How Clean is Clean?

by Paul Crumpler, Pollution Prevention Engineer

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Frying pans, cars, the Empire State Building, surgical instruments, machined aluminum light poles, and Rottweilers all have two things in common. All get dirty and somebody wants to clean them, whether they need it or not. The keys to cleaning are knowing the nature of the item to be cleaned, the nature of the soil to be removed, the number of items to be cleaned, and what will be done with the item after it is cleaned. When these items are known, an appropriate cleaning method can be chosen. Sometimes the choice is not to clean, as in the case of the Rottweiler. Some essential items to remember are that a perfectly clean part will cost more to produce, cost more to maintain cleanliness, generate more waste during cleaning, and often functions no better (and sometimes worse) than a part cleaned to a less lofty standard. Perfectly clean is also perfectly impossible to achieve.

The Importance of Specs

Specifications are often left to the imagination when cleanliness is required. "Oxygen clean," "free of oil and grease," and "remove all chips, oil, dirt, etc." are typical notes placed on engineering drawings. Besides being unmeasurable, they are often added by rote as part of standard drawing notes.

Pass / fail criteria are much better ways of specifying cleanliness. For example, a critical area of the part in question could be examined under magnification with a ten by ten millimeter (mm) field broken into 100, one millimeter squares. A maximum number of machining chips could be specified; for example, the part will be acceptable if no more than three machining chips are visible within the grid, with the largest chip no larger than 0.5 mm in any direction. The presence of oil, dust, or unidentified foreign material could also be specified in a similar manner. Other pass/ fail tests could be devised of varying sophistication; the importance of specifications is to insure that the part is suitable for use.

Functional specifications can also be applied indirectly. Cleanliness of painted parts can be specified in terms of paint adhesion. If a specific level of adhesion is specified for the part, the level of cleanliness of the part must be such that paint adhesion will not suffer. A common paint adhesion test is the scratch test. A painted surface is cut with a razor blade; adhesive tape is placed over the scratch and then pulled off. The amount of paint adhering to the tape is used as the pass / fail criteria of the paint. But it is also a direct functional test of the cleanliness of the part. Fingerprints, oils, or other materials that could cause the paint to not adhere to the part must be removed sufficiently prior to painting in order for the coating to pass the test. It should be noted that manufacturers have found that some items require no cleaning prior to painting. Certain casting techniques, oil-free machining, and proper selection of paint can allow

parts to be used without any type of cleaning prior to painting. An important aspect of no-clean methods is prevention; if parts do not get dirty then they do not need cleaning.

Cleaning is the removal of offending soils from an item without destroying the item. Offending soils are any substances that prevent the item from functioning as intended. Unfortunately, there are many types of offending soils and offended parts that need to be cleaned. The most common cleaning application is cleaning prior to painting; this generally consists of removing oils, greases, waxes, silicon, and mill scale from metal surfaces to improve paint adhesion and appearance. Maintenance cleaning jobs are also very common; maintenance cleaning is typically removal of process materials to prevent cross contamination of products, allow inspection and replacement of worn parts, or removal of a buildup of materials that may interfere with the function of the equipment. Regardless of the reason for cleaning, common methods are usually some combination of mechanical, aqueous, or solvent cleaning methods. When selecting a cleaning method, chose a method that will generate minimal waste. The amount of waste generated by the cleaning process is a critical consideration. This is compounded if either the cleaning media or the materials cleaned contain hazardous materials.

Blast Cleaning

Old paint is often removed from machinery using sand blasting. If the old paint contains lead, then it is likely that the spent sand will be considered a hazardous waste. Sand blasting generates very large volumes of spent sand; disposal costs of hazardous waste from sand blasting can very high. A blasting media that often generates less waste is steel shot. Steel shot can be collected and reused many times for blasting; sand can be reused very few times due to fracturing of the sand as it strikes a surface. Even though steel shot and steel shot blasting equipment is considerably more expensive when compared to sand, steel shot blasting is much more economical for removal of potentially hazardous coatings. In addition to sand and shot blasting, there are many other types of abrasives and blasting systems available ranging from air knives to carbon dioxide. Each system is useful for a particular situation.

Aqueous Cleaning Methods

Another common cleaning method is aqueous cleaning. Water is the primary ingredient in aqueous cleaning systems enhanced by various detergents, acids, bases, heat, agitation, and abrasives. Aqueous cleaning can be used on almost any type of material from electronics to precision bearing assemblies. Instead of causing corrosion, rust inhibitors can be applied to metallic parts while cleaning in water-based solutions. Metal parts are often degreased and pretreated prior to painting using spray wash aqueous systems. Spray wash systems range from small, self-contained cabinet systems, such as a common

dishwasher, for single part or batch cleaning, to large continuous processing systems with numerous washing, rinsing, and drying stages. Aqueous dip tanks are sometimes used to clean parts; dip tanks are often enhanced using ultrasonic vibrations to improve the solvency of the water and detergent. Dip tanks are also commonly used for hand cleaning of parts using any combination of brushes, rags, and scrapers. Vibratory and tumble cleaners use abrasive media to remove burrs and radius corners of metal parts while cleaning. Ceramic, metallic, and plastic abrasives of various sizes and properties can be added to vibratory and tumble cleaners. Rock polishers used by hobbyists are examples of tumble cleaning. Water is not free and water treatment can be extremely expensive. Detergents, phosphates, oils, and metals are introduced into wastewater and rinse water from aqueous cleaning systems. These chemicals are regulated as preset discharge limits by the EPA and local publicly owned wastewater treatment systems. Fines and surcharges will be imposed if the discharge limits cannot be met. When considering an aqueous system, minimize water use and contamination. Discuss plans with the administrator of the local POTW (Publicly Owned Treatment Works). Choose cleaning chemicals carefully. Many companies have installed expensive aqueous cleaning systems to avoid the use of solvents only to find that wastewater problems are equally as severe. Semi-aqueous Cleaning Solvents are sometimes added to water to improve cleaning or reduce cost in semi-aqueous cleaning. N-methyl pyrrolidone (NMP) can be added to water or

it can be used alone. NMP is often reduced with water for cleaning jobs that do not require the full strength solvent; cost can be reduced in this manner. Depending on the particular solvent used, semi-aqueous cleaning can be accomplished using the same methods as aqueous cleaning. Flashpoint, air emissions, worker exposure, waste treatment, and disposal are considerations when choosing a semi-aqueous method.

Solvent Cleaning

Solvents are used either in pure form or blends of several solvents to remove coatings or degrease components prior to some other processing step. Solvents became the preferred choice for cleaning chemicals in many industries due to their effectiveness as cleaning agents and fast drying time. Solvents are used in hand wiping, dip tanks, spray washing, laundry dry cleaning, and vapor degreasers. As in aqueous cleaning, cleaning can be enhanced by agitation, ultrasonic vibration, and heat. MEK (methyl ethyl ketone), toluene, xylene, Freons, 1,1,1-trichloroethane, and perchloroethylene are some traditionally used cleaning solvents that are very good at degreasing and have a wide range of solvency. They are also either toxic or ozone depleting chemicals and heavily regulated. For these reasons, many companies are seeking other methods of cleaning such as aqueous or blasting methods. Often, less hazardous solvents can be substituted; mineral spirits or NMP can be substituted for MEK in some cleaning applications. Most solvents

are sources of air pollution; their use is often restricted and regulated even when nontoxic or nonhazardous solvents are used. Solvents that are very toxic, have a low flashpoint, or are ozone depleting should be avoided.

Once solvents become too laden with soils to clean, they can either be disposed of off-site or recovered by filtration or distillation. Filtration techniques can remove solid and dissimilar liquid contaminants, leaving the solvent suitable for some extended reuse. Distillation units can be purchased to remove almost all contamination; distilled solvents can often be reused as virgin solvent either for product formulation or cleaning. After their use has been minimized, distillation and filtration are good ways to reduce disposal and operating cost.

Where to Get More Information

Table 1 lists some common cleaning methods and chemicals, their uses, and waste generating potential. These methods and others are described in a software package entitled SAGE or Solvent Alternatives Guide. SAGE is an interactive computer program designed to provide alternatives to solvent cleaning after asking specific questions about the current cleaning processes and materials. Options are ranked numerically according to their potential for successfully fulfilling the specific cleaning needs. Detailed descriptions of the cleaning technologies will be provided by SAGE in addition to vendor information. SAGE can be obtained via modem from the Environmental

Protection Agency's Technology Transfer Network (TTN) bulletin board at (919) 541-5472 or through the Internet. P²AD can also provide a diskette with the program upon request; contact Jan Bunn at (404) 651-5120 or (800) 685-2443 in Georgia to request a free diskette. More detailed information can be obtained by attending the Solvent Alternatives Workshop on June 15, 1995 in Atlanta. The one-day workshop will be held on the Georgia Tech campus, and will provided detailed descriptions of many industrial cleaning methods. Workshop attendees will have a good opportunity to ask the experts about their particular cleaning needs. P²AD also has an e-mail address, send questions, comments, or information requests to p2ad@ix.netcom.com.

Table 1 - Common Cleaning Processes

Cleaning Method	Cleaning Media	Relative Initial Cost	Relative Operating Cost	Types of Soils Removed	Waste Generating Potential
Blasting					
Sand	Silica Sand	Low	Mid	Coatings, scale,oxidation	High - Waste Sand
Steel Shot	Steel	Mid/High	Low/Mid	Coatings, scale,oxidation	Low - Spent Steel Shot
Baking Soda	Soda & Water	Low/Mid	Mid/High	Coatings, scale,oxidation	High - Waste Water
Air Knife	Air	Low	Low/Mid	Liquids, dust, machining chips	Low - Only removed soils
Carbon Dioxide	CO_2	High	High	Coatings, scale,oxidation, oils, grease	Low - Only removed soils

Solvent	Various Hydrocarbons				
Dip Tank	MEK	Low	Mid	Coatings, oil, grease, uncured paints, ink	All have high potential of generating hazardous waste,
Spray Systems	Mineral Spirits	Mid/High	Mid/High	Coatings, oil, grease, uncured paints, ink	hazardous air pollutants, and VOC emissions.
Vapor Degreasing	Perchloroethylene	Mid/High	Mid/High	Oils, grease	
Hand Wipe	MEK, Mineral Spirits	Low	Low	Coatings, oil, grease, uncured paints, ink	
Aqueous				All are capable of removing oils, greases,	Wastewater generation potential is high. If acids or
Cabinet Spray	Water with various	Low/Mid	Low/Mid	uncured paints, dust, dirt,	caustics are used for etching,
Continuous Spray	detergents, acids,caustics, and	Mid/High	Mid/High	lime deposits, scale, and machining chips. Metals	there is the potential to generate hazardous waste.
Dip Tanks	pretreatments such	Low	Low	and oxidation can be	Wastewater may require
Vibratory	as iron phosphate.	Mid	Low/Mid	removed with high concen-	treatment prior to disposal.
Ultrasonic		Mid/High	Low	tration solutions of acid or caustic in water.	