Parts Drying Made Easy

Replacement solvents are not as easy to dry and aqueous cleaners can leave surface defects. What are your choices? . . .

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The phase-out of CFCs is causing a global revolution in the way products are manufactured and repaired. By January 1, I996, it will be illegal to manufacture and sell CFCs (chlorofluorocarbons), which have been identified as capable of depleting ozone. This change must be accomplished while meeting today's stringent regulations for water and air emissions.

CFCs provided both cleaning and drying. Drying was attained by evaporation of the cleaning agent. Dry parts could be obtained in just a few minutes without surface defects (residue) or effort.

That capability essentially is gone forever. CFC-11, CFC-12, CFC-113, methyl chloroform (1,1,1 trichloroethane, TCE, 111TRI, or MCF), Halons, and carbon tetrachloride won't be manufactured after I995. There are other quick-drying cleaning solvents, but their use adds other problems.

Firms doing product or maintenance cleaning with CFC-113 or MCF will have to find another way of cleaning and drying parts.

Why is drying difficult? Drying is a synonym for evaporation. There are three drying problems related to replacement cleaning agents.

1. Aqueous and semi-aqueous cleaners dry (evaporate) and leave surface residues (watermarks).

2. Non-aqueous cleaners dry, but emit VOCs.

3. Aqueous, semi-aqueous, and non-aqueous cleaners don't dry well from internal part sections.

The high cost of treating VOCs suggests that the best approach is to avoid them. These problems occur with replacement cleaning agents, since their chemical structure isn't the same as that of the banned materials.

Drying without evaporation. Nonevaporative drying methods must be considered when replacement cleaning agents are used. There are at least six types. 1) Centrifugal force; 2) Displacement by insoluble material; 3) Drainage (gravity force) enhanced

TABLE I—Non-evaporative Drying Methods

Non-evaporative Drying Methods	Application Positives & Negatives
Centrifugal force	Very low cost. Practical only for parts that will fit into dryer, i.e., "smaller than a breadbox." Liquid recovered for reuse. Can dry some complicated internal sections. Several commercial firms (Ford New Holland, Nobles).
Displacement by Insoluble Materials	Uses perfluorinated liquids or HFCs (DuPont, 3M). Useful for "spot-free" drying of complicated sections. Liquid recovered for reuse. Several commercial firms (ULTRONIX, Greco Brothers).
Drainage (gravity force) Enhanced by Vibration	Cheap and easy, but only removes and recovers—2/3 of liquid. May be useful for goods about to be stored. Custom applications.
Entrainment into Moving Stream of Air (Vacuum)	Practical only for flat sections, like sheet. Dry to "the touch." Liquid recovered for reuse. Custom applications.
Blowoff by High Velocity Air	Useful for small parts without internal sections. Dry to "the touch." Liquid recovered for reuse. Uses compressed air. Two Manufacturers (ULTRONIX & Kleer Flo).
Evaporation under Vacuum Where Liquid is Recovered	Very expensive. Used only for drying last—hundred ppm of "moisture." Several commercial firms (T-M Vacuum Products).

by vibration; 4) Entrainment into a moving stream of air (vacuum); 5) Dislodgement by high velocity air; and 6) Evaporation under vacuum, with liquid recovery.

There is efficient commercial equipment to implement three of these methods. The others can be developed in house. The most commonly used methods are centrifugal force, displacement by insoluble material and evaporation under vacuum. See Table I.

Selecting the proper method. What is the right drying method for your situation? The answer depends on two factors, the nature of your parts and the degree of dryness you require.

Table II gives specific recommendations for a variety of situations. Other recommendations are possible based on additional information. Table II reflects the belief that the cleaning agent should be chosen based on the nature of the soil. The rest of the process should be chosen based on the nature of the parts.

Most parts-drying problems will be in the middle column of Table II. Dry "to the touch" is satisfactory, and the liquid removed is either a solvent or water. Thus, the two most common drying techniques are hot air for water removal and centrifugal dryers for removing water or solvent. High-velocity air blowoff is a useful second choice for removing water or solvent, but air consumption may be costly.

Nature of parts. Since the cleaning agent (or water rinse) doesn't evaporate, the replacement drying processes must remove liquid from ALL sections of parts. Both interior and exterior sections can hold fluid droplets in corners, blind holes, threads, depressions or cavities. Inside sections of tubing can be difficult to dry.

If hot air can directly contact the liquid, it can evaporate the liquid. But if hot air can't access corners, blind holes or other recessed areas, then it must heat the part to a temperature where evaporation occurs. Heating the part takes time and adds cost.

If there is a continuous downward path where centrifugal force can pull liquid from interior sections, the centrifugal dryer will likely be an excellent choice. For example, interior threads, which turn horizontally usually can be dried, while interior threads, which turn vertically, cannot.

TABLE II—Recommendations for Drying Processes

Nature of Parts	Parts Can Have Some Remaining "Moisture"		Dryness to "the Touch" Is Satisfactory		Very High Level of Dryness Is Needed	
	Aqueous or Semi-Aqueous Cleaning Agents	Solvent Cleaning Agents	Aqueous or Semi-Aqueous Cleaning Agents	Solvent Cleaning Agents	Aqueous or Semi-Aqueous Cleaning Agents	Solvent Cleaning Agents
Parts "smaller than a breadbox," have simple or no internal sections	Drainage or centrifugal	Drainage or centrifugal	Centrifugal, hot air, or high-velocity air blowoff	Centrifugal, high-velocity air blowoff	Hot air, followed by vacuum evaporation	Centrifugal, possibly followed by vacuum evaporation
Parts "larger than a breadbox," have simple or no internal sections	Drainage	Drainage	Hot air, or high-velocity air blowoff	High-velocity air blowoff, or hot air	Extended time with hot air	High-velocity air blowoff, followed by extended hot air
Parts "smaller than a desk" have very complicated internal sections	Displacement by insoluble materials	Displacement by insoluble materials	Displacement by insoluble materials	Displacement by insoluble materials	Displacement by insoluble materials	Displacement by insoluble materials

Compressed air blowoff can only dry parts if ALL surfaces are impacted by the high velocity air stream

How dry is dry? This is an easy question. Don't dry parts any more than necessary, based on the next processing step. Drying investment and costs are almost exponentially dependent on the degree of dryness needed. If you aren't sure how dry your parts have to be, assume "dry to the touch" is adequate. "To the touch" means remaining moisture is in the range of one to five pct.

For example, if you are going to paint your parts after cleaning, match the carrier in the paint to the carrier in the cleaning agent, i.e., water or solvent. If plating is the next step after cleaning, use an aqueous cleaning agent, rinse well, and don't worry about adding water to the water in the plating bath. If parts will be stored after drying, consider air drying them in storage.

If a high dryness is needed (< II5 ppm), the drying should be done in two steps: 1) Dry to about one pct moisture; and 2) Polish dry from about one pct down to II5 ppm. The costs of the polishing drying step are dependent on the amount of moisture removed.

Large parts. If your parts are larger than a desk, you have a difficult problem, especially if you cannot tolerate surface imperfections such as watermarks. A useful solution is to use aqueous cleaning agents in a spray cabinet with DI water in the last spray rinse.

For large parts that can tolerate surface imperfections, hot air is recommended. If the nature of the soil requires solvent cleaning, hot-air drying can be used, however, there will be VOC emissions.

Centrifugal dryers. Centrifugal dryers are an excellent choice if your parts are small enough. This technology has been in use for many decades. But, its use is relatively new to the cleaning industry.

Parts are loaded into a cylindrical mesh or plastic basket. There may be discrete sections for holding individual parts if parts could be damaged by contact. The basket will be open if the parts can be mixed. The largest basket has a diameter and height of 30 inches; the smallest is six-by-six inches. Parts are spun at 900 rpm for 30 sec to I0 min, depending on the part configuration or degree of dryness needed. For drying solvent cleaning agents, there is no air flow or heat supply. The liquid is recovered from the bottom of the dryer for reuse.

Advantages are no VOC emissions when used with solvent cleaning agents, little floor space required (five-by-five ft), and low investment ($5,000 or less) and operating costs.

Disadvantages are that not all parts will fit into available basket sizes; cylindrical dryer baskets are round while cleaning baskets are traditionally square, so labor is needed to move parts from the cleaning to the drying basket; processing is done in batch mode.

Displacement drying. Table II reflects the difficulty of drying replacement cleaning agents when parts have complicated internal sections, or must not have watermarks. The best solution is a two-part cleaning-drying system. A cleaning solvent is chosen to remove soil from parts, and a displacement material that is insoluble in the cleaning solvent displaces the cleaning solvent from the parts. Since the surface tension of most displacement materials is low relative to water, there are no watermarks. The cleaning machine separately stores both materials and dispenses them in the cleaning/drying cycle.

The semi-aqueous process was developed specifically for parts that can't have watermarks. One solvent is usually a hydrocarbon or terpene chosen to dissolve the soil; the displacement material is water.

For parts with complicated internal sections, the displacement material must evaporate quickly. Common displacement agents are close relatives of the banned CFCs, because of the degree of inertness needed. To avoid depleting the ozone layer, they contain no chlorine. There are two types. Both are expensive, and neither clean well.

1. Molecules with only carbon and fluorine (perfluorinated or PFs). These materials contribute to global warming, since it takes them more than 3,000 years to degrade in the stratosphere. But they do not deplete ozone. They have been approved by the EPA in its SNAP program, where no other substitute for CFC-113 or MCF would do the job.

2. Molecules with carbon, fluorine, and some hydrogen atoms (HFCs). Because of the somewhat more fragile carbon-hydrogen bonds, HFCs have some solubility and reactivity vs. PFs. Tailored surfactant packages are necessary to make HFCs reject cleaning agents.

HCFCs (hydrochlorofluorocarbons) contain hydrogen, chlorine, and fluorine atoms. Chlorine adds solvency, which makes them useless as displacement drying agents.

If your parts have complicated internal sections and must be well dried without watermarks, displacement drying is the best choice. Specific permission from the EPA is not needed to use perfluorinated or HFC materials; you just need to show that your parts could not have been cleaned and dried by other materials.

If you plan to use perfluorinated displacement agents, make sure the equipment you use can use both perfluorinated and HFCs so that you can easily switch when HFCs become available. After that time, perfluorinated materials may not be listed in the SNAP program. Competent suppliers can either build equipment with this capability, or possibly convert existing vapor degreasers to use both fluids.

Any fluid immiscible with the cleaning agent can be used for displacement drying.

Enhanced draining. Enhanced drainage is simply a matter of letting nature take its course, or being smart. Low-frequency vibration (I0 to I00 cycles/sec) has been shown to enhance the effects of gravity. Allowing parts to drain for 30 to 60 sec (without vibration) before additional drying steps will cut the amount of liquid to be dried by 50 to 60 pct. This can reduce the downstream drying load by about half.

Entrainment by vacuum. This technology is suited only for regular part sections such as flat surfaces or wires. Air is pulled by a vacuum device across a narrow opening, creating a high velocity. The opening (nozzle) is moved across the work, and liquid is entrained in the moving air stream. The work is usually dry to the touch with one pass of the nozzle. A de-mister recovers the liquid for reuse.

Design parameters vary with the custom application. There is no commercial "drop in" equipment.

Blowoff with high-velocity air. Air velocity is the key. At 1,000 ft/sec, 85 pct of the liquid can be recovered in a de-mister and I5 pct is lost due to evaporation. At 100 ft/sec, the ratio is reversed.

This is the best application for parts too large to fit into a centrifugal drier. Virtues of this approach are low VOC emissions when using hydrocarbon cleaning agents, because more of the cleaning agent is recovered for reuse. Drawbacks are high air consumption and difficulty of drying part bottoms. A simple sketch showing the concept is in Figure 1.

Evaporation under a vacuum. Vacuum evaporation is only a polishing technique used to get moisture content down to the range of five to I00 ppm. The best procedure is to dry the parts via some other method to the dry-to-the-touch level first.

Vacuum levels are one Torr and above; temperatures are room temperature to 250F. Cycle times can be one hour or greater. The needed equipment is expensive, large, and heavy.

Evaporation using forced hot air. This is the traditional approach. Evaporating water generally presents no environmental problems. Evaporation of organic solvents produces VOCs and possible severe environmental problems. See Figure 2.

Drying times are decreasing functions of the amount of moisture present. It takes longer to evaporate the last unit of water than the first one. Increasing temperature and air velocity aids drying times, with diminishing returns.

Costs of drying systems. Predicting generalized drying costs is an inexact science. The main cost element is energy. Electricity drives a centrifugal dryer. Natural gas or electricity heats the air. And electricity powers the air compressor. So, it makes sense to compare drying costs on the basis of energy equivalents. The values in Table III below are ballpark comparative projections.

Table IV gives general recommendations for some common situations. Caution should be used when following them, since some of your local conditions haven't been incorporated. Examples are the soil being cleaned or your next processing step.

Drying of parts is a critical part of industrial production and maintenance. If that processing step is not

TABLE III—Comparison of Projected Drying Costs

Drying Method	Projected Instantaneous Costs as Energy Requirements - KW
Centrifugal	2 to 4
Air Blowoff	8 to 22
Hot Forced Air	10 to 30

done properly, successive processing steps (and probably the final products) won't be finished as well as customers expect.

Replacement cleaning agents don't dry well vs. ozone-depleting solvents and additional processing steps are necessary to provide adequate parts drying. Existing technology and equipment, such as centrifugal dryers, exist to meet this need. **PF**

TABLE IV—Recommendations About Drying Processes

Description of Parts	Cleaning Agent [Chosen Based on Soil Type]	Recommended Drying Process for "Dry to the Touch" Performance
Batches of: bundles of tubes 15 ft long and 1/2-inch ID; airplane wing struts; truck axles and wheels	Aqueous or semi-aqueous	Hot forced air
	Solvent	Displacement
Batches of: tubes 1.5 ft long and 1/2-inch ID; 2-inch gate valve bodies; brass castings; plated cosmetic shells; circuit boards; eyeglass lens; small frames	Aqueous or semi-aqueous	Centrifugal (angle tube slightly in dryer, mount parts, shells, boards, and lens in fixtures)
	Solvent	Centrifugal (as above)
Batches of: mixed screws, nuts, rivets; electronic connectors; plastic parts	Aqueous or semi-aqueous	Centrifugal
	Solvent	Centrifugal
Continuously moving small engine assemblies	Aqueous or semi-aqueous	Hot forced air
	Solvent	High-velocity air blowoff
Batches of coiled tubing any sizes	Aqueous or semi-aqueous	Hot forced air, or displacement
	Solvent	Displacement
Batches of flat stock, sheet; rolled sheet	Aqueous or semi-aqueous	Hot forced air
	Solvent	Entrainment by vacuum
Continuously moving wires	Aqueous or semi-aqueous	Hot forced air
	Solvent	Entrainment by vacuum