Fluid Basics

Concept and Theory Training

GRACO®

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Introduction

Welcome to ***Fluid Basics***, a learning module in Graco's concept and theory sales training series. 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 products depends in part on how well you learn the basics and then apply this knowledge to addressing your customers' needs.

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.

Overview

To be effective in the marketplace, Graco and distributor sales people must understand the basic terms and concepts related to the fluids that move through Graco products. This module, ***Fluid Basics,*** introduces those basic terms and concepts and shows how they relate to the day-to-day world of Graco product specification and sales.

How to Use this Module

The basic concept and theory 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 to make the learning process convenient and productive:

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

Learning Objectives

Each section of material 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 and aid your learning. Where 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.

Basic Fluid Terminology

Learning Objectives

To discuss your customers' needs and show how Graco systems can satisfy those needs, you must understand some basic terms and concepts about fluids. This section defines those terms and shows you how they fit into your day-to-day work. After completing this section, you will be able to:

- State definitions of the most basic terms relating to the fluids commonly moved through Graco products.
- Explain every-day Graco usage of those terms.

Fluid, Liquid, and Material

In the most precise dictionary definition, a *liquid* is a substance wherein molecules move freely among themselves, but do not tend to separate like those of a gas. Similarly, in the most precise terms, a *fluid* is any gas or liquid that may be caused to flow.

But at Graco—and throughout the remainder of this training module—we commonly use *fluid* instead of *liquid*. This is a matter of practicality since the fluids that commonly move through Graco products are liquids. The major types of fluids commonly moved through Graco products are:

- Paints and other coatings
- Solvents and thinners
- Adhesives
- Fuels
- Sealants
- Lubricants
- Inks

At Graco and in industry at large, the word *material* is used in two different ways. We refer to the huge range of solid substances from which products are manufactured as materials. For example, you might hear an engineer employed by your customer say, "We need the materials in the body of this pump to be stainless steel and brass." But we also use *material* as another word—along with fluid and liquid—to refer to the substances moved through Graco products. For example, you might hear your customer say, "I need to pump about 100 gallons (379 liters) of material a day." Typically, we reserve this latter usage of *material* for the liquids being pumped.

Evaporation and Sublimation

Evaporation is the process of conversion of a fluid to a gas. Sublimation is the process of conversion of a solid directly to a gas with no liquid phase in between. Both of these conversions result from heating a substance or from reducing the pressure on a substance.

Suspensions and Solutions

A suspension is a mixture of a fluid and small solid particles. Paint is a suspension commonly moved through Graco products. The suspended particles in paints are usually pigments (coloring agents) and fillers that change the consistency and adhesion characteristics of the paint. If allowed to remain at rest, gravity will cause the particles in a suspension to settle to the bottom of the container.

A suspension is fundamentally different from a solution. In a solution, the mixing of two substances takes place at the molecular level and is completely homogeneous throughout. A common example of a solution is salt water. The solid in a solution is said to be dissolved. Dissolved material will not settle to the bottom of the container, no matter how long it is left at rest. Only chemical processes, such as evaporation of the fluid, will cause the solid to “come out of solution.”

Settling Out: a Common Problem

The phenomenon referred to above—the settling out of solids in a suspension—is a problem with the most common type of fluid moved in Graco systems: paint. If we do not prevent settling, two kinds of problems will result. First, solid paint particles may clog filters and other system components; this is commonly referred to as packing out. Second, settling may lead to application problems. For example, in the automotive industry, settling out of paints has led to problems of color-matching from one part of a car to another.

Graco fluid handling systems often include components whose role is to create and maintain mixing of suspensions so that solids do not settle out. In the home paint market, initial mixing may be achieved with a shaker, as shown at left in Figure 1. In the industrial market, initial mixing is achieved by tumblers and agitators, as shown at center and right in Figure 1:

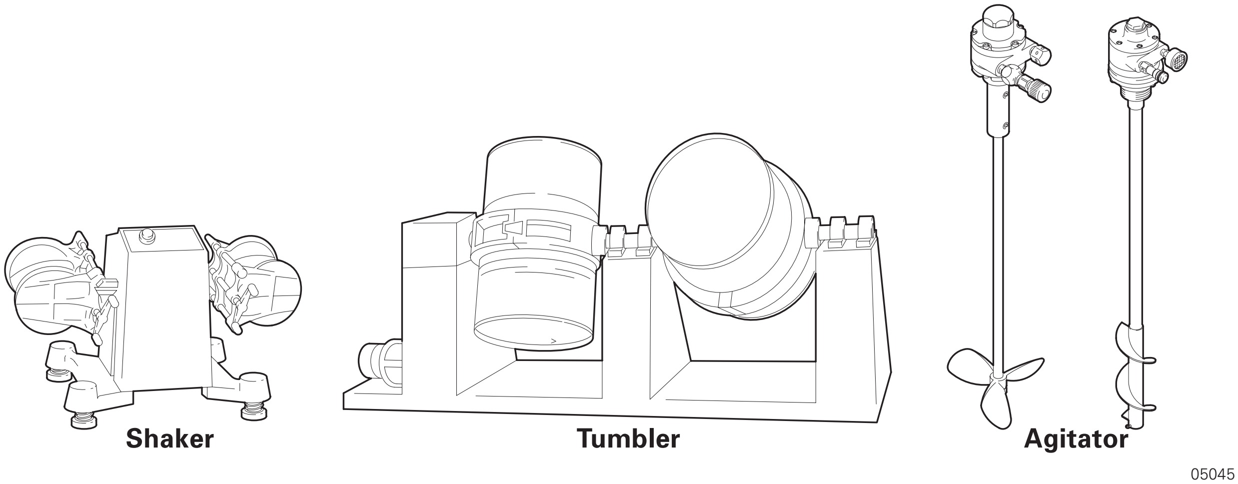

Figure 1 Types of equipment used to maintain mixture in a suspension: at left: shakers, typical in the home paint market; at center and right: tumblers and agitators, typical in the industrial market. Note: Graco does not manufacture shakers or tumblers.

In industrial systems, once a homogeneous mixture is achieved, that homogeneity may be maintained with agitators, such as the types shown in Figure 1. Or the fluid may be constantly pumped through the system to maintain the suspension. Such a system is called a recirculating system. Figure 2 shows a recirculating system:

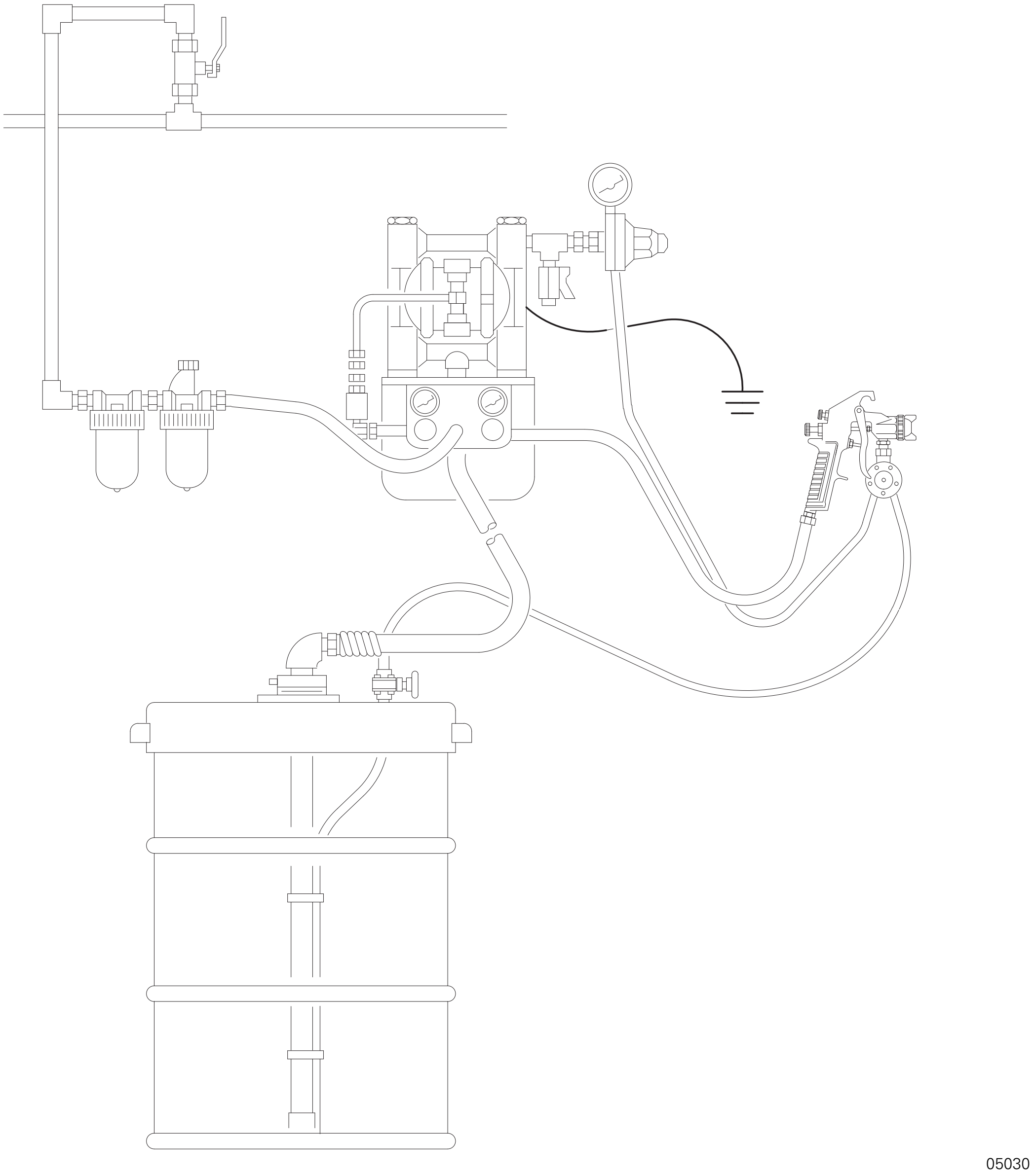

Figure 2 A Graco recirculating system; fluid is kept in constant motion to prevent settling of solids.

Progress Check

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

1. What term do we commonly use at Graco instead of liquid? ______________________________ .

2. Name five of the seven major types of fluids that are moved in Graco systems:

   ____

   ____

   ____

   ____

3. At Graco, we often use the word *material* to refer to a fluid moving through a Graco system. What is the other common Graco usage of *material*?

   ____

4. Select the statement that correctly defines the difference between a suspension and a solution:
   a. In a suspension, gravity can separate the solid from the fluid, but in a solution, only chemical processes will separate the two components.
   b. In a solution, gravity can separate the solid from the fluid, but in a suspension, only chemical processes will separate the two components.
   c. A suspension is a mixture of a solid and a fluid, while a solution is a chemical compound.
   d. A solution contains larger particles than a suspension.

5. Explain the term, "packed out."

   ____

   ____

6. Select all devices that might be used to maintain a suspension once it had been achieved:
   a. Tumblers
   b. Shakers
   c. Pumps
   d. Agitators

For items 7 through 10, match the terms with their definitions:

Terms

a. Sublimation
b. Suspension
c. Solution
d. Evaporation

Definitions

___ 7. The process of transforming a liquid to a gas.

___ 8. A mixture of solid particles and a fluid.

___ 9. A combination at the molecular level of a fluid and a solid.

___ 10. The process of transforming a solid directly to a gas with no intermediary liquid phase.

Answers to Progress Check

1. Fluid
2. Paints and coatings, adhesives, sealants, inks, solvents and thinners, fuels, lubricants
3. A solid substance from which products are manufactured.
4. a. In a suspension, gravity can separate the solid from the fluid, but in a solution, only chemical processes will separate the two components.
5. "Packed out" is a term used to describe a clog in a system caused by solid particles that have settled out of a fluid.
6. After a suspension has been achieved, pumps and agitators could be used to maintain it.
7. d. Evaporation is the process of transforming a liquid to a gas.
8. b. Suspension is a mixture of solid particles and a fluid.
9. c. Solution is a combination at the molecular level of a fluid and a solid.
10. a. Sublimation is the process of transforming a solid directly to a gas with no intermediary liquid phase.

Fluid Properties

Learning Objectives

To correctly and reliably recommend Graco products to your customers, you need to understand the properties of the fluids that will be moving through those products. This section introduces you to those properties. After completing this section, you will be able to:

- State the basic properties of fluids, including terms of expression and methods of measurement.
- Explain how to use data on each of the basic properties of fluids to help specify Graco products for your customers.
- Distinguish among the various flow behaviors of fluids and describe how these differences are relevant to Graco products.

Viscosity

Viscosity is the resistance of a fluid to flowing. Thus, the more a fluid resists flowing, the higher its viscosity is said to be. For example, axle grease is much more *viscous* than motor oil and motor oil is much more viscous than gasoline. To move a fluid, you must overcome its viscosity. And since the purpose of Graco products is to move fluids, it is safe to say that viscosity is the single most important property of a fluid to consider when you are recommending Graco products.

The viscosity of a given fluid will vary predictably with changes in many factors. The most important of these factors is temperature. In fact, to be meaningful, a viscosity rating must always be stated in conjunction with the temperature of the fluid. The viscosities of virtually all fluids decrease as their temperatures increase.

When fluids are in motion—as they are sooner or later in all Graco systems—viscosity is also directly related to another factor: *shear*. Shear is the slipping of one layer of a fluid relative to an adjacent layer. To visualize this concept, think of fluid layers that are just one molecule thick; imagine the drag that results as the layers of molecules move past each other. Shear is expressed as the relationship among several factors, including the force imparted to one surface of a fluid, the resulting velocity of that layer, and the thickness across the layers. Shear and its relationship to viscosity are discussed in more detail later in this module.

Centipoise: Standard Unit of Viscosity

The standard unit of viscosity is the poise (named in honor of Dr. J. Poiseuille). But since the poise is a rather large and inconvenient unit, the centipoise—1/100 of a poise—is customarily used. The abbreviation for centipoise is either cP or cp. Water establishes the base point of the centipoise scale. Pure water at a temperature of 68.4° F (20.2° C) has an absolute viscosity of one cp. (*Absolute viscosity* is defined on the next page.) Figure 3 is a list of some fluids commonly moved through Graco equipment and their viscosities at 70° F (21° C). Other units of viscosity include SUS and ISO numbers for lubricating oils and NLGI numbers for greases.

Viscosities of Common Fluids

in cp at 70° F (21° C)

Hot melt glue	30,000,000
Shortening (Crisco brand)	1,200,000
Ketchup (Heinz brand)	50,000
Ink	45,000
Oil - SAE 70	1,600
Spar varnish	420
Oil - SAE 40	319
Oil - SAE 30	200
Linseed Oil (raw)	28
Milk	3
Water	1
Benzene	0.3

Figure 3 Viscosities of common fluids.

Measuring Viscosity

Since viscosity is so important in characterizing fluids, you need to know how viscosity is measured. Following is information on several devices used to measure viscosity: the Brookfield Viscometer, standardized cups, and the Saybolt apparatus.

Absolute Viscosity

When viscosity is measured by any system that does not depend on gravity to pull a fluid through measuring apparatus, the measured viscosity is called an *absolute viscosity*. The most common device used to measure absolute viscosity in paint and coating manufacturers' laboratories is the Brookfield Viscometer (Figure 4). This device registers a fluid's resistance to the rotation of a disk suspended in the fluid. The result is expressed in cp and reported along with the type of disk used—stated as the "spindle number"—and the fluid temperature.

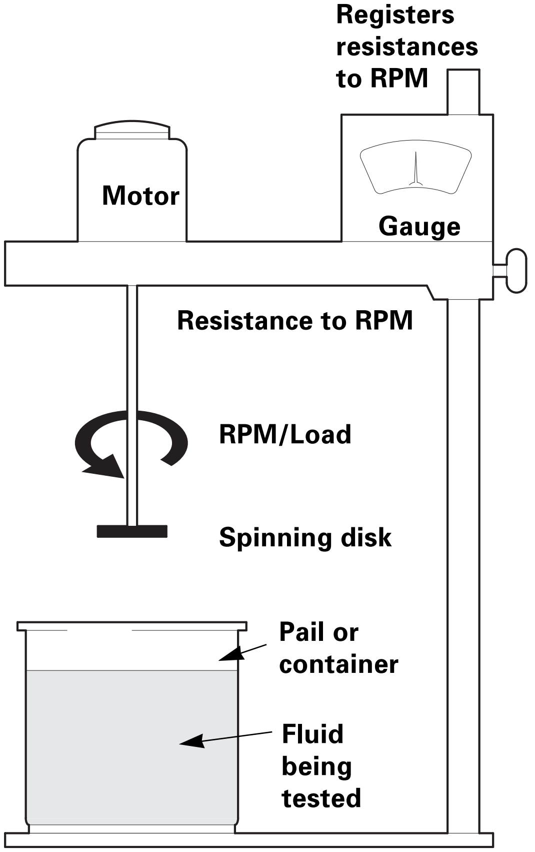

Figure 4 Brookfield Viscometer.

Kinematic Viscosity

Any time viscosity is measured with a device that depends on gravity to pull a fluid through some apparatus, we say the result is the fluid's *kinematic viscosity* (also sometimes called dynamic viscosity). You are likely to find kinematic viscosities stated for many fluids, including paints, solvents, inks, and oils. The most common approach is to measure the time it takes for a given volume of fluid to run through a hole in the bottom of a standardized metal cup. The most common types of cups are called Zahn, Ford, and Shell cups. Each type is manufactured in a range of sizes for various viscosity ranges.

The most precise way to state kinematic viscosity is in *stokes* or in centistokes (1/100 of a stoke). But in everyday use, you also may hear someone state viscosity in terms of the number of seconds a fluid took to flow through a given type of cup. Figure 5 shows common types of cups used to make these measurements.

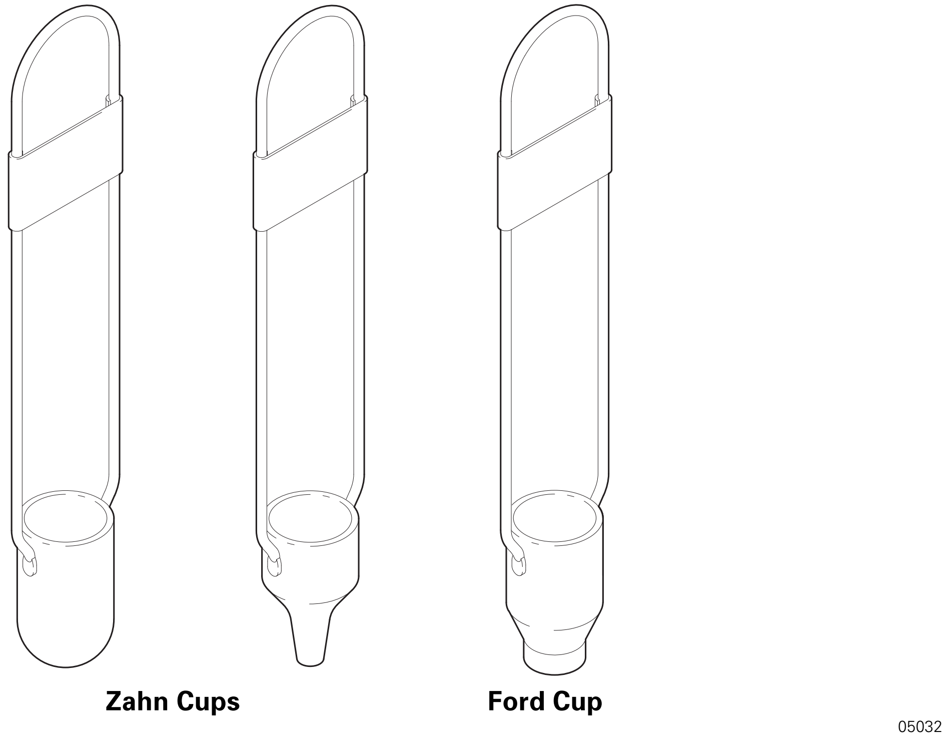

Figure 5 Cups used for measuring viscosity: The two at left are Zahn cups; the one at right is a Ford cup. Cups may or may not have wire handles as shown.

In the lubricant industry, another system is commonly used to measure kinematic viscosity: The *Saybolt Universal* system. The Saybolt apparatus is a brass cup suspended in a constant-temperature liquid bath. The unit of measure is the time in seconds required for 60 milliliters of fluid to flow through a standard-sized hole in the bottom of the cup at a given temperature. Measurements are expressed in *Saybolt Universal Seconds* (SUS) at the given temperature, for example 350 SUS at 100° F (38° C.) The relationship between SUS and centistokes is:

$$\text{SUS} = \text{centistokes} \div .216$$

The relationship between kinematic viscosity in centistokes and viscosity in centipoise is:

$$\text{centistokes} \times \text{density (at a given temperature)} = \text{centipoise}$$

Specific Gravity

The *specific gravity* of a liquid or solid—abbreviated s.g.—is defined as the ratio of the weight of a given volume of the material to the weight of an equal volume of water:

$$\text{s.g.} = \frac{\text{weight of a given volume of a material}}{\text{weight of an equal volume of water}}$$

Example; English measurements are figured using lbs/ft^3, metric measurements are figured using grams/cc. Since s.g. is a ratio no configuration is needed. The weight of a cubic foot of water is 62.4 pounds. If one cubic foot of a certain paint weighs 80 pounds, its specific gravity is:

$$80 / 62.4 = 1.3$$

The specific gravities of most paints and other surface coatings are between 1 and 1.5. You must specify specialized heavy-duty equipment for moving fluids with specific gravities above 2.

You will need to determine the pressure loss due to specific gravity of a fluid whenever your customer must pump a fluid upward through a Graco system. Due to gravity, more and more pressure will be lost as the fluid is pumped higher and higher. This pressure loss will be proportional to the fluid's specific gravity:

English - pressure loss/vertical foot = s.g. x 0.44 psi

Metric - pressure loss/vertical meter = s.g. x 0.1 bar

Take the paint mentioned as an example. Its specific gravity is 1.3. Therefore, its pressure loss per vertical foot will be:

1.3 x 0.44 = 0.57 psi (.04 bar)

Imagine that we are evaluating the possibility of using a siphon-feed system that works at atmospheric pressure, or app. 14.7 psi (1.0 bar)(typical value for a siphon-feed system) to pump this paint up 20 feet, (6.1 meters) where the paint must be sprayed. Applying the pressure loss formula, we find:

20 feet (6.1 meters) x 0.57 psi (.04 bar) / vertical foot = 11.4 psi (.79 bar)

If we used this system with this paint we would be able to siphon feed, because atmospheric pressure is greater than the pressure drop in the siphon tube 14.7 - 11.4 = 3.3 psi (1.0 - .79 = .21 bar).

Density

The *density* of a fluid (or any other material) is defined as its weight per unit volume, expressed in grams per cubic centimeter or pounds per cubic foot. For example, as stated earlier, the density of water is 62.4 lbs/ft^3 (1 gram/cc).

Surface Tension

Surface tension, a normal result of the molecular structure of a fluid, is a force that tends to minimize and constrict the surface of a fluid. Most surface tension-related problems will arise in connection with paints and other coatings. The most common of these problems is the formation of an uneven coating when surface tension of the paint is greater than that of the substrate. In most cases, this is not a problem you can solve; it must be referred to the paint supplier who may recommend a lower-surface tension paint or may actually change the formulation of the paint to lower its surface tension.

Shear

Shear is the slipping or sliding of one part of a fluid relative to an adjacent part, as illustrated in Figure 6:

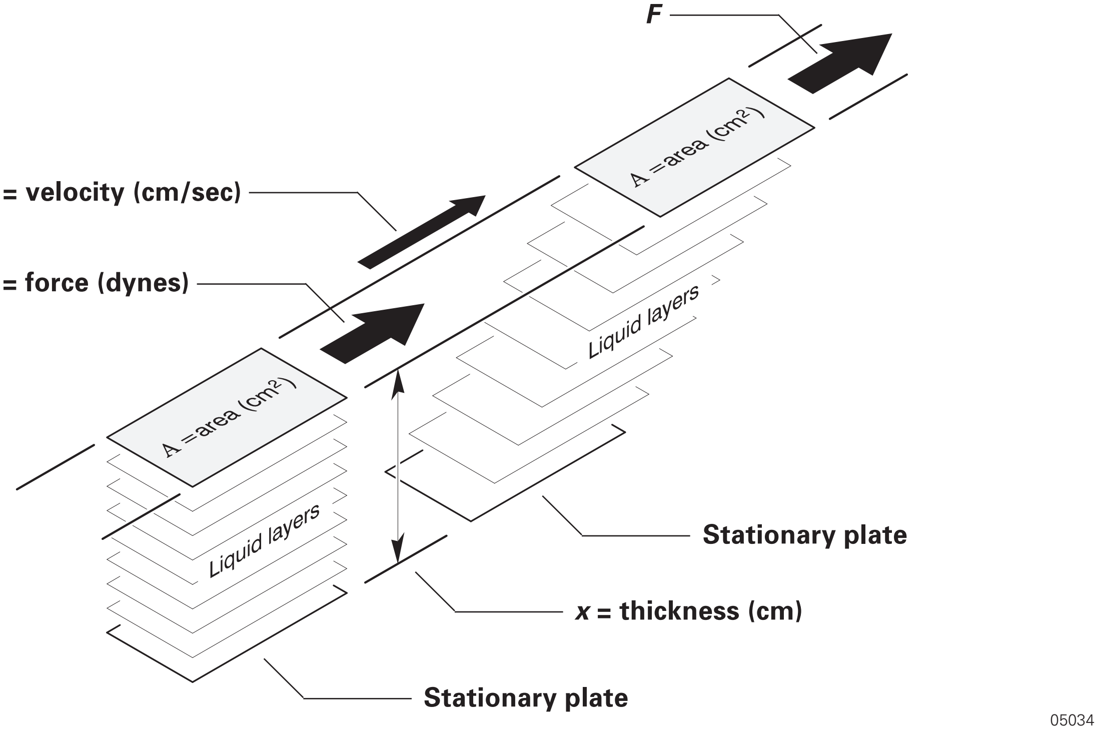

Figure 6 Model of a fluid. Left: force is applied to the fluid's upper surface, while no force is applied to the fluid's lower surface. Right: resulting shear.

Shear Rate (or Rate of Shear)

Shear rate is the rate of slip within a flowing fluid. The average or mean shear rate of a fluid in a pipe or tube is the average velocity divided by the radius of the tube:

$$\text{shear rate} = \frac{\text{average velocity}}{\text{radius}}$$

Shear Stress

Shear stress is the term used to refer to any force that tends to impart motion to a fluid. Stirring and pumping are typical forces that impart shear stress to fluids. Shear stress is expressed as a specified force exerted on a specified area:

$$\text{shear stress} = \frac{\text{force}}{\text{area}}$$

Relationship Between Viscosity and Shear

The relationship between viscosity, shear stress, and shear rate is expressed by the following formula:

$$\text{viscosity} = \frac{\text{shear stress}}{\text{shear rate}}$$

Newtonian Fluids

In a *Newtonian fluid*, at a given temperature and pressure, there is a linear relationship between shear rate and shear stress, and viscosity is constant irrespective of shear rate:

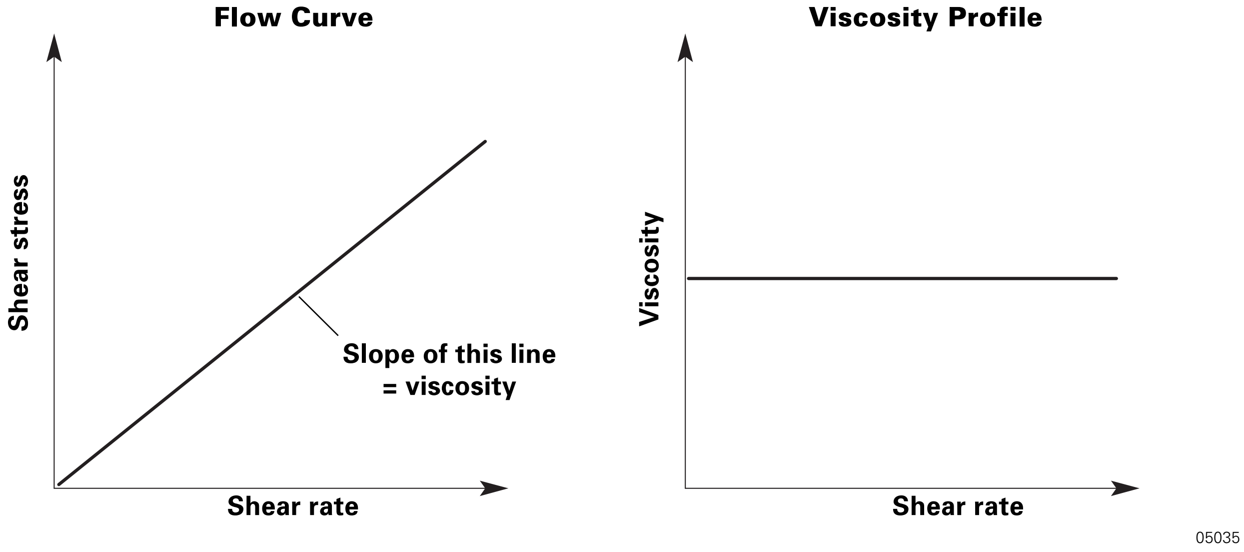

Figure 7 Newtonian fluid.

Remember that, as stated on page 14 and as expressed in Figure 7, the viscosity of a fluid may be derived by dividing shear stress by shear rate.

Newtonian fluids are named after Sir Isaac Newton, who first deduced these relationships. Examples of Newtonian fluids include water and most mineral oils.

Non-Newtonian Fluids

The viscosities of *non-Newtonian* fluids vary with shear rate. Therefore, it is misleading to state a single viscosity for these fluids. Instead, the term *apparent viscosity* is used to describe a non-Newtonian's viscous properties at a given shear rate. You will encounter three types of non-Newtonian fluids:

- Plastic
- Pseudoplastic
- Dilatant

Following are discussions and examples of each type of non-Newtonian fluid.

Plastic

As shown in Figure 8, a *plastic* fluid has a definite *yield point*. That means a certain minimum shear stress is necessary before any flow will take place. A typical plastic fluid is tomato ketchup: Turning the bottle upside down may produce zero movement, but striking or shaking the bottle hard enough suddenly produces a gushing flow. As shown in Figure 8, in a fluid that exhibits plastic characteristics, viscosity decreases as shear rate increases.

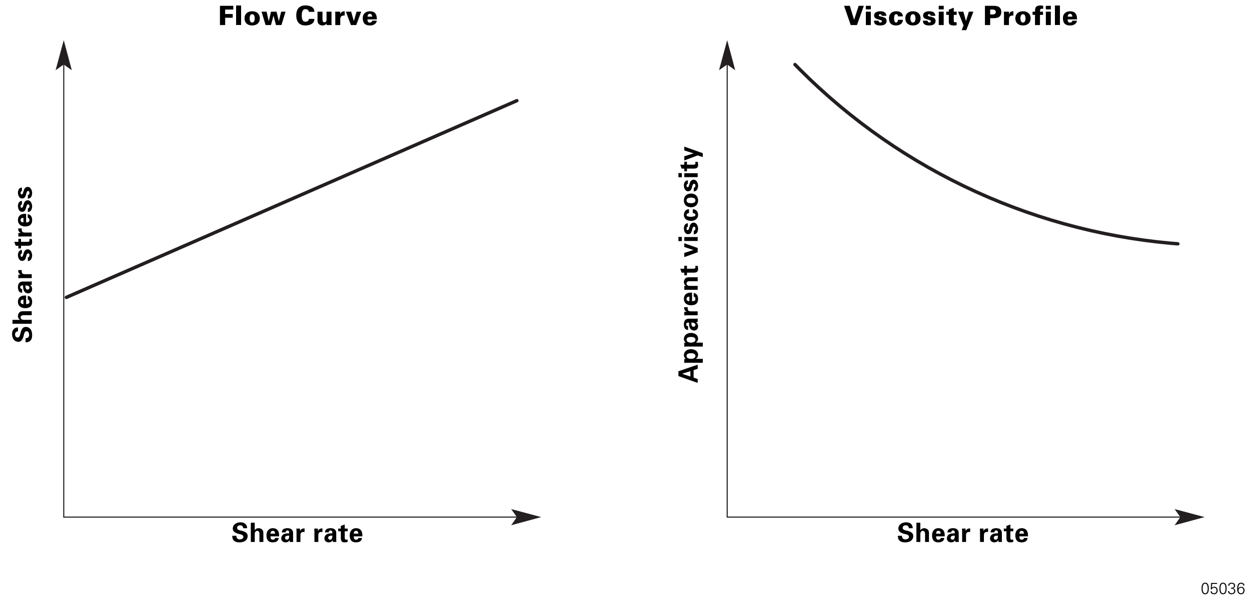

Figure 8 Plastic fluid.

Pseudoplastic

As with a plastic fluid, the apparent viscosity of a *pseudoplastic* fluid decreases with increased shear rate (Figure 9). But unlike plastic fluids, pseudoplastic fluids have no yield point—that is, even a small amount of shear stress produces some flow. Many water-borne paints and other water-borne emulsions exhibit pseudoplastic characteristics.

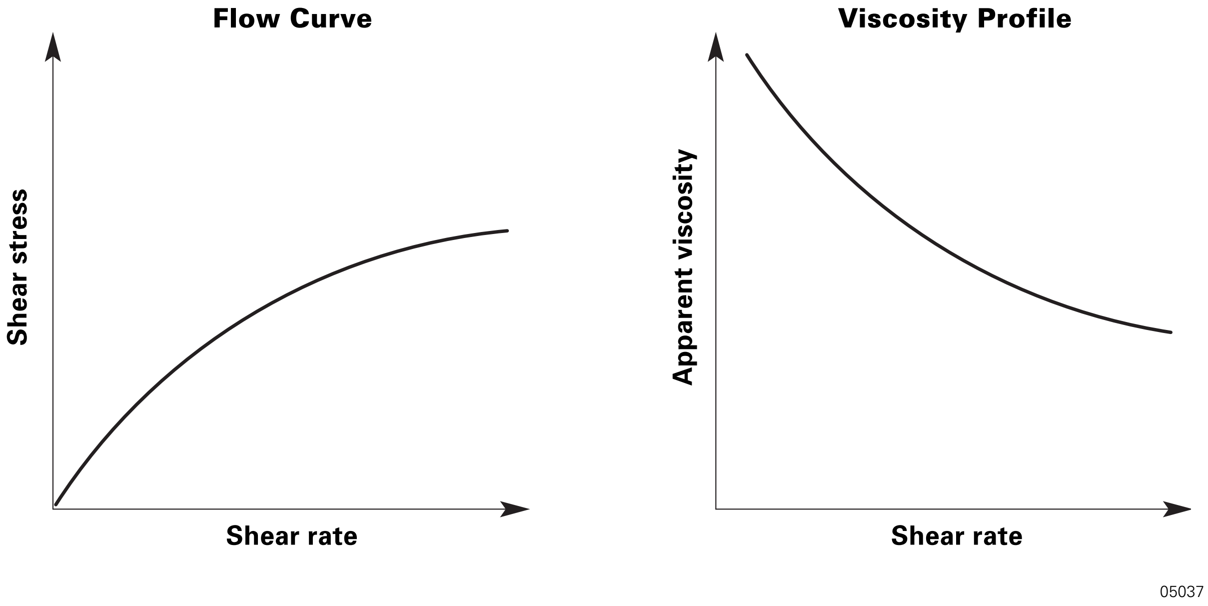

Figure 9 Pseudoplastic fluid.

Thixotropic: A Sub-type of Pseudoplastic Fluids

Thixotropic fluids are a special sub-type of pseudoplastic fluids. Like other pseudoplastic fluids, as constant shear is applied, a thixotropic fluid's apparent viscosity is reduced to some minimum value. But as shear decreases or stops, a thixotropic fluid's apparent viscosity builds back up at a rate different from the rate at which it decreased. This property is designed into paints to inhibit the settling out of solid particles suspended in the paint.

Dilatant

As shown in Figure 10, a *dilatant* fluid has the opposite characteristic of a pseudoplastic material—that is, a dilatant fluid's apparent viscosity **increases** with an increase in shear rate. Some dilatants even solidify at high shear rates. Common examples include some printing inks, starches, and some confections including taffy.

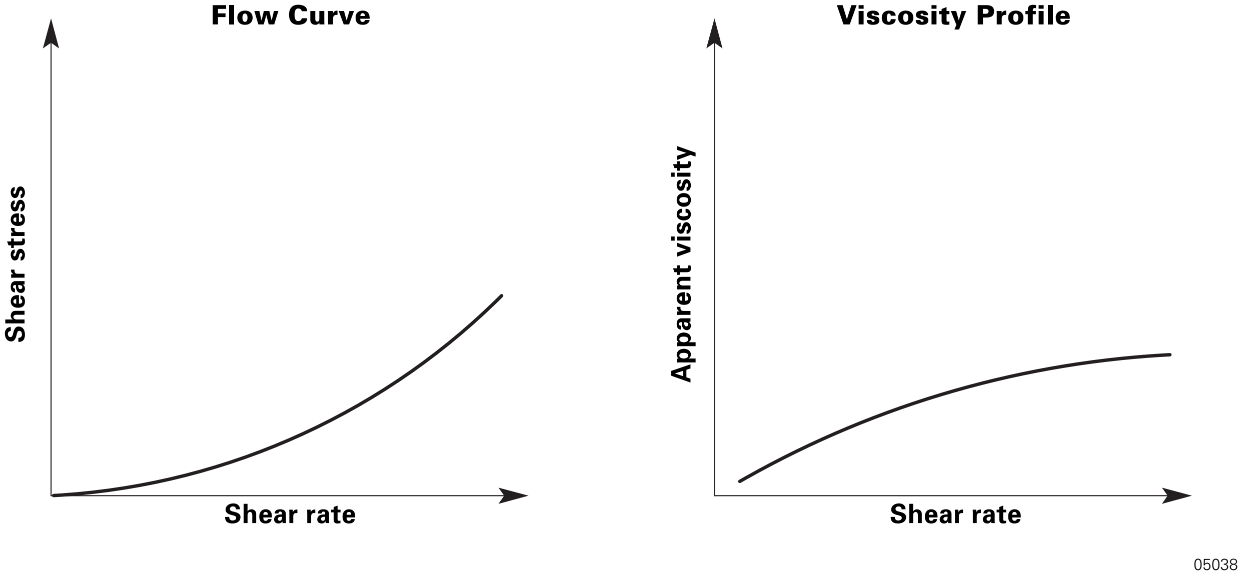

Figure 10 Dilatant fluid.

Flow and Frictional Pressure Loss

Pressure causes fluid in a system to flow, and we say a flowing fluid has energy of motion or *kinetic energy*. But as a fluid moves through tubing and other system components, friction causes a loss of kinetic energy as heat. An important result is that pressure is reduced. This phenomenon, illustrated in Figure 11, is called *frictional pressure* loss or simply *pressure drop*.

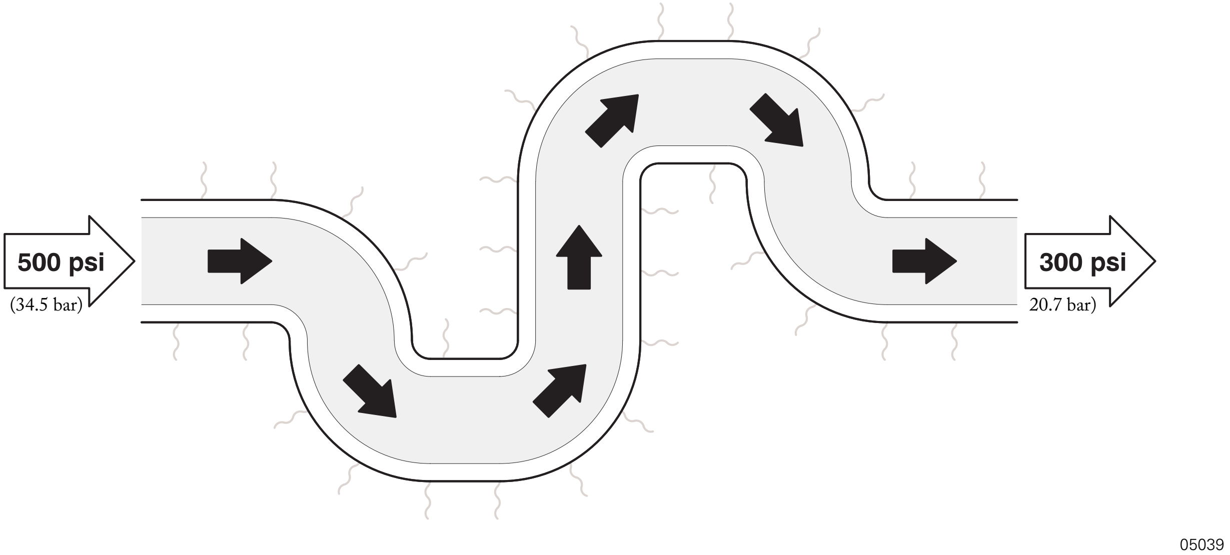

Figure 11 Frictional pressure loss.

To calculate frictional pressure loss in pounds per square inch in a pipe or tube length, we use Darcy's law:

$$P = \frac{0.000273\ Q \times V \times L}{D^4}$$

where:

P = Pressure loss in pounds per square inch.
Q = Flow rate in gallons per minute.
V = Viscosity of fluid in centipoise.
L = Length of pipe in feet.
D = Inside diameter of tube or pipe in inches.

For example, if your customer wants to pump milk, which has a viscosity of 3 centipoise, at a rate of 50 gallons per minute through 100 feet of tubing that has an inside diameter of 1.25 inches, you would calculate the pressure loss as:

$$\frac{0.000273 \times 50 \times 3 \times 100}{1.25^4} = 1.68 \text{ psi lost}$$

We also can calculate frictional pressure loss in kilograms per square centimeter, in which case Darcy's law takes this form:

$$P = \frac{69{,}300\ Q \times V \times L}{D^4}$$

where:

P = Pressure loss in kilograms per square centimeter.
Q = Flow rate in liters per minute.
V = Viscosity of fluid in poise.
L = Length of pipe in meters.
D = Inside diameter of tube or pipe in millimeters.

Note: Values of D^4 for common sizes of tubing and piping are listed in the *Graco Industrial Fluid Handling Products* catalog.

Laminar Flow and Turbulent Flow

As shown in Figure 12, two types or patterns of flow may develop in a piping system: *laminar flow* and *turbulent flow*:

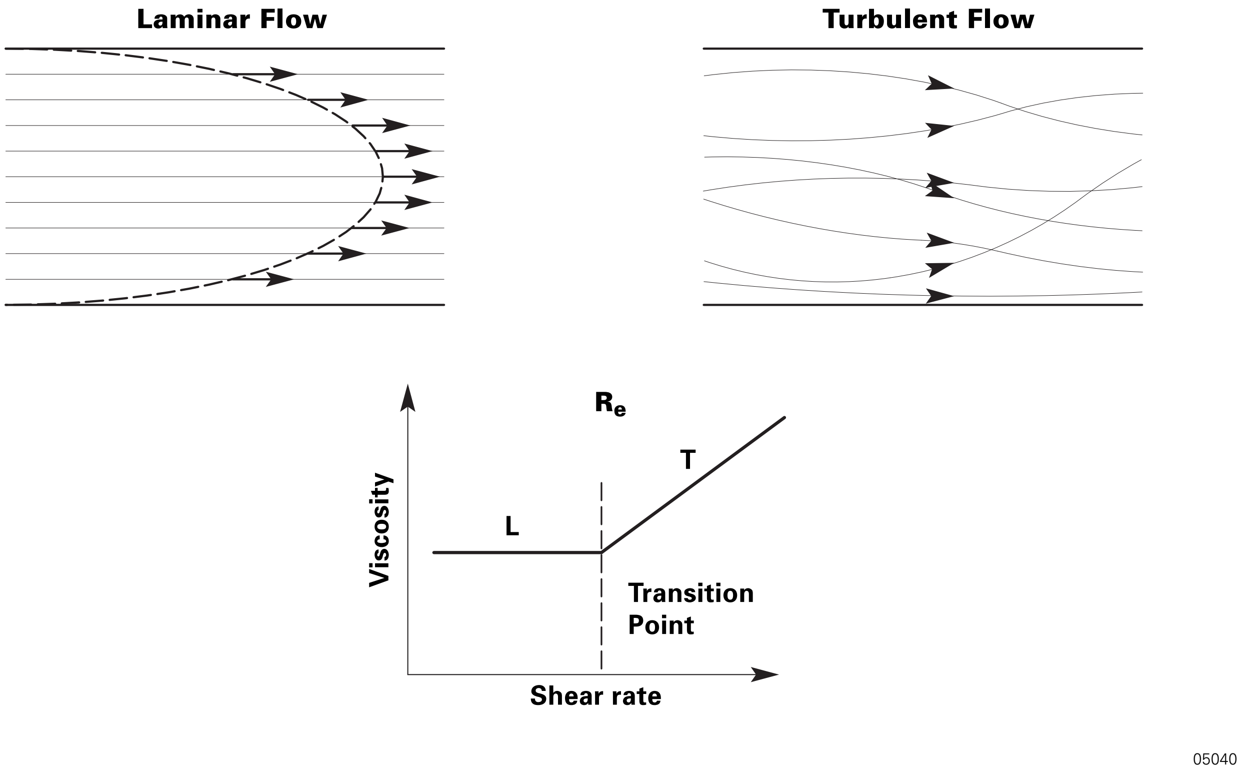

Figure 12 Laminar and turbulent flow.

The idea of laminar flow is that molecules of a fluid act as though they were arranged in coherent layers—concentric layers if the fluid is in a tube. In turbulent flow, eddies or "whirlpools" in the flow pattern reduce flow and cause an increase in the apparent viscosity of the fluid. The point at which flow changes from laminar to turbulent is called the *Reynolds Number*, labeled R_e in Figure 12. The Reynolds Number is calculated as follows:

$$R_e = \frac{\text{velocity x tube length x s.g.}}{\text{viscosity}}$$

Most fluids change from laminar to turbulent flow when R_e is between 2000 and 4000. You should know about Reynolds numbers because you may hear them discussed, but you also should know that Reynolds numbers are *not significant in Graco systems* because flow velocities in our systems are kept low enough to insure that Reynolds numbers are below 2000. Thus, turbulent flow very seldom presents a problem.

Pressure

Graco pumps exert pressure on fluids to make them flow. The 18th century scientist, Blaise Pascal, showed that fluid pressure in a closed system is the same throughout the system. This theorem is called *Pascal's law*. As illustrated in Figure 13, we state pressure in terms of force per unit area—pounds per square inch in English units; grams per square centimeter in metric units.

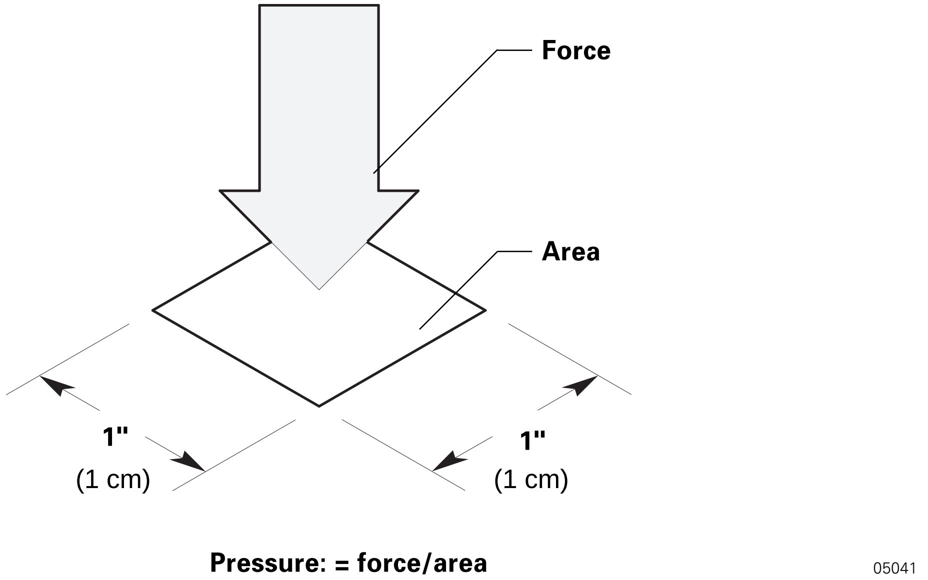

Figure 13 We express pressure as a force exerted evenly on a given surface area.

Figure 14 shows pressures you can expect to encounter in some common Graco pumping systems:

Typical Pressure Ranges in Graco Systems

Paint circulation	< 500 psi (34.5 bar)
Air spray supply pressure	50 - 100 psi (3.4-6.9 bar)
Grease	≥ 4000 psi (276 bar)
Airless spray of architectural coatings	2000 - 3000 psi (138-207 bar)
Polyvinylacetate (white glue)	100 - 500 psi (6.9-34.5 bar)
Paint-shop auto body sealant dispensing	2000 - 5000 psi (138-345 bar)
Solvent transfer and supply	< 100 psi (6.9 bar)
High-pressure water cleaning	1000 - 3000 psi (207 bar)

Figure 14 Typical pressure ranges in Graco systems.

Measuring Pressure

We commonly measure pressure in a closed fluid handling system with a *bourdon tube gauge*—often simply called a bourdon gauge. A typical bourdon gauge is shown in Figure 15.

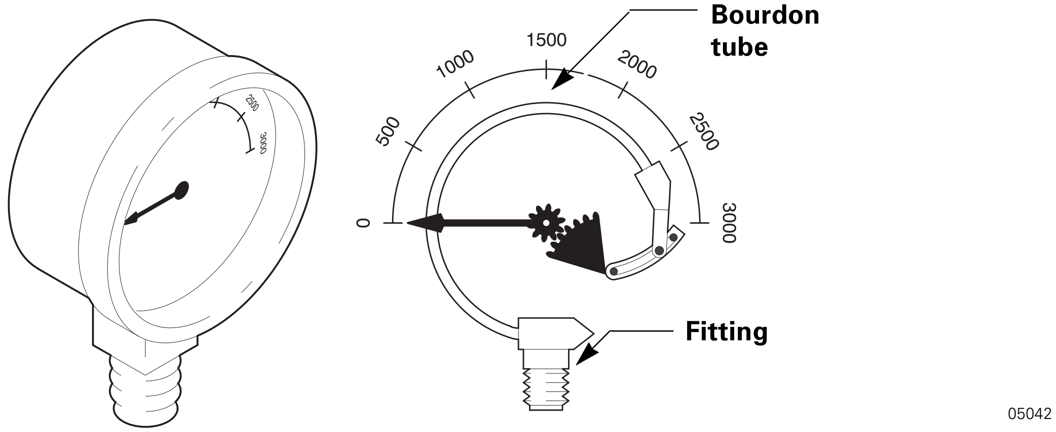

Figure 15 Left: exterior view of a bourdon tube gauge. Right: schematic diagram of internal mechanism of a bourdon tube gauge.

A bourdon gauge is inserted directly into a fluid handling system with a fitting so it registers whatever pressure is in the system. (Remember Pascal's law: fluid pressure in a closed system is the same throughout the system). As pressure in the system increases, the thin, curved *bourdon tube* inside the gauge straightens somewhat. Through gears, the straightening of the tube is converted to the motion of an indicator needle, which shows the system pressure.

Gauge and Absolute Pressure Measurement Scales

As shown in Figure 16, two different scales are used for expressing pressure values.

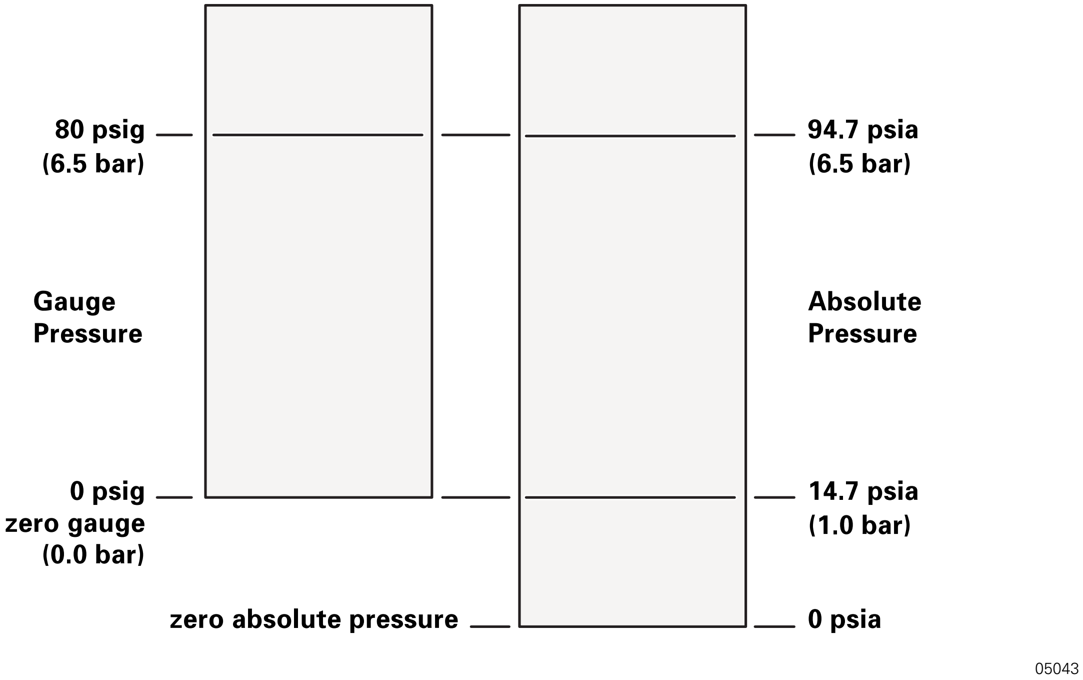

Figure 16 Left: Gauge pressure scale. Right: absolute pressure scale.

The absolute pressure scale begins with zero pounds per square inch absolute (0.0 bar) (psia), as would exist in an absolute vacuum. Gauge pressure is a scale developed for convenience in expressing pressures in closed systems, such as Graco pumping systems. The gauge pressure scale equates zero pounds per square inch(0.0 bar) gauge (psig) with 14.7 (1.0 bar) psia, because this is the nominal atmospheric pressure at sea level. In other words, gauge pressure disregards atmospheric pressure. Therefore, to convert gauge pressure to absolute pressure, we simply add 14.7 psi (1.0 bar):

gauge pressure + 14.7 psi (1.0 bar) = absolute pressure

Progress Check

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

1. Select the most important property of a fluid to consider when you are recommending Graco products:
   a. Specific gravity
   b. Density
   c. Viscosity
   d. Surface tension

2. Select all of the following statements that are true about water:
   a. Pure water at a temperature of 68.4° F (20.2° C) has an absolute viscosity of one cp.
   b. The specific gravity of water is 1 centipoise.
   c. The viscosity of water is 1 SSU.
   d. The density of water is 62.4 pounds per cubic foot (1 gram/cc).

3. Select the devices that can be used to measure kinematic viscosity:
   a. Zahn cups
   b. Ford cups
   c. Shell cups
   d. Saybolt apparatus
   e. Brookfield Viscometer

4. Select the types of fluids for which kinematic viscosity is commonly stated:
   a. Paint
   b. Oil
   c. Taffy
   d. Solvent
   e. Adhesive

For items 5 through 9, match the fluid type with its viscosity characteristics:

Fluid Type

a. Newtonian
b. Plastic
c. Pseudoplastic
d. Dilatant
e. Thixotropic

Viscosity Characteristics

___ 5. Viscosity is constant irrespective of shear rate.

___ 6. Apparent viscosity increases and decreases at different rates.

___ 7. Apparent viscosity increases with an increase in shear rate.

___ 8. Apparent viscosity decreases with an increase in shear rate.

___ 9. Has a yield point from which viscosity decreases with an increase in shear rate.

10. State Pascal's law: ____

____

11. Which statement explains how a Bourdon Gauge works?
    a. Pressure in the system presses on one side of a electrical capacitor, which is inserted in an electrical circuit so that current flow is inversely proportional to system pressure.
    b. Pressure in the system straightens a metal strip, which is converted to the movement of a needle indicator.
    c. Pressure in the system forces a metal tube to straighten; the straightening is converted to the movement of a needle indicator.

For items 8 through 13, match the formulas with their desired results:

Terms

a. Shear stress
b. Shear rate
c. Vertical pressure drop
d. Centipoise
e. Absolute pressure
f. Frictional pressure loss (Darcy's law)

Definitions

___12. centistokes x s.g. =

___13. $\frac{.000273 \text{ x } Q \text{ x } V \text{ x } L}{D^4}$ = P (English) $\frac{69{,}300 \text{ x } Q \text{ x } V \text{ x } L}{D^4}$ = P (Metric)

___14. s.g. x 0.44 psi/foot = (s.g. x 0.1 bar/meter)

___15. $\frac{\text{average velocity}}{\text{radius}}$ =

___16. $\frac{\text{force}}{\text{area}}$ =

___17. gauge pressure + 14.7 psi = (1.0 bar)

Answers to progress check

1. c. Viscosity

2. a. and d. are true:

   Pure water at a temperature of 68.4° F (20.2° C) has an absolute viscosity of one cp.

   The density of water is 62.4 pounds per cubic foot (1 gram/cc).

3. a. Zahn cups, b. Ford cups, c. Shell cups, and d. Saybolt apparatus, are all used to measure kinematic viscosity.

4. a. Paint, b. Oil, and d. Solvent

5. a. Newtonian: Viscosity is constant irrespective of shear rate.

6. e. Thixotropic: Apparent viscosity increases and decreases at different rates.

7. d. Dilatant: Apparent viscosity increases with an increase in shear rate.

8. c. Pseudoplastic: Apparent viscosity decreases with an increase in shear rate.

9. b. Plastic: Has a yield point from which viscosity decreases with an increase in shear rate.

10. Pascal's law: Pressure in a closed system is the same throughout the system.

11. c. Pressure in the system forces a metal tube to straighten; the straightening is converted to the movement of a needle indicator.

12. d. Centistokes x s.g. = Centipoise

13. f. $\frac{.000273 \times Q \times V \times L}{D^4} = \frac{69{,}300 \times Q \times V \times VXL}{D^4} =$ Frictional pressure loss (Darcy's law)

14. c. s.g. x 0.44 psi/foot = (s.g. x 0.1 bar/meter) Vertical pressure drop

15. b. $\frac{\text{Average velocity}}{\text{radius}} =$ Shear rate

16. a. $\frac{\text{force}}{\text{area}} =$ Shear stress

17. e. gauge pressure + 14.7 psi = Absolute pressure

Factors to Consider When Selecting Internal System Materials

Learning Objectives

You must understand the characteristics of fluids that will be moved through a Graco system and must specify the internal materials of the system to accommodate those characteristics. This section presents the most important characteristics of fluids to consider when specifying the materials in a fluid handling system. After completing this section, you will be able to:

- Choose Graco system materials that are compatible with a variety of chemicals, including corrosive fluids.
- Choose Graco system materials that are compatible with abrasive fluids.
- Choose Graco system materials that are compatible with the curing chemistries of single-component and plural-component adhesives.

Corrosiveness of Fluids

Corrosion is the chemical combination of metals with oxygen to form oxides. For example, Figure 17 shows how, in the presence of an electrolyte, such as water, ions of Iron (Fe^{3+}) combine with hydroxyl ions (OH^-) to form iron oxide (Fe_2O_3), commonly called rust.

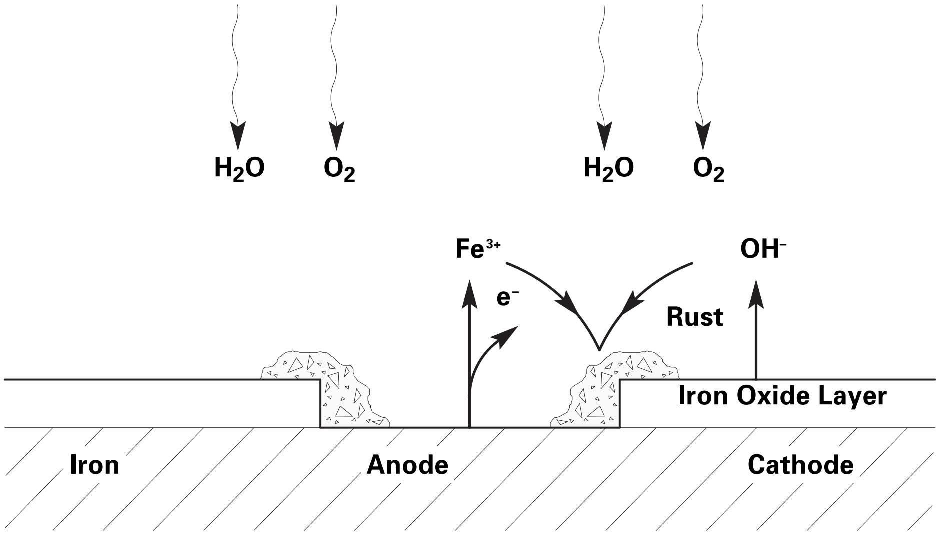

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Figure 17 How corrosion takes place.

Like iron, all metals have *positive* valences. In other words, metals are electron attractors. For corrosion to take place, there must be electrons available to combine with the metal ions. Many of the fluids that move through Graco systems have available electrons, and therefore may cause corrosion. Fluids with available electrons are called *acids* and are said to be *acidic*. Other fluids are like metals in that they are electron-attractors. These fluids are called *bases* and are said to be *alkaline*. Only the strongest bases will corrode metals. The amount of acidity or alkalinity of a fluid is expressed by its pH value. Water is said to be a neutral fluid and is therefore in the center of the pH scale with a pH value of 7.0. Decreasing pH values from 7.0 to 0.0 indicate increasing acidity. Increasing pH values from 7.0 to 14.0 indicate increasing alkalinity. Figure 18 shows pH values of some common fluids:

Approximate pH Values

acids

Hydrochloric, N	0.1
Sulfuric, N	0.3
Citric, 0.1N	2.2
Formic, 0.1N	2.3
Boric, 0.1N	5.2

bases

Sodium hydroxide, N	14.0
Trisodium phosphate, 0.1N	12.0
Ammonia, N	11.6
Borax	9.2

foods

Wine	2.8 - 3.8
Apple juice	2.9 - 3.3
Beer	4.0 - 5.0
Maple syrup	6.5 - 7.0
Cow milk	6.3 - 6.6

Figure 18 Approximate pH values of selected fluids.

Note:
A more complete list of pH values appears in the *Graco Industrial Fluid Handling Products* catalog.

Acidic fluids will corrode the internal metallic components of a fluid handling system. If a system's metal parts corrode, several problems are likely to occur:

- The resulting corrosion products (oxides) may become involved in secondary chemical reactions with the fluid being moved, thus contaminating it.
- The corrosion products may flake off and clog the system or contaminate the fluid being moved—or both.
- The corrosion action may deform a pump to the extent that it will not perform properly.

You must always determine the types of fluids that will be moved through a Graco system and must specify internal system materials accordingly. Figure 19 shows the materials you should specify when a Graco system will move fluids of various pH ranges:

pH Range	Fluid Handling System Materials to Specify
0 - 4	Stainless steels
4 - 6	All steel
6 - 8	All steel
8 - 10	All steel
10 - 14	Stainless steels

Figure 19 Guidelines for specifying fluid handling system materials.

Passivation

Graco *passivates* all stainless steel parts. *Passivation* is an acid dip process that removes the iron that is deposited during the forming or machining of a part. It is the final step in making every stainless steel part.

Chemical Compatibility of Fluids and Pump Materials

As stated earlier in this training module, you must specify Graco systems with internal parts that will not be corroded by the fluids to be moved in those systems. But corrosion is just one kind of damaging chemical reaction you must avoid in specifying the internal parts of Graco systems. In fact, there are many potential problems which may occur if a given material inside a Graco system comes in contact an incompatible fluid.

So how do you know which materials to specify for every possible fluid you might encounter? While this sounds like a daunting problem, reliable help is available. As you might imagine, most of the chemical compatibility problems you are likely to encounter have been encountered and solved before by others. The experience gained from Graco's many decades of dealing with chemical compatibility problems has been consolidated in one very useful reference source: the Graco *Chemical Compatibility Charts* in the *Graco Industrial Products* catalog.. You should always have this publication available when you are working with customers. It contains easy-to-use reference charts with the following information:

- Maximum operating temperatures of leather, elastomeric ("rubber"), and plastic materials commonly used as seals and packings in Graco systems.
- Cross-reference between scientific names and trade names of rubber and plastic materials.
- Rating (ranging between "excellent" and "not recommended") that show the chemical compatibility between hundreds of fluids and twenty-one materials commonly used as seals and packings in Graco systems.
- Ratings that show the chemical compatibility between hundreds of fluids and nine metals and alloys commonly used in Graco systems.

Abrasiveness of Fluids

The *abrasiveness* of a fluid—that is, its ability to scratch—is another factor you must consider when specifying the internal materials in a Graco system. As environmental concerns have increased, solvents previously used in paints and other fluids have been replaced by finely ground materials called *fillers*. Most common fillers are abrasive enough that they eventually will compromise the sealing capabilities of the packings and seals in Graco systems. In fact, some fillers are abrasive enough to eventually destroy the metals commonly used in Graco systems. To decide whether abrasiveness is important in choosing system materials, you must first identify the fillers that will be present in the fluids to be moved. Then consider two factors, *hardness* and *percent of filler by volume*:

Hardness

The Knoop Hardness Scale is commonly used to state the hardness of solid materials. For example, the Knoop Hardness value for many types of carbon steel is about 430. By comparison, the Knoop value for diamond—the hardest natural substance—is about 7000. Materials with higher numbers will abrade materials with lower numbers. Figure 20 shows hardness values for a few materials commonly used as fillers:

Material	Knoop Hardness (Kg / mm2)
Silica	820
Titanium Dioxide	660
Mica	520
Aluminum Oxide	2000
Cordierite	836

Figure 20 Knoop hardnesses of common filler materials.

Percent of Filler By Volume

In addition to knowing the hardness of a filler, you must also take into account the *amount* of the filler in the fluid being moved. Of course, the higher the percentage of fillers, the sooner the internal system components will be affected. Paints and other coatings are rated as to their "solids" content—that is, the percentage of fillers and other particulates they contain. While virtually everyone in the paint and coating industry refers to "low," "medium," and "high" solids content coatings, the definitions of these categories vary within the coating industry. Following is one typical set of values:

Low Solids = 20 - 30% solids
Medium Solids = 30 - 50% solids
High Solids = 50% or more solids

Figure 21 shows the kinds of materials you should specify in Graco system components when your customer will be moving medium- or high-solids fluids:

Component	Material to Specify for Medium- and High-solids Fluids
pump cylinders and rods	Chromium-plated steel If corrosion is also a problem: chromium-plated stainless steel
packings and seals	Leather or Ultra High Molecular Weight Polyethylene (UHMWPE) Leather is less expensive but is also less effective.

Figure 21 Materials to specify for medium- and high-solids fluids.

Progress Check

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

1. Select all characteristics of acidic fluids:
    a. pH values above 7.0
    b. Alkaline
    c. Electron donors
    d. Electron attractors

2. Select the statements that are correct:
    a. The pH of water is 14.0, at the top of the pH scale.
    b. The pH of water is 7.0, in the middle of the pH scale.
    c. The pH of water is 0, at the bottom of the pH scale.
    d. Fluids with pH's above 7.0 are acidic.
    e. Fluids with pH's below 7.0 are acidic.

3. Select the problems that may occur as a result of corrosion of metal parts in a Graco system:
    a. Corrosion products (oxides) may become involved in secondary chemical reactions with the fluid being moved, thus contaminating it.
    b. Corrosion products may flake off and clog the system or contaminate the fluid being moved—or both.
    c. Corrosive action may passivate the metals in the system, causing them to become highly acidic.
    d. Corrosion action may deform a pump to the extent that it does not perform properly.
    e. Corrosion may change the pH of the fluid being moved.

4. Passivation removes corrosion from stainless steel.
    a. True
    b. False

5. Your customer wants to pump toluene at room temperature in a Graco system that contains Teflon seals. In what reference document would you find information on whether the seals will stand up to the toluene?

6. Fill in the missing information in the right-hand column of this table:

pH Range	Fluid Handling System Materials to Specify
0 - 4	Stainless steels
4 - 6	
6 - 8	
8 - 10	
10 - 14	Stainless steels

7. Select the statement that explains why, in recent years, abrasiveness has become a greater concern to those of us who must specify materials in Graco systems:
   a. Manufacturers have begun producing paints with pigments that are composed of much more abrasive materials.
   b. Pressure levels in newer Graco paint-spraying systems are much higher than in previously specified systems.
   c. As environmental concerns have increased, solvents previously used in paints and other fluids have been replaced by fillers.

Answers to progress check

1. c. Electron donors

2. b. The pH of water is 7.0, in the middle of the pH scale.

   and

   e. Fluids with pH's below 7.0 are acidic.

3. a. Corrosion products (oxides) may become involved in secondary chemical reactions with the fluid being moved, thus contaminating it.

   b. Corrosion products may flake off and clog the system or contaminate the fluid being moved—or both.

   d. Corrosion action may deform a pump to the extent that it does not perform properly.

4. b. False (Passivation removes carbon steel particles from the surface of stainless steel.)

5. *Graco Chemical Compatibility Chart* in the *Graco Industrial Products* catalog

6.

pH Range	Fluid Handling System Materials to Specify
0 - 4	Stainless steels
4 - 6	All steel
6 - 8	All steel
8 - 10	All steel
10 - 14	Stainless steels

7 . c. As environmental concerns have increased, solvents previously used in paints and other fluids have been replaced by fillers.

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. _______ *Title*___________________________

Signature ____

Date ______________________

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

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Keith Weiss

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

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