Vanex using the test methods listed in Table 3. These are standard tests used in the coatings industry as described in ASTM D2932-80 (reapproved in 1988). Descriptions of the properties and test methods selected for this evaluation were included in the QAPP.

Testing at Vanex was performed by Vanex quality assurance personnel. Vanex performs these tests after the initial formulation and after a 16- to 24-hour holding period prior to dispensing into containers. If adjustments to the formulation are made to bring a parameter into a specified range, the tests are repeated after each adjustment to verify that the quality of the coating meets criteria for packaging and shipping.

The results of the product quality analyses are shown in Table 3. The paint formulated with 80%-wash solvent compared well to the paint formulated with 100%-new solvent. Table 3 contains the Vanex quality-control test results for both batches of coatings. Except for the grind determination, these tests were completed more than 16 hours after formulation and just before paint was dispensed into consumer cans. The paint made with wash solvent required no adjustments to meet the expected ranges. The paint formulated with 100%-new solvent required the addition of 2 gal of mineral spirits to bring the final viscosity from 91 Krebs units to 89 units.

TABLE 3. RESULTS OF QUALITY-CONTROL TESTS FOR PRODUCT QUALITY ASSESSMENT PERFORMED AT VANEX

Property (Units)	Test Method*	Vanex Range†	New-Solvent Batch	Wash-Solvent Batch
Viscosity (Krebs Units)	ASTM D562-81 (reapproved 1990)	88±2	89	89
Density (lb/gal) (g/ml)	ASTM D1475-90	10.36±0.05 (1.24± 0.0)	10.37 (1.24)	10.40 (1.25)
Grind (Hegman Scale)	ASTM D1210-79 (reapproved 1988)	>5	6+	5+
Linear Flow (sag)	ASTM D4400-89a	12	12	12
Color	Visual comparison with stored standard	Match stored standard	yes	yes
Gloss (gloss units)	ASTM D523-89 (60°)	>80	87.1	86.6

* American Society for Testing and Materials, 1992 Annual Book of ASTM Standards, Vol. 06.01, "Paint — Tests for Formulated Products and Applied Coatings".
† Approved range for Vanex #2-1 alkyd housepaint.

According to Vanex personnel, there has been no noticeable increase in the frequency with which adjustments are needed to bring batches manufactured with wash solvent into specifications. The field experience supports this claim in a limited way. The coating batch manufactured with new solvent required one adjustment to bring viscosity into the specified range. The coating batch manufactured with wash solvent required no adjustment.

The "fineness of grind" determination (ASTM 1210) is performed at the end of the pigment dispersion step prior to letdown. For satisfactory pigment dispersions, Vanex wants the grind at this point to be at least a "5" on the Hegman scale. The new solvent batch was rated as a "6+" and the wash-solvent batch, a "5+" on the Hegman scale.

The critical color measurement for the paint batches being evaluated was the visual match of wet color by the Vanex quality-control staff. For each of its product lines, Vanex maintains a stock of sample coatings that are used as color standards. The color of the coating being formulated is checked against these coatings by performing a visual comparison on a wet side-by-side drawdown of the batch and the appropriate color standard. Any color deviations noted are corrected for by additions of small amounts of tint, until a match with the standard is obtained. The Vanex quality-control staff judged the wet color of both batches matched the wet color of the standard without adjustment.

The other quality-control tests performed by Vanex and listed in Table 3 were not selected as "critical measurements" for comparison of the paint batches in this technology evaluation. However, these data for the two batches indicate a close match for the tested parameters. Vanex rated these two batches of alkyd house paint as comparable in quality. The batches were dispensed into cans for shipment to customers.

LABORATORY ANALYSIS AT BATTELLE

Table 4 lists the results of the Battelle laboratory analysis of the field samples collected during the site visit. Raw data for each test are included in the appendix to this report. Quality assurance data are found in Section 5, "Quality Assurance."

TABLE 4. RESULTS OF TESTS FOR PRODUCT QUALITY ASSESSMENT PERFORMED AT BATTELLE

Property (Units)	Test Method*	New Solvent Batch	Wash-Solvent Batch
Viscosity (Centipoises)	ASTM D2196-86 (reapproved 1991)	4000	4000
Density (lb/gal)	ASTM D1475-90	data not valid	data not valid
Grind (Hegman Scale)	ASTM D1210-79 (reapproved 1988)	8	8
Percent Solids (%)	ASTM D2369-90	73.4	73.5
Percent Volatiles (%)	ASTM D2369-90	26.6	26.5
Color (Δ E) CIELAB	ASTM D2244-89	Standard for comparison	0.2
Gloss (gloss units)	ASTM D523-89	79.4	81.6

* American Society for Testing and Materials, 1992 Annual Book of ASTM Standards, Vol. 06.01, "Paint — Tests for Formulated Products and Applied Coatings".

Grind

Grind was assessed using standard equipment and methods outlined in ASTM D1210-79 (reapproved 1988): "Standard Test Method for Fineness of Dispersion of Pigment Vehicle Systems." Macroscopic solid contaminant or poorly dispersed (agglomerated) solids would affect the grind results.

Results for the "fineness of grind" analysis on the final coatings are the same for both the new solvent and wash-solvent batches at 8 Hegman units. Both coatings had a uniform dispersion of particles with no evidence of agglomeration or gross solid particulate contamination. There was no discernible difference in test performance between the paint manufactured with new solvent and the paint manufactured with wash solvent. Battelle results (8 Hegman units) indicate a slightly finer grind than do the Vanex test results (5+ and 6+ Hegman units). However, the tests at Vanex directly followed the pigment dispersion step while Battelle tests were made on the final formulated coating.

Gloss

Gloss measurements were made on dry film on a HunterLab Glossmeter in accordance with ASTM D523-89: "Standard Test for Specular Gloss" and the QAPP. Gloss measurements are a gauge of the appearance of the coating as it is applied to a substrate. The experimental gloss determinations made at Battelle for the two batches are statistically different from each other at the 95%-confidence level based on the nine data points determined for each. Based on ASTM variation allowable at the 95%-confidence level for reproducibility between laboratories, results for gloss could have been 80 $\pm$ 3.5 (76.5 to 83.5) gloss units. Gloss for the wash-solvent batch had a mean of 81.6, meeting Vanex's specification that the gloss of alkyd house paint be greater than 80. Gloss for the batch formulated with 100%-new solvent had a mean of 79.4, or 0.6 of a gloss unit below the Vanex target. Both of these gloss averages fall within the 3.5 gloss units variation allowed at the 95%-confidence level for reproducibility between laboratories.

The critical objective for gloss in this evaluation is that the gloss of the batch formulated with wash solvent should be as good as the gloss of the new-solvent batch. For this paint, Vanex considers a higher gloss more desirable than a gloss lower than 80. In testing at Battelle, the gloss of the wash-solvent batch tested slightly higher than that of the new-solvent batch but not statistically different.

At Vanex the new-solvent batch had a slightly higher gloss than the wash-solvent batch but not statistically different. The variation between the gloss measurements at Vanex and those at Battelle could be attributable to the use of different instruments for gloss measurement in the two laboratories. In both tests, the new-solvent batch and the wash-solvent batch had gloss measurements that met or exceeded Vanex product specifications for this paint formulation.

Density

Density measurements were performed in accordance with ASTM D1475-90: "Standard Test Method for Density of Paint, Varnish, Lacquer, and Related Products." The density of the coating was measured to compare the consistency of the two paint sample batches. Agreement of density measurement can indicate that the solid and liquid components of the coating formulation were added in the correct proportions.

Density data measured at Battelle for the field samples were not considered valid for comparing product quality. A detailed explanation can be found in Section 5, "Quality Assurance," where QA for the data is summarized in Table 9. Data collected for replicates from the same field sample met the requirements for the 95%-confidence limit. However, the means of the density data for multiple field samples of the same sample coating batch did not meet the requirements for the 95%-confidence level. During Vanex quality-control tests, the density determination represented one sample per batch, rather than multiple samples taken at different times from the same batch. There is no background data for comparison. The testing specified in the QAPP for this evaluation was more rigorous than standard industry practice. The determinations of density were inconclusive for meeting the product quality objective.

Percent Solids/Percent Volatiles

Percent solids/percent volatiles was determined according to ASTM D2369-90: "Standard Test Method for Volatile Content of Coatings." The percent-solids (nonvolatile) content was determined by subtracting the percent-volatiles content from 100%. In paint manufacture, this test is used for one check of the solvent level in a paint. It is important for proper viscosity and film formation that the solvent level be consistent. This measurement was used in this evaluation as a basis for determining whether solid contaminant materials are introduced into the formulation when the wash solvent is used.

Determinations were made on replicate samples from three field samples collected for each coatings batch. The test was repeated on two separate days by the same technician. The average percent solids for the coating batch manufactured with new solvent was 26.6%; the percent volatiles, 73.4%. The average percent solids for the coating batch manufactured with wash solvent was 26.5%; the percent volatiles, 73.5%. There is no statistical difference between these batches of coatings based on determination of the percent solids/percent volatiles. Based on percent solids/percent volatiles determination, the use of wash solvent did not affect the solids and volatiles content of the paint formulated.

Viscosity

The measurement of viscosity was performed in accordance with ASTM D2196-86: "Standard Test Method for Rheological Properties of Non-Newtonian Materials by Rotational (Brookfield) Viscometer." Although this is not the viscosity test used routinely at Vanex, it is a widely accepted test method for evaluating viscosity in the coatings industry. Viscosity is a critical property for coatings. The viscosity of the coating impacts the paint application methods and the thickness at which the coating can be applied without running or sagging.

The average viscosity for the new-solvent batch measured 4000 centipoises. For the wash-solvent batch, the average viscosity measured 4000. These viscosities are not statistically different at the 95%-confidence level for this test. Based on the viscosity determination, no difference was found between the coatings batch manufactured with wash solvent and the coatings batch formulated with new solvent.

<u>Color</u>

Battelle performed a "noncritical" instrumental measurement of dry film color in accordance with ASTM D2244-89: "Standard Test Method for Calculation of Color Differences From Instrumentally Measured Color Coordinates." A MacBeth 2000 Color Analyzer was used to provide quantitative background information on color difference. Because Vanex does not use instrumental color analysis routinely, no data are available to establish the range of results for color differences that might be acceptable for this particular alkyd paint from batch to batch. However, in practice, a color difference of less than 0.5 is considered below the limits of detection. A color difference of 1.0 or less is considered a commercial match.

The results of the instrumental analysis are shown in Table 4 as color difference calculated by the CIELAB formula. When the batch manufactured with wash solvent was compared to the batch manufactured with new solvent, the color difference was 0.2. Therefore, the instrumental analysis of color indicated no significant difference in color between the batch made with 100%-new solvent and the batch made with 80%-wash solvent. This agrees with the results of the Vanex wet color determination. This color measurement test was not "critical" to the determination of product quality in this evaluation.

PRODUCT QUALITY ASSESSMENT

The alkyd house paint formulated with 80%-wash solvent meets or exceeds Vanex's specifications for this product in terms of grind, viscosity, linear flow, wet color, and gloss. The product satisfies the quality-control standards at Vanex. Paint manufactured with some percentage of wash solvent has been sold by Vanex for several years with no indication of unsatisfactory appearance or performance in the field.

Results of the critical measurements for the product quality analysis in this evaluation are summarized in Table 5. Data from density determinations are not included because data did not meet all the quality-control objectives. No decrease in quality was evident from the laboratory analysis of the field samples of this alkyd house paint. The batch manufactured with 80%-wash solvent compared very well with the batch manufactured with 100%-new solvent. Although the sampling and analysis were limited to two batches, these samples did represent the extremes of wash-solvent use for this formulation. In other formulations, Vanex has completely replaced the new solvent with wash solvent. However, in the alkyd formulation sampled, 20 gal of new solvent is required to dilute, or cut, the long oil alkyd for better mixing. If wash solvent is used for the cutting, the long oil alkyd is sometimes agglomerated and will not disperse in the paint-mixing process.

TABLE 5. SUMMARY OF PRODUCT QUALITY COMPARING ALKYD HOUSE PAINT MANUFACTURED WITH 100%-NEW SOLVENT TO ALKYD HOUSE PAINT MANUFACTURED WITH 80%-WASH SOLVENT

Property	Wash-solvent Batch Compared with New-solvent batch is ...
Viscosity	not significantly different
Grind	the same
Percent solids/percent volatiles	not significantly different
Wet Color	the same
Gloss	not significantly different
Density	inconclusive

Although the sample size (two batches) was limited, the quality-control tests at Vanex and the laboratory analysis at Battelle indicate that the quality of this solvent-borne alkyd house paint made with wash solvent is comparable to the product quality of the same paint made with 100%-new solvent. These results compare well with the experience that Vanex has accumulated during several years use of this wash-solvent recovery system.

SECTION 3

POLLUTION PREVENTION POTENTIAL

The pollution prevention potential of this system is based on the reuse of wash solvent that formerly was disposed of. The use of wash solvent in the subsequent formulation of coating products would (1) reduce the amount of wash solvent that must be disposed of as waste and (2) reduce the amount of solvent that must be purchased for use in the paint formulations. Interim storage for reuse must not contribute to pollution. Information from company records and from interviews with key staff was gathered to determine the volume of mineral spirits diverted from the wastestream by implementation of the reuse program at Vanex.

WASTE VOLUME REDUCTION

A major source of solvent waste in the manufacture of solvent-borne paint is the solvent required to clean the mixing and dispensing equipment between batches. Employees at Vanex make a conscious effort to minimize the amount of solvent required for cleaning by techniques such as scraping the mix tanks to remove many paint solids before solvent cleaning. Workers minimize cleanup of work areas and equipment by taking care when adding raw materials and dispensing finished batches. When possible, they arrange production schedules so that similar batches of paint are mixed and dispensed one after another to eliminate cleanup between batches.

From 15 to 20 gal of solvent are required to clean equipment between batches. This wash solvent is labeled and stored in 55-gal drums for addition back into the same or very similar paint formulations within 90 days. At Vanex, 80% of the wash solvent is reused in paint formulation. Wash solvent that cannot be reused is shipped to a fuel blender for use as supplemental fuel in cement kilns. (Note: Depending on the formulations involved, other operations could reuse more than 80% of their wash solvent.)

Calculations based on 1992 production figures and background information collected during the two site visits to Vanex (Table 6) demonstrate two areas of waste reduction potential of this technology as it is practiced at Vanex for manufacture of solvent-borne paints:

- Solvent waste for disposal was reduced from 75 drums to 15 drums.
- Volume of mineral spirits purchased for paint manufacture was reduced by nearly 16%.

TABLE 6. ANNUAL WASTE REDUCTION THROUGH WASH-SOLVENT REUSE PROGRAM AT VANEX COLOR, INC.

<u>Vanex Production Data</u>:	
Production in 1992 of solvent-borne paints:	82,500 gal (312,000 L)
Average batch size	400 gal (1,500 L)
Estimated number of batches/year:	206 batches
Quantity of mineral spirits used to clean tanks and equipment between batches:	20 gal (75 L)
<u>Wash Solvent Calculations</u>:	
Without Reuse	
Solvent required for cleanup only (206 batches X 20 gal/batch)	4,120 gal (15,600 L)
Wash solvent disposed	4,120 gal (15,600 L)
With Reuse	
Solvent required for cleaning only (206 batches X 20 gal/batch)	4,120 gal (15,600 L)
Solvent reused for formulation (80% X 4,120 gal)	3,300 gal (12,500 L)
Wash solvent disposed	820 gal (3,100 L)
Waste Reduction	**3,300 gal (12,500 L)**

It should be noted that the 15-drum figure for waste disposal does not include solid waste from tank scrapings or disposal of off-specification paints. The volume of these wastes is not affected by the solvent reuse system. Also, the ratio of 100 gal mineral spirits per 400 gal solvent-borne paint produced is based on the formulation of the alkyd house paint tested in this evaluation. Vanex makes other proprietary solvent-borne formulations that could have slightly higher or lower mineral spirits content. The percentage of mineral spirits in other solvent-borne formulations and the production volume of each type is proprietary.

WASTE REDUCTION ASSESSMENT

Vanex uses a simple storage and tracking system to divert 3,300 gal of mineral spirits (60 drums per year) from the wastestream to product formulation. This represented an 80% reduction in mineral spirits disposed of as waste in 1992. This reduction occurred with little change to the paint production process at Vanex. The volume diverted from the wastestream could vary from year to year, depending on the product mix and the annual production. However, this low-tech system has produced an appreciable reduction in solvent waste at Vanex.

POLLUTION PREVENTION IMPACT

Interim storage of wash solvent for reuse at Vanex does not create an additional source of pollution. Wash solvent is stored in closed barrels in the same way that waste solvent is stored to await disposal. The maximum storage on site for any waste is 90 days. Wash-solvent recovery storage drums are dated; solvent that is not reused for paint manufacture in less than 90 days is disposed of as waste solvent with the normal waste pickup. Vanex plans production schedules so as to avoid disposal of any reusable wash solvent. Waste solvent from the manufacture of solvent-based paint at Vanex is hazardous waste because of its flash point. All paint-manufacturing waste is handled and disposed of by Vanex in accordance with the applicable local, state, and federal regulations. The wash-solvent recovery system does not generate any additional waste at Vanex.

SECTION 4

ECONOMIC EVALUATION

The objective of the economic estimation is to calculate a payback period and/or cost reduction associated with implementation of this technology for reducing the solvent wastestream. Economic estimations for evaluating the technology are based on capital and operating costs.

CAPITAL COSTS FOR WASH-SOLVENT REUSE SYSTEM

The wash-solvent reuse system used by Vanex did not have significant capital costs. No equipment was purchased, no additional storage area was needed, and no additional energy- or air-supply systems were required. Total expenditure to implement the system is estimated by Vanex personnel to be less than $1,000 for both materials and labor.

The Vanex technical staff put together the master list of wash solvents and paints that could be formulated with the wash solvents, based on the chemistry of the polymers, the color of the pigments, and the gloss required in the paint being mixed. Initially, wash solvents stored for reuse were assigned to one of six mixing groups called solvent-recovery groups. A copy of the master list was posted on a clipboard for ready access in the storage area. The solvent-recovery groups now are down to three due to decreased production of solvent-borne paint at Vanex.

A storage area was marked off with paint stripes on the floor to create sections for each designated wash-solvent group. Fifty-five-gal drums that had held purchased raw materials were cleaned and labeled for holding stored solvent. Periodically, as the solids build up in the bottom of a storage drum, the drum is used for disposal of waste solvent and a replacement drum is labeled for holding and storage of useable wash solvent. Labeling of the drums and storage area was accomplished by the regular maintenance staff. Therefore, capital costs for implementation of the wash-solvent reuse system at Vanex were negligible.

OPERATING COSTS

The major operating costs associated with the wash-solvent reuse system are given below (Table 7). Vanex has seen no change in labor costs for paint formulation. Labor costs are the same whether wash solvent is disposed of or stored for reuse. The wash solvent must be collected in drums in both cases. Labor for adding the wash solvent to the paint formulation is not a significant added cost to the mixing operation. At Vanex, addition of raw materials to the mix tank is partly by hand from drums or bags. New solvent is available by pump from bulk storage tanks, but Vanex employees report that addition of one or more drums of stored wash solvent is not time-consuming. No additional electricity is required. Drums are lifted to the raised mixing platform by forklift along with other raw materials such as bags of dried pigment.

TABLE 7. CAPITAL AND OPERATING COSTS ANALYSIS FOR SOLVENT REUSE AT VANEX

Vanex's Capital Cost: $1,000

Total estimated costs for labor and signage materials

Comparison of Vanex's Operating Costs*

	Cost Item	Annual Amount	Unit Cost	Annual Cost
Without Solvent Reuse	Solvent for cleaning only	4,120 gal	$0.79/gal	$ 3,250
	Solvent waste disposal	75 drums†	$150/drum	$11,250
	Total Without Reuse			$14,500
With 80% Solvent Reuse	Solvent not reused	820 gal	$0.79/gal	$ 650
	Solvent waste disposal	15 drums†	$150/drum	$ 2,250
	Total With Reuse			$ 2,900
	Annual savings with reuse of 80% of wash solvent:			**$11,600**

* Electricity, maintenance, labor are the same for both cases.
† Fifty-five-gal drums.

ECONOMIC CALCULATIONS

A simple payback period calculation for this technology evaluation can be performed with the capital and operating costs. The cost savings in this system come from the reduction of disposal charges and the reduction of solvent purchases.

$$\text{Payback} = \frac{\text{capital costs}}{\text{savings in annual operating costs}}$$

Capital costs at Vanex, including materials and labor, to implement the wash-solvent recovery system were less than $1,000.

Total operating savings are $11,600; this includes savings on both waste disposal and raw material purchases based on 1992 figures. Operating costs are affected also by reducing the volume of new solvent purchased. Because solvent prices fluctuate with the market and the volume purchased, these savings vary somewhat.

Disposal for hazardous waste in drums costs about $150/drum, or $11,250 for disposal of the 75 drums of wash solvent annually if no solvent is reused. Cost for disposing of the 15 drums after implementation is $2,250 for an annual savings of $9,000. Waste disposal costs differ geographically and probably will continue to rise.

The recovery of 3,300 gal of wash solvent for use in paint manufacture reduces solvent raw material purchase by that amount. Based on a cost of $.79 per gal for mineral spirits, this represents a savings of about $2,600.

ECONOMIC ASSESSMENT

The payback period for implementation of the wash-solvent recovery system at Vanex was approximately one month. Savings for other companies instituting similar systems will vary with production volumes and the volume of wash solvent recovered from the wastestream.

$$\text{Payback} = \frac{\$1,000}{\$11,600}$$

$$\text{Payback} \simeq \text{one month}$$

SECTION 5

QUALITY ASSURANCE

A Quality Assurance Project Plan (Battelle, 1993) was prepared and approved by the EPA before testing began. This plan outlined a detailed design for conducting this technology evaluation, including parameters for field sampling, laboratory analysis, and data reduction. The quality assurance objectives included in this QAPP are discussed below.

FIELD SAMPLING

Two batches of a solvent-borne paint were manufactured at Vanex under the observation of the Battelle Laboratory Project Manager as detailed in the QAPP. The formulation was the same for both batches, but one was made with 100%-new solvent (mineral spirits) and the other with 80%-wash solvent.

Field samples were collected during the regular dispensing step in accordance with the QAPP. All samples were collected in a manner that would make them representative of the coatings batch being manufactured. Samples were taken at different times during the letdown of the coatings to increase the random nature of the sampling. The laboratory manager labeled, sealed, and documented each sample description and sample identification number.

Representativeness is the degree to which a sample or group of samples is indicative of the population being studied. Representativeness normally is achieved by collecting a sufficiently large number of unbiased samples. The field samples collected in this technology evaluation comprise a small sample of the range of products manufactured by Vanex using some percentage of wash solvent in place of new solvent. The ratio of wash solvent to new solvent varies in production from one batch to the next. The conclusions about product quality in this evaluation have been confined to conclusions that can be drawn from this limited sample. However, the two coatings batches manufactured for this evaluation represent the extremes of wash solvent use for this alkyd house paint

— one batch had no wash solvent and the other had the maximum 80%-wash solvent. If differences in quality are detectable, the comparison of these two sample batches should reveal them.

Two deviations from the planned field sampling procedure occurred and were approved by the Battelle Study Leader. First, field samples were collected in the 1-gal consumer paint cans regularly used by Vanex rather than in the sampling containers specified in the QAPP. This change allowed sampling to be less intrusive in the dispensing operation and helped meet safety precautions for shipping. Second, samples of approximately 2 qt each were collected, instead of the 1-L samples planned in the QAPP. The planned quality-control tests were performed by Vanex staff, and both batches of paint met Vanex's specifications for this type of solvent-borne paint.

LABORATORY ANALYSIS

All analyses were performed as proposed in the QAPP. Table 8 summarizes the achievement of the QA objectives for the critical measurements. More detailed information on the 95%-confidence levels for each ASTM Test Method is included in the appendix with each tabulation of raw data.

TABLE 8. SUMMARY OF QUANTITATIVE QA OBJECTIVES (PRECISION, COMPLETENESS, AND ACCURACY) FOR CRITICAL MEASUREMENTS

Test Property (units)	Number of Determinations	Precision*	Completeness	Accuracy
ASTM D2196-86 Viscosity (centipoises)	(9)—3 replicate tests on each of 3 wet samples from each formulation	Yes—results differ by less than 9.5%.	Goal = 80% Actual = 100%	Yes—viscosity determined for standard oil was ±5% of stated viscosity.
ASTM D1475-90 Density (grams/gal)	(9)—3 replicate tests on each of 3 wet samples from each formulation	No—results differ by more than 0.6%.	Goal = 80% Actual = Invalid	Yes—density determined for distilled water is ±0.6% of the known density of distilled water at 23°C.
ASTM D1210-79 Grind (Hegman Units)	(9)—3 replicate tests on each of 3 wet samples from each formulation	Yes—results differ by less than 1 Hegman unit.	Goal = 80% Actual = 100%	Yes—sample results compared to graphic standards using calibrated gage.
ASTM D2369-90 Percent Solids/ Percent Volatiles (%)	(9)—3 replicate tests on each of 3 wet samples from each formulation	Yes—results differ by less than 1.5% except for one measurement†.	Goal = 80% Actual = 94%	Yes—sample compared to sample with known solids content.
Vanex Procedure Wet Color Match	1 for each batch evaluated	Not applicable.	100%	Not applicable.
ASTM D523-89 Gloss (gloss units)	(9)—3 replicate tests on each of 3 samples (dry films) from each formulation	Yes—results differ less than two gloss units.	Goal = 80% Actual = 100%	Yes—no drift of calibrated tile measurements.

* 95%-confidence level as defined by the ASTM Test Method.
† One measurement flagged as suspect.

Analytical data for grind, viscosity, color, and gloss were judged valid. One data point was flagged as invalid in the percent-solids/percent-volatiles analysis. This data differed more than the 1.5% specified at the 95%-confidence level for this ASTM Test Method (See Table A-4 in the appendix). The mean for this determination was calculated both with and without the suspect data point, and both results were statistically the same. The Battelle Study Leader decided to flag the suspect data point as invalid. The completeness goal for this analysis was 80%. Including the one invalid data point, 94% completeness was obtained.

The density data for the samples met 0.6% variation at the 95%-confidence limit for the replicate measurements within each field sample. However, the mean densities of samples 4-1, 4-2, and 4-4 (samples from the same coatings batch) differ by more than the 0.6% variation that is acceptable for samples that represent the same population. The same is true for samples 7-1, 7-2, and 7-4. The variation between the means of the field samples is greater than the 0.6% acceptable at the 95%-confidence level. The control determination of the density of distilled water run with these samples was within 0.6% of the known density of distilled water at 23°C. The density determination was repeated with similar results. Therefore, the raw data as recorded (Table A-6 in the appendix) do not meet the quality assurance standards specified in the QAPP.

The internal consistency of the measurements for each field sample and for the control sample of distilled water indicate that the test procedure was performed accurately. However, the densities of the field samples collected at different points in the dispensing process appear to vary more than is allowable for identical samples tested in the same laboratory by the same operator. The determined density values suggest that the field samples varied somewhat in density. It should be noted that this sampling and testing matrix is more rigorous than routine quality-control testing used in the coatings industry. In industry testing, one sample from large batches (>400 gal) is checked for density, not multiple samples from different areas of the tank. The test plan in the QAPP for this coatings parameter may require a higher standard than is used in the coatings industry.

The density data do not meet the quality assurance objectives defined in the QAPP. The data and the objectives are summarized in Table 9. The Battelle Quality Assurance Officer, the Battelle Study Leader, and the Laboratory Project Manager determined that analysis of the reserve samples likely would not alter these results.

Viscosity, grind, and gloss test results for each batch are reported as the mean of nine determinations. Percent-solids/percent-volatiles test results are reported as the mean of 18 determinations for the wash-solvent batch and 17 determinations for the new-solvent batch (one data point flagged). Wet color, the critical color determination for this evaluation, is based on a visual examination of side-by-side drawdowns of the batch being tested and a stored color sample of like paint.

TABLE 9. QUALITY ASSURANCE OBJECTIVES FOR DENSITY DETERMINATION DATA AT 23°C

Sample #	W	Density, lb/gal	Within Sample Set	Between Field Samples
Wash Solvent				
46481-4-1-A	241.05	10.23	Valid*	Invalid†
46481-4-1-B	241.06	10.23		
46481-4-1-C	241.05	10.23		
46481-4-2-A	241.78	10.31	Valid*	
46481-4-2-B	241.77	10.30		
46481-4-2-C	241.73	10.30		
46481-4-4-A	241.60	10.28	Valid*	
46481-4-4-B	241.61	10.28		
46481-4-4-C	241.60	10.28		
New Solvent				
46481-7-1-A	241.59	10.28	Valid*	Invalid†
46481-7-1-B	241.60	10.28		
46481-7-1-C	241.60	10.28		
46481-7-2-A	239.52	10.08	Valid*	
46481-7-2-B	239.57	10.08		
46481-7-2-C	239.55	10.08		
46481-7-4-A	242.41	10.36	Valid*	
46481-7-4-B	242.60	10.38		
46481-7-4-C	242.48	10.38		
Distilled Water	221.99	8.32 at 23°C	Valid	Valid compared to known density
Distilled Water	222.00	8.33 at 23°C		
Distilled Water	222.00	8.33 at 23°C		

* Results valid at 95%-confidence level if difference is less than 0.6%.
† Results (mean of multiple determinations) are valid at 95%-confidence level if difference is less than 0.6%.

COMPANY RECORDS AND INFORMATION FROM INTERVIEWS

The representativeness of pollution prevention potential data and economic data from company historical records is as good as possible, given the sources available to the project team. Calculations are based on 1992 data provided by Vanex. However, assumptions were made to work around proprietary information (e.g., product formulations, business sensitive records, raw material prices). At the request of Vanex, actual copies of company records were not collected. The Battelle Study

Leader chose representative data for the longest time period available. The data collected are documented in the Laboratory Record Book and in this final report.

LIMITATIONS AND QUALIFICATIONS

Given the QA assessment cited above, results of the field collection of samples, the data collected from company records, and the laboratory testing can be considered valid bases for drawing conclusions about the product quality, pollution prevention potential, and economics of this wash-solvent reuse system. Density data differ more than 0.6% (95%-confidence level) from one field sample to the next for the same coatings batch. Therefore, density data are considered invalid for comparing product quality. The calculations of waste reduction and of economics are based on certain assumptions about coatings formula and batch size. Assumptions made for the calculations are identified in the text and figures so that readers can simulate specific paint-manufacturing scenarios for their own products and processes.

SECTION 6

CONCLUSIONS AND DISCUSSION

Vanex Color has instituted an aggressive pollution prevention program that has been recognized by the National Paint and Coatings Association as one of the most effective in the coatings-manufacturing industry (Greenfield, 1993; O'Neill, 1992). One element of this pollution prevention program is reducing solvent waste by reusing wash solvent to cleanup equipment between batches of paint. In the past, this cleaning solvent was disposed of as waste.

On-site evaluation of the wash-solvent recovery system included product quality, pollution prevention potential, and economics. Wash solvent is the primary source of solvent waste in the paint manufacturing process. While a number of companies now are using variations of this concept, there has not been a rigorous analysis of the environmental or economic impacts.

PRODUCT QUALITY

The objective of the product quality testing was to determine whether or not use of retained wash solvent in the formulation of subsequent batches of solvent-based coatings affected the quality of the final product. Two batches of a solvent-borne alkyd house paint were prepared at Vanex under the observation of the Battelle Laboratory Project Manager and sampled for laboratory analysis at Battelle. One batch was made with 100%-new solvent; the other, with 80%-wash solvent. The same series of standard analytical tests was run on representative samples of each batch.

Although the sample size (two batches) was small, the quality-control tests at Vanex and the laboratory analyses at Battelle indicate that the product quality of this solvent-borne alkyd house paint made with recovered wash solvent is comparable to that of the same paint made with 100%-new solvent. These results compare well with the experience that Vanex has accumulated while using this wash-solvent recovery system for several years in a variety of paint formulations. Every batch of paint formulated at Vanex must meet company QA standards established for that paint type.

POLLUTION PREVENTION POTENTIAL

The pollution prevention potential of this system is related to the reuse of wash solvent that formerly entered the wastestream. The reuse of wash solvent in the subsequent formulation of coating products (1) reduces the amount of wash solvent that must be disposed of as waste and (2) reduces the amount of solvent that must be purchased for use in the paint formulations. Interim storage of the wash solvent prior to reuse does not contribute to additional pollution. Vanex is able to reuse about 3,300 gal of mineral-spirits wash solvent per year.

ECONOMICS

The payback period for implementation of the wash-solvent recovery system at Vanex was about one month. Vanex has estimated yearly savings through the wash solvent recovery system at $15,000. The conservative estimate, based on figures from 1992, that resulted from Battelle's calculations in this technology evaluation was $11,600 per year . Capital costs in the first year were estimated at less than $1,000.

Savings for other companies instituting similar systems will vary with production volumes and volumes of wash solvent recovered from the wastestream. Waste disposal costs probably will continue to rise. Operating costs are reduced by reducing the volume of new solvent purchased. Solvent prices fluctuate with the market and the volume purchased. Therefore, these savings vary somewhat.

DISCUSSION OF IMPACT

The major source of solvent waste in paint manufacture is wash solvent used to clean tanks and equipment. The very simplicity of this technology makes it desirable for paint companies actively pursuing reduction of solvent waste. It is especially useful for small-to-medium companies manufacturing several solvent-borne paints in small production batches.

The wash-solvent recovery system can be used by manufacturers of solvent-borne paint to reduce the volume of solvent waste without affecting product quality. Sound experience and knowledge of the chemistry of the paint formulations are needed to plan a reuse protocol for a particular facility. This technology system can produce cost savings with little capital outlay for implementation and little or no increase in operating expenses.

Other companies besides Vanex are using a similar system. Jamestown Paint has identified products in which wash solvents from other, compatible products can be used and has set up a system for storing and reusing wash solvent whenever possible (Maty, 1993). Other companies reuse wash solvent in different ways to reduce waste. For example, Red Spot Paint & Varnish Co. reuses cleaning solvents for multiple cleaning operations until the solids content is higher than 15% before off-site recycling. This change is reported to have reduced their wash-solvent volume from 1000 gal per day to 100 gal (Beels, 1990; Ruthenburg, 1993).

Using the production figures for solvent-borne coatings and the Vanex wash-solvent recovery rate, it is possible to estimate the impact that this technology could have on wash-solvent waste reduction per year in the U.S. According to U.S. Department of Commerce figures for 1992, production of paints in the U.S. was 1.10 billion gal (Bureau of Census, 1993). This production is reported for three coatings groups: architectural coatings, industrial-product coatings, and special-purpose coatings. There is significant lack of agreement in the technical literature between available industry figures and market-share analyses concerning the volume of solvent-borne coatings manufactured in the U.S. each year. However, it is well accepted that environmental pressures are decreasing the percentage of solvent-borne coatings produced. The percent of coatings produced in the U.S. in 1992 that are solvent-borne has been cited from a low of 62% to a high of 75% (Paint & Resin, 1991; Mercurio, 1992; Seymour, 1991; Schrantz, 1993). Because the percentage is decreasing yearly, Battelle based calculations of potential impact on the low 1992 percentage of 62% (682 million gal).

As the calculations in Table 10 show, equipment cleaning in production of solvent-borne paint may generate as much as 13.6 million gal (248,000 55-gal drums) of wash-solvent waste. Recovery of 80% of this wash solvent could reduce the volume of solvent waste requiring disposal from 13.6 million gal to 2.7 million gal, a reduction of 10.9 million gal.

This evaluation of the wash-solvent recovery system at Vanex has accomplished the program objectives for product quality, pollution prevention potential, and estimation of economics. Wash solvent used in the manufacture of similar solvent-borne paint did not lower product quality. Solvent waste entering the wastestream was reduced by 60 drums per year at Vanex, and no additional pollution was produced by the technology. The payback period for implementation was about one month. Many small-to-medium paint manufacturers could use a similar practice to reduce solvent waste from the manufacture of solvent-borne paint.

TABLE 10. ESTIMATE OF ANNUAL WASTE REDUCTION IF WASH SOLVENT REUSE IMPLEMENTED THROUGHOUT THE U.S.

Assumptions Based on Industry Data:	
Annual production of solvent-borne paints:	682 million gal (2,580 million L)
Estimated number of batches @ 1,000 gal/batch:	682,000 batches
Quantity of mineral spirits used to clean tanks and equipment between batches:	20 gal/batch (75 L)
Wash Solvent Reduction Calculations:	
Without Reuse	
Solvent required for cleanup only (682,000 batches X 20 gal/batch)	13.6 million gal (51.5 million L)
Wash solvent disposed	13.6 million gal (51.5 million L)
With 80% Reuse	
Solvent required for cleanup (682,000 batches X 20 gal/batch)	13.6 million gal (51.5 million L)
Solvent reused for formulation (80% X 13.6 million gal)	10.9 million gal (41.3 million L)
Wash solvent disposed (13.6 - 10.9 million gal)	2.7 million gal (10.2 million L)
Waste Reduction	**10.9 million gal (41.3 million L)**

SECTION 7

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APPENDIX

RAW DATA FROM LABORATORY ANALYSIS

TABLE A-1. 60° GLOSS READINGS USING HUNTERLAB D48D GLOSSMETER

Sample No.	60° Gloss Readings*			Average
	1	2	3	
46481-4-1	81.6	81.6	81.6	81.6
46481-4-2	81.5	81.2	81.3	81.3
46481-4-4	82.0	81.7	82.0	81.9
46481-7-1	79.3	79.2	79.8	79.4
46481-7-2	80.1	79.9	80.2	80.0
46481-7-4	79.0	78.9	78.7	78.9

* At the 95%-confidence level, all data are valid, i.e. differ by no more than 0.9 gloss units for determinations of same sample.

TABLE A-2. HEGMAN GRIND

Sample No.	Battelle Hegman Units* (average of three readings)
46481-4-1	8
46481-4-2	7-3/4
46481-4-4	8
46481-7-1	8
46481-7-2	8
46481-7-4	8

* At the 95%-confidence level; all data are valid, i.e differ by no more than 3/4 Hegman units for the same sample.

TABLE A-3. RAW DATA* FOR VISCOSITY AT 25°C

Sample No.	Reading, cps		
	1	2	3
46481-4-1	4175	4150	4150
46481-4-2	3925	3925	3950
46481-4-4	3900	3950	3950
46481-7-1	4125	4125	4150
46481-7-2	3875	3875	3950
46481-7-4	3850	3862	3900

* Raw data as recorded. Three digits are significant.

TABLE A-4. RAW DATA AND CALCULATIONS FOR VANEX ALKYD HOUSE PAINT PERCENT VOLATILES ASTM D2369

Formula #	W1 Dish Wt.*	S Sample Wt.*	Sample Wt. After Heat	W2 Dish Wt. + Sample Wt. After Heat	% Volatile	% Nonvolatile
46481-4-1-A	1.56372	0.79029	0.57785	2.14157	26.88127	73.11873
46481-4-1-B	1.58319	0.72185	0.52767	2.11086	26.90033	73.09967
46481-4-1-C	1.55093	0.80467	0.58826	2.13919	26.89425	73.10575
					26.89195	73.10805
46481-4-2-A	1.55891	0.76308	0.55771	2.11662	26.91330	73.08670
46481-4-2-B	1.55375	0.76275	0.55802	2.11177	26.84104	73.15896
46481-4-2-C	1.58538	0.78691	0.57505	2.16043	26.92303	73.07697
					26.89245	73.10755
46481-4-4-A	1.59081	0.81314	0.59501	2.18582	26.82564	73.17436
46481-4-4-B	1.56873	0.77517	0.56750	2.13623	26.79025	73.20975
46481-4-4-C	1.58532	0.84565	0.62095	2.20627	26.57128	73.42872
					26.72906	73.27094
46481-7-1-A	1.59206	0.73223	0.53458	2.12664	26.99288	73.00712
46481-7-1-B	1.55596	0.73933	0.54039	2.09635	26.90815	73.09185
46481-7-1-C	1.55547	0.73528	0.53798	2.09345	26.83332	73.16668
					26.91145	73.08855
46481-7-2-A	1.58053	0.78208	0.57094	2.15147	26.99724	73.00276
46481-7-2-B	1.54059	0.76955	0.56268	2.10327	26.88194	73.11806
46481-7-2-C	1.58253	0.77643	0.56743	2.14996	26.91807	73.08193
					26.93242	73.06758
46481-7-4-A	1.58753	0.81014	0.59129	2.17882	27.01385	72.98615
46481-7-4-B	1.58419	0.82086	0.60183	2.18602	26.68299	73.31701
46481-7-4-C	1.57842	0.81985	0.60198	2.18040	26.57437†	73.42563
					26.75707	73.24293
CONTROL-1‡	1.59499	0.51312	0.00208	1.59707	99.59464	0.40536
CONTROL-2‡	1.58509	0.78820	0.00125	1.58634	99.84141	0.15859
CONTROL-3‡	1.58227	0.66828	0.00157	1.58384	99.76507	0.23493
					99.73371	0.26629

* Balance reads five decimal places, so five are recorded by technician as raw data. Only four are significant. However, for ASTM reporting, figures are rounded to 0.1% (Table 4)

† Invalid for sample set. ‡ Control is reagent-grade toluene.

(Continued)

TABLE A-4. (Continued)

Formula #	W1 Dish Wt.	S Sample Wt.	Sample Wt. After Heat	W2 Dish Wt. + Sample Wt. After Heat	% Volatile	% Nonvolatile
46481-4-1-D	1.56703	0.81731	0.60250	2.16953	26.28256	73.71744
46481-4-1-E	1.56007	0.75858	0.56020	2.12027	26.15149	73.84851
46481-4-1-F	1.58892	0.88022	0.64928	2.23820	26.23662	73.76338
					26.22356	73.77644
46481-4-2-D	1.60184	0.96332	0.70936	2.31120	26.36299	73.63701
46481-4-2-E	1.58432	0.70824	0.52269	2.10701	26.19875	73.80125
46481-4-2-F	1.55245	0.77050	0.56844	2.12089	26.22453	73.77547
					26.26209	73.73791
46481-4-4-D	1.56006	0.81822	0.60457	2.16463	26.11156	73.88844
46481-4-4-E	1.58795	0.85275	0.63009	2.21804	26.11082	73.88918
46481-4-4-F	1.59988	0.91967	0.67895	2.27883	26.17461	73.82539
					26.13233	73.86767
46481-7-1-A	1.59091	0.59114	0.43531	2.02622	26.36093	73.63907
46481-7-1-B	1.58755	0.71794	0.52897	2.11652	26.32114	73.67886
46481-7-1-C	1.58645	0.66302	0.48923	2.07568	26.21188	73.78812
					26.29798	73.70202
46481-7-2-A	1.58720	0.68266	0.50309	2.09029	26.30446	73.69554
46481-7-2-B	1.59906	0.77862	0.57313	2.17219	26.39156	73.60844
46481-7-2-C	1.57567	0.74247	0.54725	2.12292	26.29332	73.70668
					26.32978	73.67022
46481-7-4-A	1.55824	0.75386	0.55553	2.11377	26.30860	73.69140
46481-7-4-B	1.59850	0.81042	0.59692	2.19542	26.34436	73.65564
46481-7-4-C	1.57013	0.80694	0.59492	2.16505	26.27457	73.72543
					26.30918	73.69082
CONTROL-4‡	1.59832	0.43745	0.00016	1.59848	99.96342	0.03658
CONTROL-5‡	1.58867	0.42703	0.00016	1.58883	99.96253	0.03747
CONTROL-6‡	1.58050	0.43104	0.00028	1.58078	99.93504	0.06496
					99.95367	0.04633

‡ Control is reagent-grade toluene.

TABLE A-5. RAW DATA FROM COLOR DIFFERENCE MEASUREMENTS USING CIELAB*

Sample #	L	A	B	YI	ΔE
46481-4-1	93.71	-1.58	1.77	2.53	0.2
46481-4-2	93.65	-1.49	1.68	2.43	0.2
46481-4-4	93.67	-1.60	1.69	2.35	0.2
46481-7-1	93.84	-1.58	1.93	2.85	†
46481-7-2	93.88	-1.61	1.97	2.90	†
46481-7-4	93.81	-1.57	1.98	2.96	†

* Macbeth MS-2000, Illuminant C; each reading is the average of three readings.
† Results of 7-1, 7-2, and 7-4 averaged for use as standard for color difference calculations.

TABLE A-6. DENSITY DETERMINATION DATA FOR VANEX 2-1 HOUSE PAINT AT 23°C

Sample #	W*	w†	k/v‡	Density, lb/gal
		Wash Solvent		
46481-4-1-A	241.05	138.83	0.1001013	10.23
46481-4-1-B	241.06	138.83	0.1001013	10.23
46481-4-1-C	241.05	138.83	0.1001013	10.23
46481-4-2-A	241.78	138.83	0.1001013	10.31
46481-4-2-B	241.77	138.83	0.1001013	10.30
46481-4-2-C	241.73	138.83	0.1001013	10.30
46481-4-4-A	241.60	138.83	0.1001013	10.28
46481-4-4-B	241.61	138.83	0.1001013	10.28
46481-4-4-C	241.60	138.83	0.1001013	10.28
		New Solvent		
46481-7-1-A	241.59	138.83	0.1001013	10.28
46481-7-1-B	241.60	138.83	0.1001013	10.28
46481-7-1-C	241.60	138.83	0.1001013	10.28
46481-7-2-A	239.51	138.83	0.1001013	10.08
46481-7-2-B	239.57	138.83	0.1001013	10.08
46481-7-2-C	239.55	138.83	0.1001013	10.08
46481-7-4-A	242.41	138.83	0.1001013	10.36
46481-7-4-B	242.60	138.83	0.1001013	10.38
46481-7-4-C	242.48	138.83	0.1001013	10.38
Distilled Water	221.99	138.83	0.1001013	8.32 at 23°C
Distilled Water	222.00	138.83	0.1001013	8.33 at 23°C
Distilled Water	222.00	138.83	0.1001013	8.33 at 23°C

* W = weight of cup plus sample.
† W = weight of cup empty.
‡ k/v = factor specific to actual cup used in testing calculated in cup calibration process, ASTM D1475.