DRY HEAT FOR COOL SAVINGS: DRY HEAT STERILIZATION OF MICROISOLATION CAGES

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INTRODUCTION

Dry heat sterilization (it turns out) is a cost-effective alternative to steam autoclaves for sterilization of rodent caging. Working with a leading manufacturer of industrial ovens, Rutgers commissioned a one-of-a-kind industrial oven (sterilizer) for installation in an existing facility. The goal was a design that met our specific needs but one that would also be reasonably flexible in operation to serve as a proof-of-concept design that would be accepted by the animal research community. Was this a smart thing to do?

Why (you think) dry heat sterilization won' t work:

A dry heat sterilizer:

- Will be too expensive to purchase
- Will be too expensive to operate with electric heat
- Will exceed the electrical power capacity of my facility
- Will not be effective in killing micro-organisms
- Will not be effective inside enclosed spaces without pre-vacuum
- Will damage plastic cages
- Will take too long to process each cycle
- Will make the workplace too hot and uncomfortable
- Is not available commercially
- Will not totally replace the need for a steam autoclave

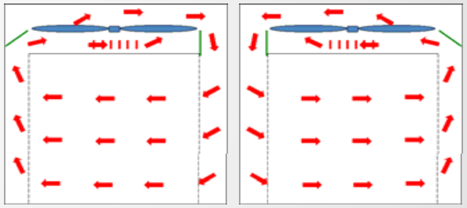
DESIGN AND OPERATION

Specifications:

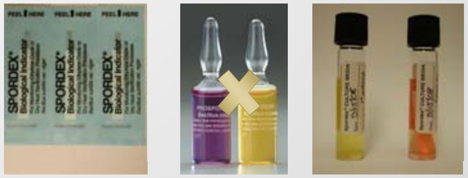
- Cabinet interior: 139 cu ft
- Wall and door construction
  - 4" Fiberex® insulation
  - Chamber interior 304L stainless steel, 18 and 20 ga.
  - Exterior 304 stainless, 18 and 20 ga.
- Floor: 3/16" plate, 304L stainless, beveled front edge, uninsulated
- Chamber interior dimensions
  - 62" wide x 54" deep x 70" high
- Heating elements
  - 6 heating elements, total 54 kW
  - Electrical power: 480V, 3 phase
- Circulation and exhaust
  - Circulation fan in upper plenum = 6,600 CFM
  - 2-level exhaust up to 290 CFM during cool-down
  - Intake and exhaust HEPA-filtered

Factory photo: this view shows the process chamber which is composed of front and rear halves which are bolted together. The upper chamber houses a circulation fan, electrical heating elements and dampers that control the alternating convection airflow. Not visible in this view are the intake and exhaust filter housings, and the exhaust fan which sit on top. The control panel is shown mounted to the unit, but can be installed remotely.

Site Preparation and Installation: Dry heat sterilizers have several advantages over steam autoclaves, especially for renovations in existing facilities. A large steam autoclave pressure vessel may not fit through doors or in elevators. The process chamber can be shipped in pieces. All components of the Rutgers oven fit through a 42"x84" door. A dry heat sterilizer requires no pit, no drain, no steam or water supply. Electrical service (480V, 3 phase) and compressed air are all that are required. Above right, upper plenum being hoisted in preparation for installation of process chamber halves underneath. The circulation fan and heating elements are visible.



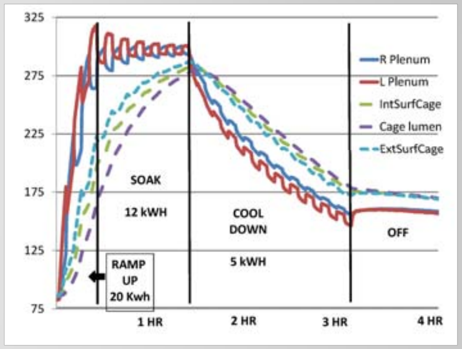
Horizontal, alternating, convection (the key to success): The knock on dry heat sterilization has always been longer cycle times. The Rutgers design uses horizontal air-flow which reverses at a user set interval (5 minutes). Airflow parallel to the cart shelves allows air to flow between stacks of cages. Loading preserves space between stacks of cages to allow for air flow. A 6,600 CFM circulation fan in the upper plenum moves air about 3 mph through the oven chamber.



Validation: Validation cannot be done with ampoules as used for steam sterilization (they would boil and explode!) Dry heat validation is done with spore strips containing 10^6 spores of *Bacillus subtilis var. niger*. These are transferred to sterile media. Color change is interpreted as for ampoules. Killing spores is almost overkill. What pathogenic spore do you need to kill? When was the last time you had a clinical outbreak of Tyzzer's disease?

The inner side walls of the process chamber are removable, perforated panels, computer-designed to provide uniform horizontal airflow across the chamber. Above, left, cart loaded with assembled polysulfone microisolation cages and right side perforated panel. Above, right, same view as that to the left with one perforated panel removed.

Loading: Four custom-designed carts each have 3 removable cantilevered shelves. The oven will take 300 nested mouse-bottoms or 180 assembled, low-profile, micro-isolation cages. This allows for ample space between stacks of cages to allow for air flow, important for uniform heating and cooling.



The Cycle: A sterilization cycle consists of 3 phases:

1) **Ramp Up** – heating elements ON continuously. Exhaust on LOW. This phase ends when SET temperature is reached. SET temperature set by user (300°F). Greatest energy consumption.

2) **Soak** – heating elements ON about 20% of time to maintain temperature. Exhaust on LOW. Soak Time is set by user. 20% of Ramp Up power, 60% of Ramp Up energy consumption.

3) **Cool Down** (optional) – heating elements OFF. Exhaust on HIGH. Cool down ends when oven reaches user defined endpoint. We use 150°F. While Cool Down is optional, the early part of this phase contributes heat and time to total sterilization process.

Measured Energy Consumption

STAGE	TIME (MIN)	POWER (KW)	ENERGY (KWH)	COST ($)
RAMP UP	20	61	20.3	$2.64
SOAK	60	12	11.7	$1.53
COOL	100	4	5.4	$0.83
TOTAL	180		37.4	$4.99

Energy consumption of the Rutgers/TPS sterilizer. Set temperature = 300F°; Soak phase = 60 minutes; Cool down cutoff = 150°; Total cycle time = 3 hr.

Dry Heat Sterilization Compared to Steam Autoclaving

	RUTGERS DRY HEAT STERILIZER	NEW STEAM AUTOCLAVE
VOLUME (CU FT)	139	139
FOOTPRINT (SQ FT)	34.3	STERILIZER 48.5 PIT 91.2
MINIMUM DIMENSION OF PARTS (IN)	31.5	62.4
UTILIITIES	Electric power, flat floor, compressed air	Steam, cold water, drain, pit, electric, compressed air
WATER USAGE (GAL)	0	700
COST PER CYCLE (*CALCULATED)	$4.99	$8.20*

A dry heat sterilizer will cost 60-70% less than a comparably-sized steam autoclave. It requires 1/3 the footprint, ½ the door opening for installation, and less than 2/3 the utilities cost per cycle. A steam autoclave will use 700 gallons of water per cycle!

Advantages of Dry Heat Sterilization over Steam:

- Purchase price - ~ 60% less
- Cheaper to install
- No steam, no water, no pit, no drain
- Less expensive to maintain
- No humidity added to the workplace
- Modular construction, component parts fit through existing doors, elevators
- Minimal heat load to workspace
- Dry loads on completion of the cycle
- No apparent damage to plastic cages
- Smaller footprint
- Non-proprietary control

Limitations of Dry Heat Sterilization:

- No sealed chamber, not suitable for BSL2 or above decontamination (newer models may address this)
- No liquid cycle – cannot process water bottles
- Longer cycle times
- Higher temperatures limit the materials that can be processed
- No "process indicator" as inexpensive as autoclave tape

DISCUSSION

We have been extremely pleased with what is essentially a prototype sterilizer. Although the manufacturer has extensive experience in making "hot boxes", it was not clear until our oven was built and tested that we would know if it could do what it was designed to do. The controls are easy to operate. It loads and unloads easily.

Cycle time - the horizontal, alternating convection design of the Rutgers oven has proven effective in reducing cycle time. At the current settings, we are achieving a 3 hour cycle which includes an optional cool down cycle. Experimentation will undoubtedly allow us to validate shorter cycles. The factory held polysulfone cages at 300°F for up to 6 hr. While we operate at 300°F, plastic temperature only reaches 285°F, so we may experiment with higher temperatures. The longer cycle time is offset by the ability to purchase and install a larger unit in the same footprint as compared to a steam autoclave.

For **installation** in an existing facility, dry heat may be your only choice. Any number of issues may make a large steam autoclave an impossibility: steam availability, door openings, elevator size, the need for a pit, and weight, to name a few.

As to **efficacy**, we validate with 10^6 spore strips. Heat kills. Because of the physics of steam production, dry heat sterilizers can achieve higher temperatures than steam given the limits of safety, cost, weight and engineering. (Dry heat at 500°F is used for depyrogenation.) Higher temperatures require higher pressures which make steam pressure vessels not practical. Pressure and vacuum assist in evacuating closed spaces and drying loads (not an issue with dry heat!). Steam transfers heat faster than air. But, ultimately it is time and temperature that kill microorganisms. Dry heat works.

In our experience and that of others, **plastic** cages seem to suffer **no damage** from dry heat. Repeated cycles do not seem to damage plastic the way steam does. Expensive microisolation cages should last much longer.

Technicians like the dry heat sterilizer. The effect on room temperature is not noticeable. The exterior of the control panel gets hotter than that of the oven.

Dry heat will not eliminate the need for steam in a large facility. It will allow you to specify a smaller autoclave, use it less frequently, and will provide **redundancy** for sterilization capability.

The Rutgers model can be **readily adapted** to other situations. It can easily be made in a pass-through design. The length could easily be extended while maintaining the airflow pattern. The heater plenum can be located on the back or side.

From a **cost** perspective, there is no contest between dry heat and steam. From purchase, to renovation, installation, maintenance and operation, dry heat is less expensive. Concerns about the cost of electricity have not been borne out. Perhaps only compared to a large, hi-vac steam autoclave could a 54 kW, 480V, 3 phase electrical appliance be considered **green**, but our measured energy consumption trials prove it to be so.

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DISCLAIMER

Neither Rutgers University nor the author have any affiliation with Thermal Product Solutions or its Gruenberg Division.