

# ***Transfer Efficiency***

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# Introduction

Welcome to *Transfer Efficiency*, a learning module in Graco's basic concept and theory sales training curriculum. Your understanding of the information in this module provides the basis for further study on specific Graco products. Your ability to successfully promote and sell Graco's products depends in part on how well you learn the basics and then apply this knowledge to addressing your customers' needs for Graco equipment.

While this curriculum best fits the requirements of Graco and distributor sales people, it will also benefit anyone whose job function depends on knowledge of Graco's products.

## **Module Overview**

This module explains the concept of the transfer efficiency of spray finishing processes. It prepares sales people to put in perspective the transfer efficiency data they encounter in the industry, and to help their customers do the same. This module, in conjunction with others in this phase of the curriculum, prepares sales people for later training on specific Graco products.

## **How to Use This Module**

The curriculum consists of a series of self-study modules. As the term self-study implies, you work through the materials on your own at a comfortable pace. Plan sufficient time (approximately 30 minutes) to complete at least one section of a module in a working session.

This module combines a variety of features that make the learning process convenient and productive:

- Learning objectives
- Text
- Charts and illustrations
- Progress checks
- Additional resources

## **Learning Objectives**

Each section of materials offers a set of learning objectives. Read the objectives and use them to guide you to the most important concepts. After you finish each section and before you complete the progress check, reread the objectives to confirm that you understand the key concepts.

## **Text**

Definitions, examples, and explanations comprise the learning module text. Read it carefully and return for review if necessary.

## **Charts, Illustrations**

An important element of any instruction is visualizing the concepts. This module contains graphics and illustrations to enhance the text material. Wherever appropriate, the module also contains charts that help you organize or summarize information.

## **Progress Checks**

Progress checks are self-tests that provide reinforcement and confirm your understanding of important topics. After completing each section of the module, return to review the objectives, and then work through each of the progress check items. Upon completion, check your answers against those provided. If you answered any incorrectly, return to the text and reread the pertinent information.

## **Additional Resources**

This module may refer you to other documents or sources that expand on the concepts covered in the module. The reference will include the name of the source and how you can obtain it.

# The Concept of Transfer Efficiency

## **Learning Objectives**

This section provides a foundation for learning about transfer efficiency. It defines the term “transfer efficiency” and explains its significance to the spray finishing industry. After completing this introduction to the concept of transfer efficiency, you will be able to:

- Define the term *transfer efficiency*.
- Describe the conditions and variables that impact transfer efficiency.
- Explain the importance of standardized testing conditions to the validity of transfer efficiency claims and comparisons.

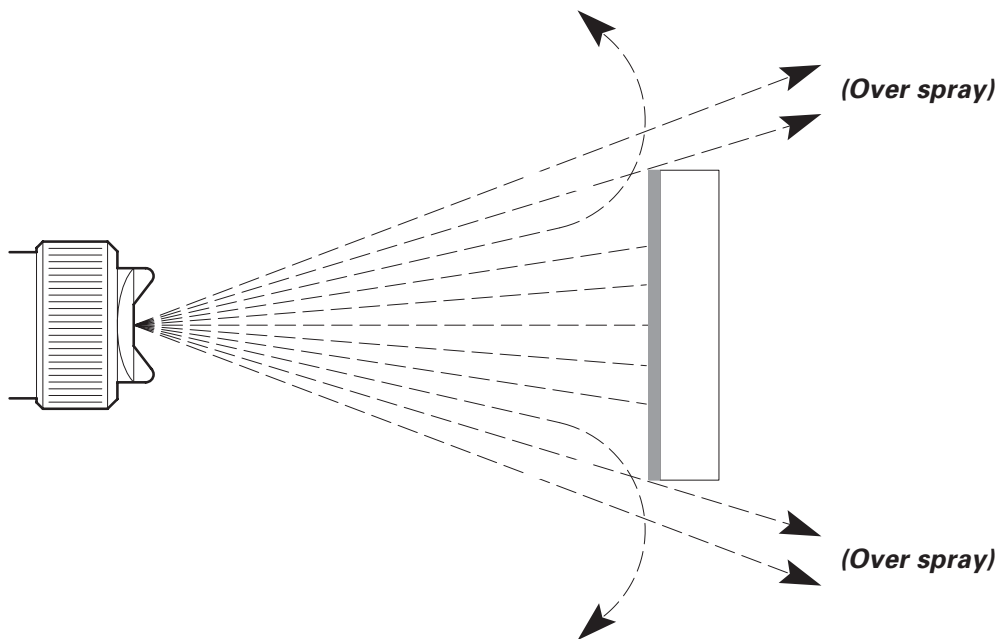
## **What Is Transfer Efficiency?**

Put very simply, the *transfer efficiency* of a spray finishing process means the amount of material that adheres to the target compared to the amount of material that was sprayed through the applicator toward the target. Transfer efficiency is expressed as a percentage, as in “under these testing conditions, this HVLP spray finishing process is 60 percent transfer efficient”, or “the addition of electrostatics made the spray finishing process 90 percent more efficient”.

Transfer efficiency is critical to the spray finishing industry from both a cost and a regulatory standpoint. Although transfer efficiency is a relatively simple concept, it can lead to considerable confusion (or even deception) if it is not clearly understood. To serve your customers well, you need to know more about transfer efficiency and how it is used in the industry, beyond its simple definition.

Transfer efficiency is usually expressed as the percentage of the weight of solids sprayed versus the weight of solids gained by the target. As an example, 60 percent transfer efficiency means that 60 percent of the weight of the solids in the material that was sprayed actually reached the target. The balance of 40 percent was lost to the spray booth or other areas during the spray finishing process.

Figure 1 on the next page illustrates the concept of transfer efficiency by showing the amount of material reaching the target as only a portion of the total amount of material that is sprayed. The material that is lost as over spray is both a regulatory problem and a cost overrun for the manufacturer, as you will learn later in this module.



**Efficiency = Amount on target vs. Amount sprayed**

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**Figure 1:** Transfer Efficiency Illustrated

Expressed mathematically, transfer efficiency is the net amount of material deposited on a part divided by the total material sprayed. A simple formula for calculating transfer efficiency is expressed below in Figure 2. The necessary inputs for using this formula can be obtained by measuring the amount of material sprayed and the amount of material on the part.

<p> <math>W_s</math> = Weight of material sprayed  <math>W_p</math> = Weight of material on the part  <math>T.E. = W_p / W_s \times 100\%</math> </p>
---

**Figure 2:** A Simple Formula for Calculating Transfer Efficiency

The amount of material sprayed can be measured with a totalizing flow meter or by monitoring the weight of the material supply before and after spraying. The amount of material on the part can be measured by weighing the part before and after spraying. However, the measurement will be inaccurate if a significant amount of solvent evaporated before the sprayed part was weighed.

An alternate, more accurate method for calculating transfer efficiency is expressed below in Figure 3. The inputs for this formula require that you measure the amount of sprayed material, weigh the part before and after spraying and drying, and know the percentage of solids in the material.

$$\frac{\text{Weight of solid material the part gains}}{\text{Weight of wet material sprayed}} \times \text{Percent solids of the fluid}$$

**Figure 3:** Alternate Formula for Calculating Transfer Efficiency

Both of these methods of calculating transfer efficiency determine how much material reached the part compared to how much was lost to the surrounding environment. Obviously, when a greater percentage of material adheres to the target, less material is needed to achieve the desired film thickness. This means the operator reduces the emissions of chemicals into the air and lowers the costs for materials and cleanup. Therefore, improved transfer efficiency is a major objective for the spray finishing industry.

### ***Factors Impacting Transfer Efficiency***

If optimal transfer efficiency is a key objective in spray finishing, how can it be improved? To improve transfer efficiency, you need to control the factors that influence the efficiency of the transfer of material to the target.

The primary spray finishing conditions that impact transfer efficiency are:

- **Substrate** (target or part) **characteristics**, such as size and shape
- **Operator variability**
- **Atomization and spray finishing methods**
- **Equipment characteristics**, including the balance of fluid pressure and air pressure
- **Air conditions in the spray booth**, such as humidity, temperature, and air velocity
- Others (such as the **electrical conditions** of the equipment, target, operator, and spray booth; **material characteristics** such as viscosity and conductivity; and when using electrostatics, the **electrode voltage and position** in the spray pattern)

These spray finishing conditions can be complex and difficult to measure and control. Yet, to perform a valid, accurate test of transfer efficiency, spray finishing conditions must be specified and controlled. Operator variability alone can account for a 20, 50, or even 100 percent difference in transfer efficiency.

To accurately measure the transfer efficiency of a specific spray finishing process, you need to do the following:

1. Specify in advance the spray finishing parameters you will use, including production rate, material type, finish quality, and atomization method.
2. Weigh the parts before spray finishing and record their weight.
3. Measure the weight (or volume) of the material container, fully charged, before beginning the test.
4. Coat the parts as required, using the same method of application to be used in product production.
5. Measure the weight (or volume) of the material container after spray finishing.
6. Cure the parts completely.
7. Weigh the coated parts to determine their weight gain after finishing and record the weight increase.
8. Determine the weight solids of the material, either by measuring or by obtaining the data from the material supplier, and calculate the dry weight of the solids sprayed.
9. Use the formula (presented in Figure 3) to calculate transfer efficiency.

Note that when you are using a totalizing flow meter, you can eliminate Steps 3 and 5 above.

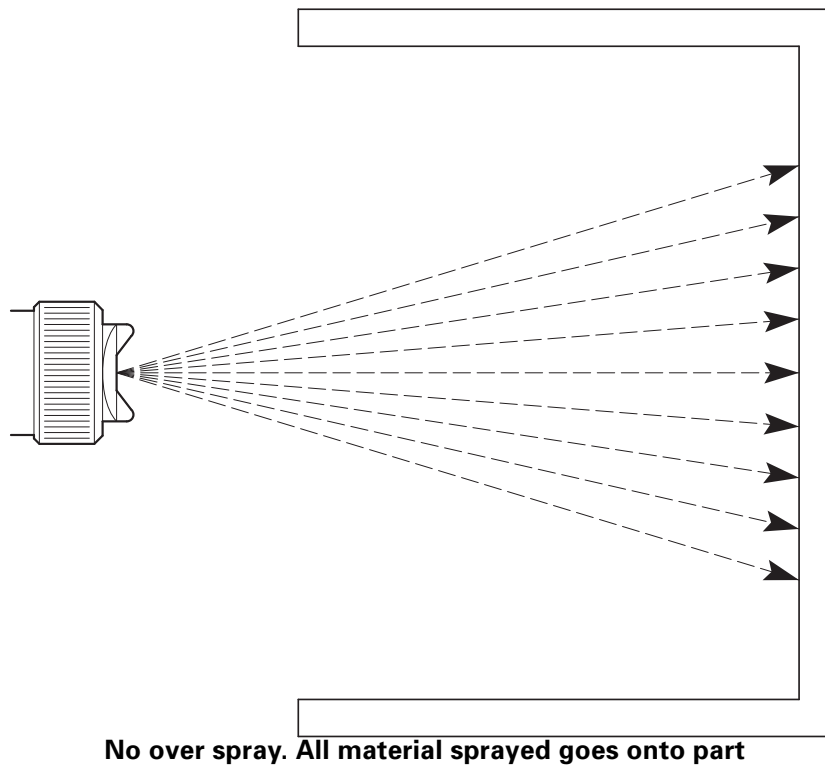
### ***The Difficulty of Comparing Transfer Efficiencies***

You cannot accurately calculate or compare transfer efficiencies without standardizing the specific conditions under which you determine them. Unfortunately, it is very difficult to specify, control, and replicate all the factors that impact transfer efficiency. For the test conditions to be valid, you must document them in detail so that they can be replicated in a follow-up test to check for variability or compare to other testing situations.

As of yet, the spray finishing industry has no standardized, universally recognized transfer efficiency testing method. Equipment manufacturers each have their own methods for determining the transfer efficiencies of their products. Since they do not use the same set of testing conditions, it is nearly impossible to make accurate, fair comparisons among products. While manufacturers may make an effort to use realistic testing conditions, the opportunity to make unfair product claims is certainly present.

For example, Figure 4 shows the sort of test conditions one could set up to claim an unusually high rate of transfer efficiency. By spraying within a very restrictive enclosure such as a waste basket, the surrounding air movement is controlled to eliminate over spray. This example shows how one can

demonstrate equipment to be much more transfer efficient than it is in another application.



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**Figure 4:** Artificial Conditions for Achieving a High Rate of Transfer Efficiency

Using transfer efficiency calculations as a comparison is only meaningful if you standardize test conditions. One effort to standardize testing methods is the ASTM D 5009/U EPA test. In this test, ten vertical six-inch wide panels are set up with 12 inch (304 mm) center spacing. The spray gun is held in a fixed position with no gun movement. The spray gun is triggered prior to the first panel and released six inches (152 mm) after the last panel. These test conditions have the advantage of eliminating any operator influence, and they can be easily replicated.

There are other standardized testing methods, in addition to the ASTM method described above. For example, other ASTM standards for spray transfer efficiency testing are D5286 (General Production Conditions for Spray Application of Fluids) and D5066 (Spray Application of Automotive Fluids, Weight Basis).

Each of these test standards has a different set of conditions and associated advantages. However, no one test is, at this point, held up as the industry standard to which all manufacturers adhere. The best test is a direct comparison under identical application conditions so that the outcomes can easily be

compared without concern for exact numbers.

## ***Evaluating Transfer Efficiency Data***

Since most reported transfer efficiency results are not based on a common standard, manufacturers' claims and advertising can be misleading. Manufacturers may publish transfer efficiency claims about their products without specifying testing parameters. Customers can be misled by transfer efficiency claims if they are unaware of the relative nature of transfer efficiencies and the difficulty of standardizing test conditions. As a representative of Graco, you can help your customers by:

- Putting transfer efficiency claims in perspective by asking about test conditions and encouraging fair comparisons
- Pointing out that transfer efficiency comparisons are only meaningful if the test conditions are standardized
- Focusing on transfer efficiency improvements as a worthwhile objective for both cost control and regulatory reasons.

Graco strives to design products that show real gains in transfer efficiency. Therefore, all Graco products are tested against a single, standardized method. Graco's transfer efficiency testing utilizes a highly accurate test, the ASTM method D 5009/U. (Please see the previous discussion of this test method.) This test method employs sophisticated measurement and advanced statistical review. While Graco considers its test methods to be fair and non-discriminating, (a point that may be argued by Graco's competitors), the test results it publishes cannot be directly compared to the claims of other manufacturers.

# Regulation of Volatile Organic Compounds (VOCs)

## **Learning Objectives**

To explain how transfer efficiency relates to the regulation of air quality, you must first understand Volatile Organic Compounds (VOCs). After completing this section on Volatile Organic Compounds, you will be able to:

- Explain how transfer efficiency relates to federal and state regulation of Volatile Organic Compounds (VOCs).
- Describe how to reduce and control VOC emissions.

## **What Is A Volatile Organic Compound (VOC)?**

*Volatile organic compounds (VOCs)* are photochemically reactive agents that, in combination with oxides of nitrogen and sunlight, form ground level ozone, which contributes to smog. Most solvents and thinners contain photochemically reactive agents (VOCs) and are therefore subject to federal and state air quality regulations.

## **Federal Regulation of VOCs**

The federal Clean Air Act, which has been in existence for some time, empowers the federal government's Environmental Protection Agency (EPA) to limit the VOCs that are emitted into the air during manufacturing processes. In 1990, President Bush signed amendments to the Clean Air Act. Among other provisions, the Clean Air Act Amendments of 1990 empowered the Environmental Protection Agency (EPA) to develop new guidelines for how state environmental protection agencies regulate specific industries. The Clean Air Act Amendments also enabled the EPA to make existing regulations more restrictive and the states to take more aggressive enforcement actions.

The Clean Air Act Amendments of 1990 are lengthy, detailed, complex, and sometimes difficult for the lay person to understand and interpret. To date, the states are responding to the new federal mandates by instituting new policies and procedures to regulate the air emissions of manufacturers in their state. The key portions of the Clean Air Act Amendments that pertain to the spray finishing industry are Titles I, III, and V.

Title I of the Clean Air Act Amendments of 1990 establishes an ozone threshold level for the entire country, called the National Ambient Air Quality Standard (NAAQS). The NAAQS standard is .12 parts per million. The importance of this standard is discussed in greater detail in the section to follow on state regulation of VOCs.

Title III of the Clean Air Act Amendments names 189 chemicals that are considered *hazardous air toxins*. A number of the solvents commonly used by spray finishers are among these hazardous air toxins, including Methanol, Toluene, Xylene, MEK, MIBK, and some chlorinated compounds. A facility that emits ten tons (9,072 kilograms) per year of one chemical or 25 tons (22,680 kilograms) of a combination of chemicals is classified as a *Major Source*. Title III mandates that Major Sources utilize specific, highly effective methods to control emissions, such as technical pollution controls, process changes, materials substitution, operator training, and operator certification.

Title V of the Clean Air Act Amendments of 1990 requires that manufacturers who have emissions sources obtain an Air Quality Operating Permit from their state. To complete the application for the Air Quality Operating Permit, the facility must monitor and report its emissions in detail and agree to certain operating restrictions.

### **State Regulation of VOCs**

The Clean Air Act Amendments of 1990 make the individual states responsible for:

- Issuing air quality permits to existing facilities and regulating their operations
- Issuing air quality permits to new facilities and regulating their operations
- Regulating and permitting upgrades and modifications to facilities (which require that the entire facility be brought up to code)
- Enforcing the Clean Air Act Amendments.

Title I of the amendments requires that states specify geographic areas that do not meet the NAAQS air quality standards for particular pollutants, including ozone. These locations are called *non-attainment areas*, and they must reduce ozone within a specific time frame as indicated in the State Implementation Plans (SIPs). Each state's SIP must be approved by the federal EPA. Therefore, Title I means that spray finishing processes in non-attainment areas must adhere to a more stringent set of air quality guidelines.

Title V of the Clean Air Act Amendments of 1990 requires that facilities monitor their VOC emissions in order to obtain an operating permit. Under Title V, states must implement an operating permit program within a certain time frame to ensure compliance with the new federal regulations. This means that manufacturers are responsible for determining if they need an operating permit, based on their emissions levels, and then obtaining one from the state. The operating permit the state issues specifies the operating restrictions the manufacturer must accept to control its VOC emissions.

The net, long-term impact of the Clean Air Act Amendments will undoubtedly lead to increasingly stringent air quality standards, as well as changes in the composition of materials. It may also bring about more solvent recovery systems and the incineration of solvents. There may also be greater use of waterborne, high solid, and radiation curable materials to reduce the emission of VOCs into the air.

## ***Controlling the Emissions of VOCs***

Optimal spray finishing transfer efficiency is critical to controlling the emissions of VOCs into the air. In spray finishing processes, the resulting VOC levels are impacted by the chemical composition of the materials used in spray finishing and the quantity of the materials used. Therefore, to control the emissions of VOCs into the air, you can:

- Control or alter the spray finishing process
- Control or alter the VOC level of the material (with or without adding solvents).

Conventional air spray finishing methods are characterized by large amounts of over spray, which lowers transfer efficiency. The new, more restrictive air quality standards may, in some cases, prohibit the use of conventional air spray methods. HVLP (high volume low pressure) methods usually offer better transfer efficiency, and are therefore generally more compliant with air quality equipment rules. Electrostatic finishing methods, which are fully compliant with air quality rules, tend to have better transfer efficiencies than non-electrostatic methods and are better able to keep up with production needs. The electrostatic rotary and air-assisted airless methods may be more efficient than electrostatic air spray.

The new rules not only require that manufacturers use compliant equipment, but also that they operate it properly to avoid violations. For example, most HVLP processes are sufficiently transfer efficient to be compliant with air quality rules. However, an HVLP air spray gun's atomizing air has a lower velocity and atomizing pressure, making it more difficult to atomize the material. The lower atomizing power forces the operator to reduce the fluid flow rate, and therefore slows down production. If the operator compensates for these limitations by increasing solvents or air pressure, the spray finishing process may no longer be compliant. In summary, you are responsible not only for using compliant equipment, but also for using it in a compliant manner.

Keep in mind one important point about altering the spray finishing process to control VOC emissions. Altering the spray finishing process does not change the VOC level of the material, it only changes the amount of material you use. When you use less, you emit less. By using less, you emit smaller quantities of VOCs. However, the composition of the material has not been altered to a lower VOC level.

In summary, highly efficient equipment is essential to controlling both VOC emissions and production costs. Never before have we had more reason to improve the efficiency of spray finishing processes.

# Controlling Costs Through Transfer Efficiency Improvements

## ***Learning Objectives***

Improved transfer efficiency can bring about significant reductions in operating costs. After completing this section on controlling costs through improved transfer efficiency, you will be able to:

- Describe how customers can limit the costs associated with spray finishing by improving transfer efficiency.

## ***Costs Associated With Spray Finishing***

The costs associated with spray finishing processes include expenses for:

- Coatings
- Filters
- Conveyers
- Operator cleanliness
- Booth maintenance
- Maintenance of walls and floors
- Sludge removal.

In addition to regulating air quality, the EPA also regulates the storing, transport, and disposal of the hazardous materials produced by the spray finishing industry. These requirements represent additional costs to the manufacturer. For example, the manufacturer must remove sludge from the water it uses for clean-up, as well as determine if its sludge wastes (materials and solvents) are hazardous. Users of materials and solvents must also keep accurate records of the waste materials they discard.

If the company contracts for waste removal, it must select a properly permitted disposal firm to transport, treat, store, or dispose of hazardous waste. Finally, the company's records must detail the contents of the materials it transports or disposes of (whether the company disposes of hazardous waste independently or through a contractor). All of these requirements represent additional costs that can be reduced through more efficient spray finishing processes.

## ***Helping Customers Reduce Costs***

As a representative of Graco, part of the service you provide should be to help customers reduce their costs through transfer efficiency improvements. For example, you can assist them in:

- Choosing alternate materials having fewer VOCs
- Altering the spray finishing process by using electrostatics or other methods with higher transfer efficiencies
- Limiting sludge to reduce sludge removal expenses
- Improving operator techniques to realize maximum efficiency from equipment.

In the spray finishing industry, improved transfer efficiency is always a worthwhile objective, from both a regulatory and a cost-savings standpoint.

# Progress Check

Directions: After answering the following questions, compare your answers with those provided in the answer key following this progress check. If you responded to any items incorrectly, return to the text and review the appropriate topics.

1. Which of the following is an accurate definition of the term transfer efficiency?
  - a. The amount of material that adheres to the target compared to the total amount of material that is sprayed.
  - b. The amount of material that adheres to the front of the target compared to the amount that adheres to the back of the target.
  - c. The amount of material that adheres to one target compared to the amount of material that adheres to another target.
  - d. The amount of material that adheres to the target when sprayed from one spray gun compared to the amount of material that adheres to the target when sprayed from another spray gun.
  
2. How is a transfer efficiency expressed?
  - a. As a fraction
  - b. As a negative number
  - c. As a ratio
  - d. As a percentage
  
3. What inputs do you need to calculate the transfer efficiency of a spray finishing process?  
(Check all that apply.)
  - a. Weight of the part before spraying
  - b. Weight of the part after spraying
  - c. Amount of material sprayed
  - d. Operator efficiency
  - e. Spray booth dimensions
  
4. Which of the following factors can you control to realize an improvement in transfer efficiency?  
(Check all that apply.)
  - a. The size and shape of the substrate (target)
  - b. The viscosity and conductivity of the material
  - c. Operator technique
  - d. The balance of fluid pressure and air pressure in the equipment
  - e. Spray booth humidity, temperature, and air velocity
  - f. Grounding of the equipment, target, operator, and spray booth

5. Which of the following describes an accurate, fair comparison of the transfer efficiencies of two different pieces of equipment? (Check all that apply.)
- a. Testing conditions are documented.
  - b. Repeated tests produce different results.
  - c. One test uses ASTM D5286 test conditions and the other uses ASTM D5066 test conditions.
  - d. Both tests used the widely accepted industry standard.
  - e. Test conditions can be replicated in follow-up tests.
  - f. Direct, comparative (head-to-head) testing.
6. What is a Volatile Organic Compound (VOC)? (Check all that apply.)
- a. A photochemically reactive agent
  - b. An emission that contributes to smog
  - c. A solvent or thinner subject to air quality regulations
  - d. An emission that can be controlled by altering the material or the spray finishing process
7. Which of the following are spray finishing costs that can be controlled by improving the transfer efficiency of the spray finishing process? (Check all that apply.)
- a. Coatings
  - b. Filters
  - c. Conveyers
  - d. Operator cleanliness
  - e. Booth maintenance
  - f. Wall and floor maintenance
  - g. Sludge removal

## **Answers to the Progress Check**

1. a. In spray finishing, the term *transfer efficiency* means the amount of material that adheres to the target compared to the total amount of material that is sprayed.
2. d. Transfer efficiency is expressed as the percentage. A transfer efficiency of 60 percent means that 60 percent of the total material adhered to the target and 40 percent was lost in the surrounding environment.
3. a, b, and c. The inputs necessary to calculate the transfer efficiency of a spray finishing process are the:
  - Weight of the part before spraying
  - Weight of the part after spraying
  - Amount of material sprayed
4. a, b, c, d, e, and f. To realize an improvement in transfer efficiency, you can control any (or all) of the following factors:
  - The size and shape of the substrate
  - The viscosity and conductivity of the material
  - Operator technique
  - The balance of fluid pressure and air pressure in the equipment
  - Spray booth humidity, temperature, and air velocity
  - Grounding of the equipment, target, operator, and spray booth
5. a, e, and f. For a valid comparison, all testing conditions must be carefully documented so that they can be replicated in follow-up tests. Repeated tests under the same conditions should produce similar results. Although there is no widely accepted industry standard, transfer efficiencies that are compared to each other should be the result of the same test conditions.
6. a, b, c, and d. A Volatile Organic Compound (VOC) is a photochemically reactive agent that contributes to smog and is subject to air quality regulations. Many solvents or thinners are VOCs. VOC emissions can be controlled by altering the material or the spray finishing process.
7. a, b, c, d, e, f, and g. Spray finishing costs that can be controlled by improving the transfer efficiency of the spray finishing process are:
  - Coatings
  - Filters
  - Conveyers
  - Operator cleanliness
  - Booth maintenance
  - Wall and floor maintenance
  - Sludge removal



# Module Evaluation

*The purpose of this Module Evaluation is to help the Graco Technical Communications department determine the usefulness and effectiveness of the module.*

*Instructions: Please complete the evaluation, tear it on the perforation, and return it Graco Technical Communications Department, P.O. Box 1441, Minneapolis, MN 55440-1441, USA.*

1. *Based on the objectives, this module:*

- Significantly exceeded my expectations
- Exceeded my expectations
- Met my expectations
- Was below my expectations
- Was significantly below my expectations

2. *Why did you select the above rating?*

3. *How do you plan to use the module information in your job?*

4. *How do you think the module could be improved?*

*I verify that I have successfully completed Module No. 321-036*

*Title **Transfer Efficiency***

*Signature \_\_\_\_\_*

*Date \_\_\_\_\_*



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*This module was developed by the Graco Technical Communications Department with assistance from the following individual:*

Glen Muir

*The Graco Concept and Theory Training program consists of the following topics:*

Fluid Basics  
Atomization  
Electrostatic Spray Finishing  
Safety  
Airspray Technology  
Fluid Types: Paints and Other Coatings  
Fluid Types: Lubricants  
Fluid Types: Sealants and Adhesives  
Airless Atomization  
Spraying Techniques  
Transfer Efficiency  
Fluid Movement  
Fluid Controls  
Pumps  
Motors and Power Sources  
Plural Component Paint Handling  
Plural Component Sealant and Adhesive Handling  
Paint Circulating Systems  
Automatic Finishing  
Lube Reels and Dispense Valves  
Lube Metering Systems  
Electronic Fluid Management Systems