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Management of Industrial Cleaning Technology and Processes

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John Durkee, Ph.D., P.E.

2006

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OXFORD • PARIS • SAN DIEGO • SINGAPORE • SYDNEY • TOKYO

Elsevier
The Boulevard, Langford Lane, Kidlington, Oxford, OX5 1GB, UK
Radarweg 29, PO Box 211, 1000 AE Amsterdam, The Netherlands

First edition 2006

British Library Cataloguing in Publication Data
Durkee, John B.
Management of industrial cleaning technology and processes
1. Industrial equipment – Cleaning 2. Manufactures – Cleaning
I. Title
670.4'2

Library of Congress Cataloging-in-Publication Data
A catalog record for this book is available from the Library of Congress

ISBN 13: 978-0-08-044888-6
ISBN 10: 0-08-044888-7

Typeset by Charon Tec Ltd, Chennai, India
www.charontec.com
Printed and bound in United Kingdom

06 07 08 09 10 10 9 8 7 6 5 4 3 2 1

Management of Industrial Cleaning Technology and Processes

Preface

The challenge in preparing this book was deciding what material to omit. That the organization, research, and presentation required more than three years to complete speaks to how that challenge was addressed. No material necessary for managers responsible for cleaning work was left out.

Managing industrial cleaning processes and technologies requires knowledge of engineering and chemistry, environmental science and regulations, industrial equipment, statistical process control, and analytical testing. No less important is knowledge of health hazards and workplace safety, human relations and motivation, choosing cleaning equipment and chemistries, and dealing with suppliers. All are covered in this volume.

About the Author

John B. Durkee, Ph.D. studied at Lehigh University (Chemical Engineering, 1962, 1964, 1969). Throughout a 25-year career with DuPont and Conoco, he managed industrial technologies and processes, including the development and implementation of environmentally friendly, commercially successful alternatives to CFCs. A professional consultant, his monthly columns appear in *Controlled Environments* (critical cleaning), *Galvanotechnik* (precision cleaning), and *Metal Finishing* (metal cleaning). Dr. Durkee is a member of AICHE, ACS, IEST, and ASTM.

Dedication

I owe the managers who guided me and allowed me the freedom to learn and grow professionally over a 25-year career at Du Pont/Conoco: Ed Brugel, Tom Schrenk, Fred Radloff, Al Lundeen, Barry Coon, and Gene Harlacher, among others. Many of their lessons are communicated here.

I owe Gifford Pinchot, who motivated me to be an entrepreneur, and Janice Baker, who partnered with me as an independent consultant.

I owe Tom Robison and Ron Joseph, who encouraged me in development as an author.

Many acted as mentors as I began learning about cleaning technology and how to use it. I owe Kenny Dishart, Art Gillman, Joe McChesney, Rajiv Kohli, Mike Goodson, and many others.

I owe my parents for encouraging me to learn how things really work.

And I owe my wife, Dorothy Rosa Durkee, for her personal support and role as an editor. Without her help, my writing would be less clear – and completed sooner.

To all, my thanks for your needed and generous support.

JBD

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Modern cleaning technologies

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This chapter covers how cleaning technologies do that which is valued – manage soil. Also covered are the reasons why managers choose to implement these technologies.

1.1 WHAT CLEANING IS NOT

Cleaning work receives mixed reviews. There is a dichotomy of opinion. By many industrial managers, it isn't well thought of. By a minority of others, it's recognized as crucial to commercial success.

Why? Because there is a mixed understanding about what cleaning work is, and is not. One minor aim of this book is to clarify the information on which these conflicting opinions are based upon.

Cleaning is not:

- *Rocket science*: But aerospace technology depends upon successful cleaning operations. The same engineering and scientific fundamentals upon which cleaning is based also support manufacture and use of the parts upon which cleaning work is done.
- *Simple minded*: Granted, some solvents were and are capable of making some situations involving parts cleaning appear no more complex than dunking a doughnut into a cup of coffee. Those are exceptions.
- *Valueless*: Cleaning work allows parts to effectively perform in the next expected step of processing, or use. Few customers would want to purchase uncleaned parts. Few inspectors would accept the surfaces of parts as defect-free if they couldn't see all of the surfaces. Few operators would machine, form, or assemble parts which were contaminated with debris from previous operation.
- *Difficult to implement*: Yes, cleaning work can be poorly done so as to produce performance damaging to an enterprise. But it's easy to do it well.

A major aim of this book is to describe how to complete successful cleaning work, how to recognize when that outcome isn't achieved, and how to manage cleaning work to produce that outcome.

Generally, cleaning is not being outsourced. While there is a modest contract cleaning business, in the US cleaning work is done in-house. If your enterprise makes or repairs or tests, you must manage cleaning work.

1.1.1 The Nature of Cleaning Work

It's simple. Cleaning work is soil management.

Managers manage soil by causing it to be moved from where it is found (perhaps on the parts) to where it is wanted (perhaps in some container staged for disposal or treatment).

Cleaning work includes at least the five management tasks given in Table 1.1.

Table 1.1 Tasks in Soil Management

Cleaning step	Description
1. Cleaning	Managing *to remove* soil(s) from metal, glass, or plastic surfaces by emulsification with a surfactant or by solution with a solvent.[1]
2. Rinsing[2]	Managing *to dilute* or displace the emulsion or solution of soil(s) wetting the part surfaces with more pure material. This task is done until the amount of soil(s) remaining on the part surfaces are acceptably small when the emulsion or solution of soil(s) is removed (usually by evaporation).
3. Relocation of soil within cleaning machine	Managing *to convey* the bulk soil-bearing emulsion or solution of oil(s) from where the parts are located to where the soil(s) can be separated from the emulsion or solution. This task is done so that oil-laden emulsion or solvent is not stored within the cleaning machine and reapplied to cleaned parts.
4. Drying[3]	Managing *to relocate* dilute emulsion or solution of soil(s) from the part surfaces so that they are available for the next step of use.
5. Disposal of waste soil	Managing *to remove and concentrate* soil(s) from the emulsion or solution so that the detergent or solvent can be reused, *and* that the soil(s) can be recovered in a pure enough form for either efficient disposal, or possible reuse.

In each of these five tasks, soil is managed to produce a set of acceptable ends: part quality, productivity, disposal impact, and operating cost.

Yet, cleaning work involves other management tasks, so that:

- No one gets injured or has their health impaired.
- No environmental regulations are violated.
- No better choice for cleaning work is ignored, which might be paying another firm to do this work (contract cleaning).

That's the nature of cleaning work – soil management.

1.1.2 The Nature of Soils

Soils are something managers don't want where they don't want them. The same chemical may or may not be a soil depending upon where it is and whether or not managers want it there:

- Managers desire soil(s) contaminated with a small amount of cleaning agent (solvent or surfactant) to be located in some container. These soils can be efficiently disposed as waste, reused, or perhaps sold for further reprocessing.
- Managers don't desire soil(s), diluted with a large amount of cleaning agent, to surround valuable parts. Additional cleaning agent will have to be used to further dilute or displace the soil(s) *and* convey the dilute stream away from these parts.

The nature of soils is that they must be *relocated.*

1.1.3 The Nature of Cleaning Processes

Cleaning work is about moving chemical materials from where they are not wanted to where they are so. The tools by which this is done are the components of or stages within a robust cleaning process.

Some cleaning agents almost function as their own process. Halogenated cleaning solvents (e.g. CFC-113 or 1,1,1-Trichloroethane) effectively and efficiently dissolve many other chemicals. Parts treated with these solvents dry quickly as the solvents evaporate rapidly without outside action.

[1] If this was the only step in cleaning: the cleaning machine would be full of oil-bearing fluid, the parts would still have diluted soil around them and still be wet with cleaning agent, the bill for waste disposal would have probably have cost someone for their job, and the surface quality of the parts would be out of control.

[2] Please note that the "soil" in this case is not the oil(s), but rather the relatively concentrated mixture of oil(s) in cleaning agents.

[3] Please note that the "soil" in this case is not the raw soil(s), but rather the dilute mixture of soil(s) in cleaning agents.

Other cleaning agents, such as aqueous cleaning agents, implement process equipment, space, and time to provide effective cleaning, rinsing, and drying. Aqueous cleaning agents[4] require mechanical force, controlled temperature, as well as considerable space and time when used to clean parts.

Still other cleaning agents, such as blast media, also implement process equipment, space, and time but there is no need for rinsing and drying *per se*. Blast media are worthless as cleaning agents until process equipment propels and aims a stream of them at contaminated parts.

The nature of cleaning processes is that they enable cleaning agents to *perform as desired*.

1.1.4 The Nature of Individual Process Steps

A "written picture" may help here:

- After cleaning, part surfaces are surrounded by cleaning agent saturated, or nearly so, with soil. Nothing is attached to these surfaces, but they are fully wetted with dirty liquid. In other words, in the cleaning step it is valued to separate parts from soils.
- After rinsing, the valued condition is the part surfaces being surrounded by pure cleaning agent (no soil). In other words, in the rinsing step it is wanted to flush the parts to remove all soluble, emulsified, entrained, or insoluble soil. All will become unwanted residue if not removed.
- After drying, the parts are surrounded by nothing. In other words, in this step it is valued to separate pristine cleaning agent from the parts via evaporative or non-evaporative drying.

The nature of cleaning process steps is that they are *all necessary*. All must be managed together or cleaning quality will suffer.

1.1.5 The Nature of Cleaning Agents

Cleaning agents are chemicals, as are soils. As soils are usually chosen for their properties in some upstream operation (e.g. lubrication, heat transfer, cutting, etc.), so are cleaning agents chosen for their performance in process cleaning equipment.

Solvents or detergent solutions which provide good rinsing have the following:

- Low surface tension (so they can penetrate into crevices or flush through sections with small clearances between components).
- Low viscosity (so frictional pressure drop does not limit flow volume).
- High specific gravity (so lighter materials are easily displaced).
- Either complete miscibility or complete immiscibility with the cleaning agent (so they can dilute or displace the cleaning agent, respectively).

Solvents or detergent solutions which provide poor cleaning can be described as follows:

- Having a strong affinity for a soil but having a low holding capacity for it (solubility).
- Only gradually penetrating and swelling the soil and so it can be removed by rinse fluids.
- Efficiently dissolving a soil only at a temperature above its boiling point. This is nearly useless, as pressurized contacting equipment is expensive.
- Having a low evaporation rate, without regard to its solubility for the soil. After all, any undried cleaning or rinsing solvent is just another soil on the parts.

The nature of cleaning agents is that they are *chosen for their properties relative to those of soils*, to the character of parts, and to the specification of the cleaning process machinery.

1.1.6 Food Fights

There is an analogy to the human body. Food plays multiple roles:

- It satisfies our need for good taste and texture, provides energy to support activity, and supplies nutrition for long-term stability. So-called junk food only satisfies one need – our taste buds.

[4] Early ones were called "soaps."

A cleaning agent also plays multiple roles:

- A cleaning agent with good affinity for the soil but with a high surface tension and a low evaporation rate is a poor choice for a process to clean complex parts. It won't penetrate the parts, or easily and uniformly leave them! That's a major reason why *n*-methyl pyrrolidone solvent has only found narrow acceptance in industrial cleaning applications. It satisfies only one need – solvency.

It is the process which provides good cleaning (washing, rinsing, and drying). The cleaning agent does play vital roles in that process. The process wouldn't function without it.

The attention of managers must be on *the overall cleaning process.*

1.2 HOW IT'S DONE

Consultants are often asked to make sense of the varied options and outcomes associated with cleaning systems. Clients ask if there is some "structure" or methodology which can simplify options and outcomes.

The answer to that question is YES.

All cleaning systems depend on *one* or a *combination* of three basic actions:[5]

- A *mechanical* action, such as abrasive surface cleaning or spray agitation.
- A *thermal* action, such as where the environment is heated.
- A *chemical* action, such as:
  - a *dissolving* action (absorption and dilution effect such as an organic solvent dissolving an oil) or
  - a *surface active* action whereby soils are de-sorbed (the reverse of adsorption) from the part surfaces with the aid of surface active agents.

It doesn't matter if the cleaning process is: "dip-and-dunk" cold solvent cleaning, vaporization of debris by lasers, popular detergent-based aqueous cleaning, dislocation of particles by "energy storms" created by laser energy, ozone oxidation, or blast cleaning

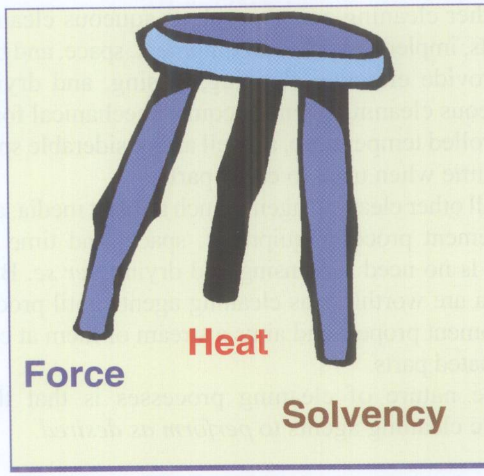

Figure 1.1

with hulls from vegetable products. The three actions are involved in all.

1.2.1 Said Another Way

The design of any cleaning system is supported by those three functions. This structure, shown in Figure 1.1 is called the "three legged stool." The legs are as follows:

- Mechanical force
- Heat or temperature
- Chemistry (detergency/solvency)

Solvency means choice of solvent (for solvent cleaning) or detergent (for aqueous cleaning).

Implicit in selection of temperature are reaction or solution rates, change in viscosity or fluidity (thinning), or formation/breakage of an emulsion.

Mechanical force means choice of spray system, use of ultrasonic transducers, or hand cleaning with a brush.

1.2.2 Examples of How It's Done

Aqueous, semi-aqueous, solvent cleaning, or other cleaning processes are all based on these three functions as shown in Table 1.2.

[5] Remember this covers cleaning. Rinsing, soil management, and drying are other issues which will be discussed below.

Table 1.2 How Cleaning Work is Done

Cleaning Process	Role of		
	Mechanical Force	**Heat or Temperature**	**Chemistry**
Aqueous	Dislocation of soil	Thinning of soil	Formation of emulsions
Semi-aqueous		Breaking/making of emulsions	
Boiling solvent	Removal of particles	Solution of soil	Solvency of soil
Cold solvent	Dislocation of soil	Control of emissions	
"Energy storms" generated by laser		Oxidation of soil	None
Vaporization by laser	Removal of debris	Vaporization	
Ozone oxidation	Removal of oxidation products	Optimizing rate versus ozone loss	Oxidant
Blast	Dislocation of soil		None
"No-chemistry"	Emulsification of soil	Optimizing cleaning rate versus rusting	

Two general cleaning processes (solvent and aqueous technology) and one specific situation involving both will be discussed in more detail below. They were chosen because of their frequency of use.

1.3 SOLVENT CLEANING

Not as simple as "dip-and-dunk" with your favorite chlorinated solvent. Not as vulnerable to environmental regulation as expressed by those with politically correct opinions.

1.3.1 The Past Decade

Three developments make solvent cleaning processes a more credible option than they were during the chlorofluoro carbon (CFC) phaseout of the 1990s.

The most important development supporting solvent cleaning processes is the various environmental regulations whose aim was to restrict solvent emissions from solvent cleaning processes. These regulations produced at least the following:

- Validation of an engineering approach(es) to control of emissions from open-top solvent cleaning machines via the US EPA's NESHAP[6] for halogenated solvents.
- Development of vacuum vapor degreasers which require significantly less than €100,000 of investment for purchase.

Said another way, environmental regulations produced the effect desired – solvent cleaning processes (and machines) which can comply with all but the most restrictive emission control regulations,[7] are affordable, and can produce clean parts.

The second most important development is the chemical identification and commercial production of "designer" cleaning[8] solvents.

If some halogenated solvents are considered to hold the extreme position of having excellent solvency but provoking concern about health and environmental issues, "designer" solvents are considered to hold the opposite extreme position of minor concern about health and environmental issues while having limited solvency.

These new products have survived expensive and lengthy health and environmental testing. Some are exempt from US EPA Volatile Organic Compound (VOC) regulations. It is the cost and uncertainty of developments and testing which make it unlikely

[6] The US EPA's National Emission Standard for Hazardous Air Pollutants.

[7] The most restrictive environmental regulations are those which either directly ban solvent cleaning processes or which indirectly do so.

[8] Granted some of these solvents also play commercial roles as heat transfer agents (HFE 7500 or PFPE ZT-85), flushing agents (the OS series), and high-voltage testing and dielectric fluids (HFC-43 10mee).

that chemical firms will produce significant new "designer" solvents for cleaning work.

The third most important development was the belated recognition that azeotropes[9] of existing solvents can fulfill technical demands of cleaning solvents while providing most of the safety and environmental qualities of the "designer" solvents.

The value of azeotropes is their number. More than 400 have been identified. Many include the "designer" solvents. Consequently, a great variety of cleaning problems can be solved because of the available variety of solvencies, boiling points, and other solvent properties.

Excellent management of solvent cleaning processes requires understanding and possible implementation of these three developments rather than the "wisdom" inherent in political correctness. Political correctness is a point of view[10] – not a method of solving cleaning problems. These three recent developments may do so if they are properly applied.

1.3.2 The Solvent Cleaning Process

A solvent cleaning process has three steps: wash, rinse, and dry.

1. The washing step brings parts and a chosen solvent together. Usually, the togetherness means immersion[11] of the parts in solvent. The choice of solvent is chiefly based on compatibility of the solvent with the soil to be removed.[12] Soil is removed only[13] when it dissolves in the solvent. The solvent is usually boiling, as within a vapor degreaser.[14]
2. The rinsing step brings fresh (or more soil-free) solvent together with the parts, using the same contact method used in the washing step. The aim is to dilute the soil-rich solvent. *A fundamental limitation on cleanliness is the cleanliness of the solvent material which last contacts the parts.* Soiled solvent can't ever produce perfectly cleaned parts.

   Washing and rinsing steps are usually separated in time and space because good cleaning can't be obtained if parts are being contacted with soil-rich solvent.
3. The drying step means separation of nearly clean solvent from parts. Almost always this is done by evaporation of the solvent.

Solvent cleaning is preferred by some because of the simplicity inherent in the above three steps.

1.3.3 Hidden Functions of a Solvent Cleaning Process

If any cleaning process was as simple as one described above, consultants would have to seek other employment. The situation is like that of a movie or a play. Activity outside the view of the camera or behind the curtains is vital to the performance, but is seldom seen. This means management of solvent cleaning is more complex than implied above.

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[9] Azeotropes are mixtures (usually binary) of solvents. When heated, it is the multi-component azeotrope which is vaporized and not its individual components. Further, the mixture boiling point remains fixed as long as there is enough of both components present to complete the azeotropic composition.

[10] No criticism is intended here of the politically correct approaches which apply only certain solutions to problems. These approaches are responsible, often credible, and common. They are based on the point of view that the politically preferred approach should be tried first, and that it usually can be made to work. Approaches which are not politically preferred generally don't receive equal consideration despite their being based on positive experience, engineering and chemical fundamentals, and useful economics.

Judgements which are politically correct are common outside of cleaning work. The principle, currently politically correct, of continuous improvement (see Chapter 4) is based on taking action not justified in the short term in order to profit from improved quality in the long term.

[11] In some maintenance cleaning work parts are sprayed with solvent. This is done either to pre-soak the soil so that immersion time can be reduced or occasionally to dislodge the soil.

[12] Frequently, liquid physical properties, such as surface tension, viscosity, or density, are significant in the choice of solvent. In these cases the chosen solvent may not have maximum compatibility with the soil, but is more able to flow through restricted passages to reach all part surfaces.

[13] In critical cleaning applications, where soil load is light and probably includes particulate, mechanical force provided by ultrasonic transducers is used to dislodge tiny particles from surfaces. The particles are suspended in the flowing solvent.

[14] Within the US, there are thousands of solvent cleaning machines (called "sink-on-a-drum") in which the solvent is not heated. Worldwide, "sink-on-a-drum" machines are very common because of their cost, size, and simplicity. Cleaning is done at ambient temperature to minimize solvent emission and loss.

Table 1.3 Hidden Functions of a Solvent Cleaning Process

Hidden Function	Purpose	Management Issue
Solvent storage	Reservoir for virgin and/or distilled solvent	1. Contamination 2. Available volume for changeout
Solvent distillation	1. Remove soil from machine 2. Prepare clean solvent for use	1. Maintain required overhead and bottom temperatures 2. Maintain reservoir level
Heating coil	Boil solvent for cleaning	1. Balance heat load versus cooling load 2. Balance heat load versus thermal load of parts
Water separator	Remove water from system	Stable water–solvent interface within separator vessel
Cover	Reduce emissions	1. Closed when work not entering or leaving 2. No odor
Cooling coil		Temperature above coil no more than 30% of solvent boiling point
Refrigeration coil		1. No permanent frost to inhibit heat transfer 2. No odor
Parts hoist	1. Reduce emissions 2. Load and unload machine	1. Speed less than 11 ft/min 2. Timing between steps sufficient for solvent drainage
Parts basket	Align solvent application with orientation of parts	Avoid retention of solvent within parts
Parts transport	Maintain productivity	Not overload capacity of degreaser
Stabilizer addition	Avoid solvent degradation ("acid degreaser")	1. Water content 2. Stabilizer content

Additional functions to be managed within a solvent cleaning process are described in Table 1.3.

Managing events occurring within the cleaning chamber is not enough. Cleaning is about soil management. That happens *throughout* the cleaning machine. Events *throughout* the entire machine must be managed as all are interconnected. One can't clean parts with soil-laden or degraded cleaning agents.

Solvent cleaning technology is described in complete detail in a companion book by this author.[15]

1.4 AQUEOUS CLEANING

Aqueous cleaning is not as user and environmentally friendly as "soap[16] and water." Yet this technology is the dominant approach to industrial cleaning used by the majority of global users.

1.4.1 Why Aqueous Cleaning?

Water is the ideal solvent for water-soluble soils – road salt, some food and beverage products, plating salts, organic compounds rich in hydroxyl[17] groups such as glycerin, and stable water emulsions such as water-based or latex paints and heat-transfer agents.

But that extensive and significant list of soils are minuscule compared to the depth and variety of soils found in global applications of industrial cleaning. For nearly all oils and greases, water is not the ideal solvent. In fact, it is usually the worst choice of solvents because the common hydrocarbon is not soluble in water.

The basic guidance is that if the oil or grease was derived from crude oil (hydrocarbons), it is not water soluble. If the oil or grease was produced synthetically

[15] Durkee, J.B., *On Solvent Cleaning*, to be published in 2007 by Elsevier, ISBN 185617 4328.

[16] The invention of soap relates to a desire for personal cleanliness. Generic soap dates several millenia before the formulation of Ivory Soap. Animal fats were boiled with ashes to produce soap. The chemical identity of soaps is that they are usually esters. An excellent reference is http://www.ccspa.org/conseducation/SDAC_soaps.html.

[17] The species composed of two atoms, Oxygen and Hydrogen, and a negative charge: OH^- species.

or is derived from vegetable material, it may be water soluble.

Aqueous cleaning is the technology used to clean oils and greases which are not soluble in water. That's why it was developed.

1.4.2 How Aqueous Cleaning Works

Table 1.4 gives some simple principles for use of an aqueous cleaning system, and commentary about them. If your aqueous cleaning system isn't performing to your satisfaction, the odds are high that you are violating at least one of these principles.

Granted, all of these 14 principles are not equally important. Principles 5, 10, 11, and possibly 14 are probably of lesser importance.

But the point is that the quality, consistency, and production rate of cleaning with aqueous technology can be improved by applying and managing the above principles to the cleaning system for which a manager is responsible. This type of situation is found in many sites in industry, where conversions from solvents were completed.

Aqueous cleaning technology is described in complete detail in a companion book by this author.[18]

1.4.3 What's a Mixed Metaphor?

Examination of Table 1.4 reveals concern about a mistake too commonly made. It is to assume that an aqueous cleaning is the same as a solvent cleaning process, except that a detergent is used instead of a solvent.

The two processes have little in common outside of a hoped-for outcome (clean parts) and reliance upon the same three actions (mechanical, thermal, and chemical).

Said more simply:

- One probably can't do effective solvent cleaning work in a tank designed for aqueous cleaning.
- One probably can't do effective aqueous cleaning work in a tank designed for solvent cleaning.

That's right. A cleaning tank is not a cleaning tank. Consultants have made good income from helping those who have converted a solvent cleaning system to an aqueous cleaning system only to learn that the new system didn't perform as desired.

Some differences are described in Table 1.5 (also see Chapter 7, Section 7.4).

Using aqueous cleaning technology in equipment designed for solvent cleaning technology is like trying to fry a juicy steak in a cocktail blender. Facilities and methods, specific for one cleaning process, don't translate to the other.

1.5 MANAGEMENT OF CHOICES AMONG CLEANING PROCESS

Yet, some find it curious that *either* aqueous *or* solvent cleaning technology can successfully fulfill many parts cleaning challenges when the needed facilities are so different. That was shown to be true during the phaseout of CFC solvents in the 1990s. Many jobs done with solvent cleaning technology were ported to aqueous technology. Both solvent and aqueous cleaning effectively met the cleaning needs of much more than half of all cleaning problems.[19]

Said another way, the choice among aqueous and solvent cleaning technologies doesn't matter if one measures the outcome by the cleanliness of the produced parts.

1.5.1 Hot Air: Not Used for Parts Drying

For the past decade, or more, the aqueous versus solvent choice has dominated industrial cleaning. The associated spirited dialog has been characterized as political correctness (aqueous technology) versus practicality (solvent technology). Seemingly, the noun *solvent* is hyphenated with the adjective *toxic* and the adjective *simple* is hyphenated with the term *aqueous technology*.

The arena in which this dialog has (and is) taken place is environmental regulations. Speakers are regulators sincerely interested in reducing emissions and associated atmospheric damage and suppliers properly interested in retaining or increasing market

[18] Durkee, J.B., *On Aqueous Cleaning*, to be published in 2007 by Elsevier, ISBN.

[19] This means that a significant fraction of users should have a preference for aqueous or solvent cleaning technology based on the nature of their application.

Table 1.4 Principles for use of Aqueous Technology

General Principles	Comments
1. Aqueous cleaning is performed by a combination of the following: • Detergents to lift the soils from the parts. • Heat to make detergents more compatible with the soils and to soften the soils. • Fluid force to dislodge the soils from the parts and collect the insoluble soils in some removal system.	Users obtain poor cleaning if they are operating an aqueous cleaning bath as if it were a solvent cleaning bath: chemistry, heat, but little or no fluid force. Generally this produces inconsistent cleaning: OK with levels of some soils, but not with others. This can be a very expensive problem to fix because the tank is designed to support the wrong cleaning method.
2. Soils should be periodically or continuously removed from the cleaning bath, via some skimmer or purge system.	A cleaning bath isn't a waste pit where soils are discarded, it is the vessel in which soils are permanently separated from parts. Soils aren't generally dissolved in an aqueous system, they are suspended or emulsified. Perhaps only ½% soil (or less) can be tolerated without reinfecting the parts. Soils are dissolved in a solvent cleaning bath, so as much as 10% or 20% soil can be tolerated without reinfecting the parts.
3. Time and motion should be provided to allow cleaning solution to be dislodged from the rack of parts and not to contaminate the rinse tank.	Operators are frequently trained to let the parts basket drain before moving it to the rinse tank. But they frequently forget to do it. Automation can be a cheap fix. This problem of poor drainage is called "dragout" when dirty cleaning agent adheres to supposedly cleaned parts (see Section 1.13.7).
4. Parts should be removed from cleaning and rinsing tanks without being recontaminated with soil floating on or suspended in any of the tanks.	In the last decade, some clever technology has been commercialized keeping the top surface of an aqueous cleaning bath clean (see Section 7.4.3).
5. Rinsing should be normally done at the temperature of the cleaning bath so that the detergents remain soluble, and don't come out of solution.	Rinsing at reduced temperatures normally isn't a good idea because solubility of detergents is reduced, surface tension of water is increased, and chances of foaming are increased.
6. Monitoring should be done of concentration of detergents in the cleaning bath, pH, and temperature, and they must be adjusted to a consistent and correct level.	Many firms do little or no monitoring, and make adjustments by discarding the bath. This is the largest possible adjustment, which makes the largest possible change in the quality of cleanliness.
7. Typically, aqueous cleaning lines are not used for pre-clean, in-process, and finish cleaning in the same system. Typically, soils are not mixed. The reason is that aqueous detergents are not as forgiving of differences in soil chemistry as are solvents.	The fastener industry is a good example. Parts are made in three to five stages of work. In some plants a central washer for all parts is preferred for reasons of work flow. Cleaning quality may not get the priority that it deserves in this decision. Often the result is that parts are wet with some soil from all previous stages of work!
8. The rinse water must be clean, or the parts won't be clean – especially true for the final rinse bath.	Self-evident, but not universally followed.
9. If spot-free drying is needed, the final rinse of cleaned parts is with pristine (mineral-free) water so that evaporation does not leave mineral deposits.	The consequences of violating principles eight and nine are often the same: stains on parts. Poor rinsing produces detergent-based stains; use of mineral-laden water produces mineral-based stains.
10. Water replacement should be of mineral-free water into the last rinse tank, and cascaded forward.	As with principles eight and nine, the parts should be last contacted with the cleanest fluid.

(Continued)