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Like the self-cleaning oven, industrial thermal cleaning systems free the user from labor-intensive manual cleaning and the environment from unsafe chemicals.

Cleaning with Heat: Old Technology with a Bright New Future

BY KENNETH MAINORD

Many are familiar with "cleaning with heat" whether they realize it or not. Abandoning their rubber gloves, scrub brushes, and chemical cleaners, millions of households across America have been quick to accept a better and easier way to clean their kitchen ovens. This ready acceptance has made the self-cleaning oven one of the most successful new products introduced to the consumer marketplace in recent years.

Self-cleaning ovens operate on a very simple principle: using heat to clean. When the oven interior becomes dirty from baked-on food spills or grease, the self-cleaning cycle engages by bringing the oven temperature up to 850°F to 900°F, substantially higher than the normal cooking temperatures of 250°F to 550°F.

This additional heat removes the baked-on residues by a combination of vaporization, thermal decomposition, and oxidation. Once the oven is cool, remaining small amounts of ashes or residue normally can be removed with a quick wipe from a damp sponge or towel. No scrubbing, no chemicals, no mess.

Among cleaning furnaces available in a variety of sizes, represented here are models with internal capacities of 27, 52, and 260 cubic feet.

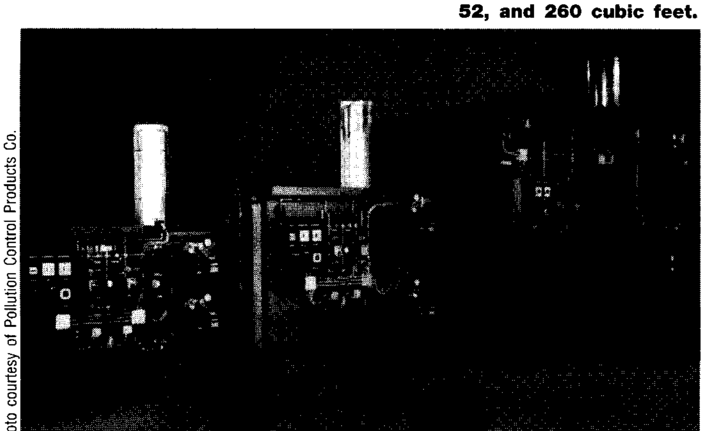

Photo courtesy of Pollution Control Products Co.

Environmental Compatibility

If cleaning with heat has been applied so successfully in the household oven market, what potential does it hold for the industrial market? The answer, of course, is that industry has used thermal cleaning for many years — a technology that's responsive to ever-increasing environmental pressures to reduce the use of solvents and chemicals in the industrial workplace.

In many cases, it simply does not make much sense to remove a small amount of organic contaminant by cleaning it with large amounts of chemicals, merely transferring the contaminant from the substrate to the cleaning solvent. Repeated rinses to achieve good cleaning greatly increase the volume of chemical waste to be dealt with, magnifying the problem even more.

Removing the organic contaminants directly with heat can offer the enormous advantage of eliminating chemical/solvent cleaning completely. However, the high temperatures inherent in thermal cleaning rule out this technology for a variety of applications. Obviously, you cannot clean printed circuit boards or plastic bottles with high heat!

Nonetheless, thermal cleaning is a viable — if not preferred — option for many industrial cleaning applications, particularly for metal parts, ceramics, and lab glassware.

Common Industrial Applications

Although there are literally hundreds of specific applications for thermal cleaning in industry, they can be grouped into at least five general classifications or markets:

Electric motor rewinding industry

The electric motor rewinding industry was among the first to adopt heat cleaning as a means of removing varnish and insulating coatings from electric motor rewindings to be rebuilt. Temperatures of 700°F to 750°F are commonly used.

Automotive parts rebuilding industry

Thermal cleaning is increasing in popularity for the removal of oils and greases from automotive engines, blocks, and related metal parts. The classic method of using caustic tanks for oil/grease removal is being replaced where possible in favor of "dry" cleaning — with heat.

Painting and coatings industry

The finishing industry is rapidly replacing chemical and solvent cleaning of paint line fixtures in favor of thermal cleaning. Automated paint lines, whether for wet-paint or powder coatings, generate a lot of hangers and hooks coated with paint residues. These represent a real cleaning challenge.

In particular, today's new tough powder coatings are generally more difficult to remove chemically. Reclaiming or "burn-off" furnaces have become almost a necessity in most powder coating operations, and cleaning temperatures of 800°F are common.

Plastics industry

Thermal cleaning is appropriate for many metal parts used in plastics production and processing. Most plastics and polymers are organic materials removable with heat. Extruder and molding machine hardware, spinnerettes, dies, breaker plates, filters, polymer pumps, piping, and other production parts are all good candidates for thermal cleaning.

Long, thin furnaces in lengths up to 20 feet are available for cleaning extruder screws. Because many plastics are not readily soluble in chemicals or solvents, thermal cleaning assumes even greater prominence in this industry.

Industrial laboratories: research, analytical, environmental, medical, polymer

The problem of difficult-to-clean laboratory glassware has plagued chemists for many years. Heavy residues of tars, waxes, gums, polymers, resins, carbonized matter, and other organic contaminants are common in almost every laboratory. Difficult-to-clean glassware is especially prevalent in industrial laboratories involved with organic and polymer research.

Although they're not present in large amounts, trace organic contaminants (milligrams or less) also represent a problem for analytical chemists who are constantly stretching the limits of detectability and sensitivity of micro analysis.

Heat-resistant lab glassware is a perfect candidate for thermal cleaning, as many individual chemists have discovered by using a small muffle furnace or their glassblower's annealing furnace to clean labware having small amounts of organic contaminants.

In the past year, specialty cleaning ovens specifically sized and designed for cleaning lab glassware have appeared on the market. Unlike ordinary muffle or annealing furnaces, these incorporate several features essential for safe cleaning.

Equipment Diversity and Sizes

Diverse types of thermal cleaning systems are available from various manufacturers, encompassing various technologies. Some systems are gas-fired, others electric, and still others combine these two approaches to heat input.

Chamber sizes range from as small as 10 by 10 inches to 25-foot-long cleaning furnaces large enough to hold heat exchangers weighing as much as 12 tons. The ability to process parts at temperatures from 600°F to 1000°F is common to all of the units, regardless of the specific engineering design and technology of each.

The more common types of thermal cleaning systems are briefly described in the following sections:

Molten Salt Baths

Molten salt baths are probably among the oldest technologies used for thermal cleaning. When heated, certain mixtures of inorganic salts melt and remain liquid. When metal parts — generally loaded into wire baskets — are immersed in the hot molten salt, their organic residues vaporize. After cooling, a water rinse removes any salt residues.

Cleaning with a molten salt bath is among the fastest of all thermal cleaning methods, as the bath is generally always kept hot, and the liquid salt transfers heat to the part very rapidly. Cleaning times of 15 to 30 minutes are not uncommon for small parts.

Disadvantages of molten salt baths include a tendency to splatter or even explode if the parts are not dry and free of liquids.

Fluidized Bed Systems

Fluidized bed systems are somewhat similar to molten salt baths, but use a different heating medium. Fluidization is the principle by which inert particles of aluminum oxide, loosely packed in vessel, are set into motion by a rising stream of air or nitrogen. With the proper air flow, the bed of alumina particles becomes "fluidized" and exhibits many of the properties of a true liquid, including excellent heat transfer.

Because the alumina is inert, fluidized beds have no melting or boiling points, and no vapors or odors are emitted from the media at the cleaning temperatures used. Like molten salt baths, fluidized beds also are among the fastest thermal cleaning methods because of their good heat transfer.

Wire baskets are used to suspend the parts inside the fluidized bath. Some manufacturers also offer as an option unheated fluidized beds in which the hot, clean parts can be suspended for rapid cooling.

Speed comes at a price for both of these technologies. Simply because cleaning occurs so rapidly, pyrolysis gases and vapors from the organics being removed come off very rapidly, in bursts or "pulses," and thus pollution control of the fumes is more difficult and more costly. Sometimes pollution control devices and other accessories for salt baths or fluidized beds cost more than the basic cleaning system itself.

For example, direct gas-fired afterburners for this type of equipment tend to be relatively large and costly relative to the basic size and expense of the molten salt or fluidized beds themselves. This is a result of the afterburner or other pollution control device having to be sized large in order to handle the bursts of fumes which occur rapidly over a very short period of time.

One manufacturer of fluidized cleaning baths has approached this problem by igniting and burning the smoke directly above the bed in a post-com-

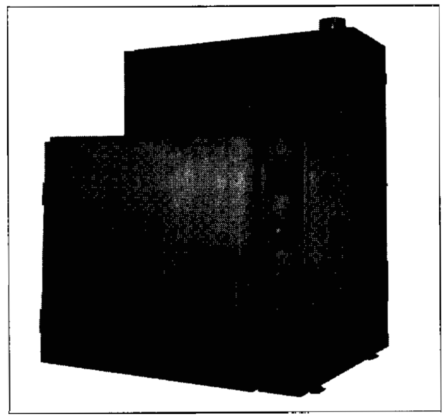

Photo courtesy of Tempyrox

Specific designs of bench-style ovens suitable for cleaning metal parts on laboratory glassware include built-in safety features.

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bustion chamber. Fresh secondary air injected into this chamber ensures complete combustion.

High-Temperature Vacuum Ovens

At least one manufacturer uses the novel approach of cleaning with heat inside specially designed, high-temperature vacuum ovens. Such systems are inherently very safe because pyrolysis occurs in the absence of an atmosphere (vacuum). Consequently, the chances for uncontrolled combustion in the cleaning chamber are completely eliminated.

For plastics which will melt and flow, melting and drainage remove much of the residue. The molten plastic drains into a primary, unheated chamber to capture the bulk of the polymer. Pyrolysis gases are cooled with water mist in a secondary chamber to promote condensation and reduce the fumes from the cleaning process.

The vacuum pumps used for these ovens are special water-ring models which utilize water as the pumping medium. With this technology, cleaning chambers as small as 10 inches in diameter by 10 inches deep are standard, with units up to 160 inches long for cleaning extrusion screws or other special applications. Parts placed on a loading dolly roll inside the oven, and the door is clamped tightly shut.

Reclaiming or "Burn-Off" Furnaces and Ovens

So called "burn-off" or reclamation furnaces were among the first widespread industrial systems using heat to remove organic matter from metal parts, allowing them to be reused, rebuilt, or reclaimed for salvage. Unfortunately, the earliest versions had little or no control of the fumes created by the cleaning process.

In 1970, Pollution Control Products Co. (Dallas, TX), a pioneer in the development of pollution-controlled burn-off furnaces, introduced its first system to clean electric motor stators. The smallest unit was top-loading, using chain and hoist to load the stators in and out. Later units used loading carts with high-temperature casters that rolled out on removable tracks in front of the furnace.

Virtually all of the earlier burn-off furnaces were batch models — still the predominant type manufactured today, though some continuous, conveyor-style burn-off furnaces are available. Because pollution-controlled burn-off furnaces eliminated the smoke and odor from the cleaning process, the electric motor rewinding industry adopted this method widely. Today, you will find such cleaning furnaces in virtually every motor rewind shop, large or small.

Other industries, including three major ones, quickly recognized the value of "clean with heat" furnaces: the painting and coating industry for cleaning paint hangers and hooks, the automotive parts industry for removing oil and grease, and the plastics manufacturing and compounding industries for cleaning metal tooling.

Normally of box-like shape, burn-off furnaces typically have interiors constructed of fire-brick or other very high-temperature insulation capable of withstanding temperatures exceeding 2000°F. Space-age, lightweight ceramic blanket fiber is common in many brands.

Although burn-off furnaces are not incinerators, their basic construction and insulation are similar because of their history of occasional ignitions or fires inside the furnace chamber. Metal interiors simply would never tolerate this exposure without severe crumpling or damage.

Specialty Cleaning Ovens

This category of thermal cleaning equipment applies to units designed and engineered basically as modified high-temperature ovens. In general, they tend to be smaller than burn-off furnaces and have stainless steel interiors to handle temperatures up to 1000°F. They have front-loading doors, with interior trays or racks to hold the parts.

In essence, these units look more like ordinary ovens than the first four types of equipment. Consequently, they are more suitable for use in laboratories and similar environments than the more industrial designed burn-off furnaces. However, special features allow these ovens to clean safely without pollution.

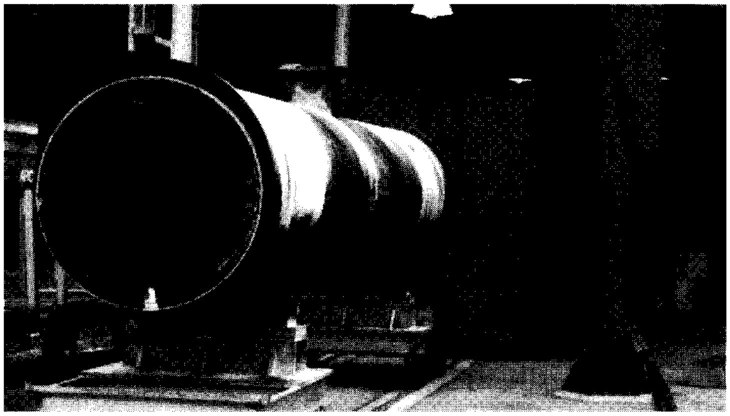


Photo courtesy of Pollution Control Products Co.

A 12-ton heat exchanger is poised for duty in front of a 24-foot-long industrial cleaning furnace.

Cleanliness Capabilities and Limitations

Thermal cleaning is primarily limited to the removal of organic contaminants or residues. Because inorganic compounds not affected by the heat of cleaning are not removed, secondary cleaning operations are often required.

A typical application involves the cleaning of cured paint residues from metal paint jigs and fixtures. Many paints contain large amounts (30 to 40 percent) of inorganic pigments and fillers not removed in a typical industrial burn-off cleaning furnace. However, once the organic resin or "binder" is destroyed, the ash residues are normally fairly easily removed by mechanically tapping the hangers.

Depending on the level of cleanliness needed, water washing may be used. Some pigments, such as titanium dioxide, are more difficult to remove, and dipping in dilute acid solutions may be necessary to achieve suitable cleaning.

With automotive parts such as engine blocks and heads, thermal cleaning removes oils, greases, and some of the carbonized residues. To achieve the high level of cleaning necessary for this industry, glass-beading or shot blasting is often the method of choice for secondary cleaning.

In the plastics industry, ultrasonic cleaning is widely used for post-cleaning of filters, spinnerettes, or other metal parts having tiny orifices or holes. Although thermal cleaning will remove the large bulk of plastic residues, the inorganic ash or dirt caught in a metal filter media is not removed. Ultrasonic cleaning to mechanically dislodge these particles is frequently the method of choice.

When post-cleaning of thermally cleaned parts is necessary, the methods used normally do not involve chemicals or solvents. Thus the primary advantage of thermal cleaning is generally not compromised by the need for secondary cleaning.

Time and Temperature

The control scheme for various thermal cleaning equipment designs ranges from simple to complex. Most systems have temperature controllers that allow adjustment of the actual cleaning temperature. The simpler systems utilize adjustable timers to hold the unit at processing temperature for so many minutes or hours, then shut it down.

More sophisticated cleaning equipment with built-in pollution control employ schemes which automatically control the cleaning times required for different loads. These advanced control methods usually rely on sensing when smoke production from the cleaning process has ended, and adjusting the time cycle accordingly.

Inherent Technological Problems

When compared to the household self-cleaning oven, industrial cleaning equipment presents certain technological challenges. Consumer self-cleaning ovens are designed to clean themselves and nothing else.

In contrast, industrial cleaning furnaces or ovens clean metal parts often containing substantial amounts of heat-degradable residues. Large burn-off furnaces may be loaded with metal parts containing tens, hundreds, and even thousands of pounds of residues. The large amounts of organic contaminants involved in industrial heat-cleaning units create two unique concerns:

- Potential for ignitions or fires from the fumes created during cleaning
- Pollution control of the fumes

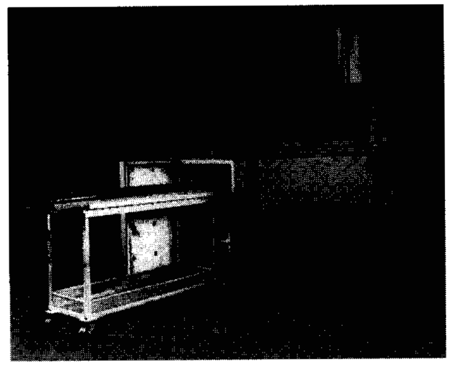


Photo courtesy of Pollution Control Products Co.

Cleaning furnaces for the plastics industry include those designed especially for the processing of extrusion screws. The model pictured accommodates lengths up to 12 feet.

Manufacturers have approached these two problems, especially the first, in a variety of ways. Fluidized bed systems were introduced using alumina as the fluidizing medium for the cleaning oven. Alumina is inert and avoids the chemical reactivity of molten salt baths.

Another manufacturer eliminated the possibility of ignitions in its equipment by employing heat in a vacuum. Eliminating the air in the heating chamber where pyrolysis occurs also eliminates any chance of ignitions or fires. This design technology is generally best suited to smaller cleaning chambers and systems, as it becomes quite expensive to scale up high-temperature/vacuum technology to large systems.

Manufacturers of reclaiming or burn-off furnaces today use a variety of sophisticated control schemes to monitor and control processing rates to prevent fire or ignitions in their equipment. In their earlier years, however, burn-off furnaces were not much more than "hot boxes" in which parts were loaded and heated to a processing temperature of about 700°F to 800°F.

As the part temperature rose, the organic contaminants decomposed to combustible smoke and vapors. If the loading of combustible material on the parts was too large or the heat-up rate too fast, and venting rate inadequate, then enough combustible gases could be evolved to ignite and burn. Such excess temperatures often led to part warping or damage.

Solving these problems commonly involved limiting the amount of combustible material on the parts to be cleaned to relatively low levels — 2 percent by weight or less. In addition, programmed, slow heat-up rates limited the evolution rate of combustible smoke and gases from the parts. However, such procedures often resulted in inconveniently long cleaning cycles. Also, many of the early burn-off furnaces lacked pollution control to rid of smoke and odors evolved during the cleaning process.

Improvements in Progress

Over the past decade, substantial improvements have been made with heat-cleaning technology, particularly in the areas of safety and pollution control. These developments promise to expand markets and applications.

Because thermal cleaning works by vaporizing organic contaminants from the parts being cleaned, a potential for pollution virtually always exists. The advent of stricter environmental protection regulations has prompted manufacturers to add pollution control equipment to their cleaning systems.

Because the contaminants are organic, the vapors are normally combustible, making an afterburner or thermal oxidizer the best pollution control technology of choice for most applications. Direct-flame thermal oxidizers operating at 1400°F to 1600°F for a minimum of 0.5 second are generally considered best available technology (BAT) and are integral parts of various large cleaning furnaces.

Historically, manufacturers of small thermal cleaning systems have downplayed the need for pollution controls. Scrubbers and thermal oxidizers typically listed as optional equipment often cost more than the basic thermal cleaning equipment itself. In practice, many small systems were sold without any pollution control devices at all.

In some respects, this has been perhaps justified because the quantity of emissions was quite small by absolute standards — grams rather than ounces or pounds. However, with today's ever-stricter environmental regulations and awareness, cleaning methods with zero tolerance for emissions will be the real winners.

Toward this goal, manufacturers of small thermal cleaning systems are challenged to develop scaled-down, miniaturized pollution control technologies to handle the small emissions from their systems. This and other advances will ensure a bright future for cleaning with heat. PC

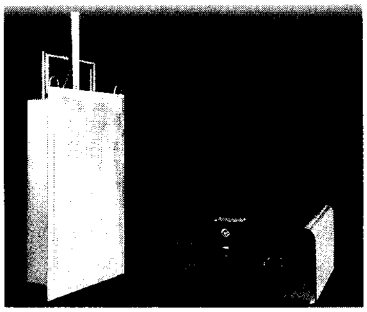
About the Author

Kenneth Mainord is founder and president of Tempyrox (Dallas, TX), a manufacturer of small cleaning ovens for metals and lab glassware. Previously, he was vice president of Pollution Control Products Co., manufacturer of large industrial cleaning furnaces. With an M.S. degree in organic chemistry, he also served 17 years as a research chemist for Texas Eastman Co. (Longview, TX).

BUYER'S RESOURCE

The Buyer's Resource section features information on products and services for all cleaning operations. Use this resource for the selection of cleaning agents, equipment, and services by reviewing the descriptions, then circle the appropriate number on the Reader Service Card (opposite pages 12 and 52) to request additional information.

Precision Cleaning Products and Services



Immersible transducers

Blue Wave Ultrasonics' immersible tranducers, engineered for use with water-based cleaning solutions, clean dirt, oils, and buffing and polishing compounds from various substrates such as metals, plastics, ceramics, and glass, reports the company.

The silver-brazed magnetostrictive transducers, welded into water-tight, stainless-steel submersible units, are equipped with mounting hooks and plumbed to user specifications, the company states. Controls are located in a remote, 30 kHz sweep-frequency generator. Each of three standard models can be used singly or in multiple unit configurations.

The transducers are portable, easily adapted to conveyorized lines, and permit easy movement from one conveyor tank to another. The company credits magnetostrictive technology for four lifetime guarantees against deterioration in transducer performance, failure, damage if tank should run dry, and diaphragm wear-through.

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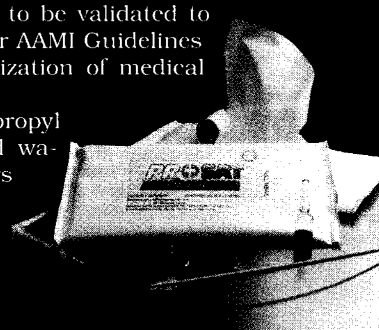
ON THE COVER

Sterile wipers

Prosat Sterile Wipers, presaturated in a resealable pouch from **Contec**, are reported to be validated to a 10^{-6} Sterility Assurance Level per AAMI Guidelines for electron beam radiation sterilization of medical devices.

Saturated with 70 percent isopropyl alcohol and 30 percent deionized water, the wipers allow manufacturers to control solvent consumption, reduce open solvent containers, and eliminate in-plant solvent mixing, the company states.



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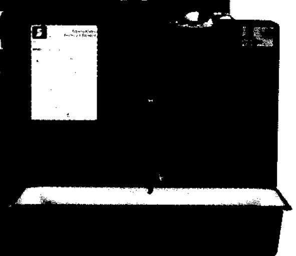
Cyclonic parts cleaner

The Green Machine, utilizing centrifugal force to separate contaminated particles from parts cleaning solvent, draws contaminated solvent into the separator, while centrifugal action forces solid particles toward its perimeter, reports the manufacturer, **Safety-Kleen**.

While gravity draws these solid particles down into a chamber and traps them for later removal, the clean solvent at the center is drawn upward and back to cleaning parts. This, the company states, results in a solvent that stays fresher longer with more sustained cleaning power and that needs to be replaced less frequently.



Available with the Green Machine is Safety-Kleen Premium Solvent, a hydrocarbon derivative that reportedly features a higher, 150°F flash point and lower vapor pressure to improve safety while reducing emissions and odor.

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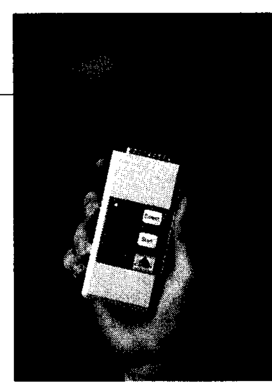
Memory device

Designed for use in the fluid power and industrial machinery markets, **Hiac/Royco**'s hand-held memory device, Datalync, stores particle count data for up to 1000 runs.

Plugging directly into the RS232 port of Hiac/Royco's Model 8000 and MicroAir particle counters, Datalync automatically captures, stores, and easily transports data to a PC for downloading into a spreadsheet or database application via the company's Logger software.

The pocket-size Datalync weighs less than 5 ounces, the company adds, and requires no diskettes or any special firmware on the counter.



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