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 acceptable 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 in all 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:

- 
- Chamber interior 304L stainless, 16 and 20 ga.
- Floor: 3/16" plate, 304L stainless, bevel front edge, unribbed
- Chamber interior dimensions: 16.5" wide x 54" deep x 70" high
- Heating elements, total 54 kW
- Electrical power: 480V, 3 phase
- 6 heating elements, total 54 kW
- 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 sits atop. The control panel is shown mounted to the unit, but can be installed remotely.

The inner side walls of the process chamber are removable, perforated panels. Top-to-bottom, vertical perforation is provided 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 to the left with one perforated panel removed.

Validity: validation cannot be done with amphibia as used for steam sterilization (they would boil and explode). Dry heat validation is done with one-ship containing 10" spacers of black/white/white checker. These are transferred to sterile media. Color change is interpreted as 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?

Energy consumption of the Rutgers/TPS sterilizer. Set temperature = 300°F; Cool down phase: 80 minutes; Cool down output is 150°F. Total cycle time = 3 hr.

Measurements

<table>
<thead>
<tr>
<th>STAGE</th>
<th>TIME (MIN)</th>
<th>POWER</th>
<th>ENERGY</th>
<th>COST ($)</th>
</tr>
</thead>
<tbody>
<tr>
<td>RAMP UP</td>
<td>20</td>
<td>61</td>
<td>20.3</td>
<td>$2.64</td>
</tr>
<tr>
<td>SOAK</td>
<td>60</td>
<td>12</td>
<td>11.7</td>
<td>$1.53</td>
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<tr>
<td>COOL</td>
<td>100</td>
<td>4</td>
<td>5.4</td>
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<td>TOTAL</td>
<td>180</td>
<td>37.4</td>
<td></td>
<td>$4.99</td>
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</table>

Energy consumption of the Rutgers/TPS sterilizer. Set temperature = 300°F; Cool down phase: 80 minutes; Cool down output is 150°F. 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) | 54.3 | 48.5 |
| MINIMUM DIMENSION OF PARTS (IN) | 31.5 | 62.4 |
| UTILITIES | Electric power, flat floor, compressed air | Steam, cold water, drain, pit, electric, compressed air |
| WATER USAGE (GAL) | 8 | 700 |
| COST PER CYCLE (CALCULATED) | $4.99 | $8.20 |

Advantages of Dry Heat Sterilization over Steam:

- Purchase price ~60% less
- Can be installed
- No steam, no water, no pit, no drain
- Less expensive to maintain
- No humidity added to the workplace
- Modular construction, component parts fit existing doors, elevators
- Smaller footprint
- Non-proprietary control
- No "process indicator" as inexpensive as autoclave tape
- Higher temperatures limit the materials that can be processed

Limitations of Dry Heat Sterilization:

- No sealed chamber, not suitable for BSL2 or above decontamination (newer models may address this)
- No "process indicator" cannot process
- Long cycle times

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

As to efficiency, we validate with 10" spore strips. Heat killing. 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 50°F is used for depropagation.) 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. Repeat cycles do not seem to damage plastic the way steam does. Excessive 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, see it less frequently, and will provide reasonable maintenance 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 plate 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.

ACKNOWLEDGEMENTS

The following people were instrumental in completing the project:

- Rutgers LAS: David Miller, Elaine Simpson
- Rutgers Facilities/Utilities: John Fritzen, Pat Harrity, Chris Hack, Glenn Vliet
- Thermal Product Solutions (TPS): David Willard, Gary Shute
- HITEC, Inc: Stan Thommer
- Precision Control Solutions, Bob Ovissi
- Mass General: Steve Nemi
- Special thanks to Bruce Rodger and Bob Ovissi for their efforts.

DISCLAIMER

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