

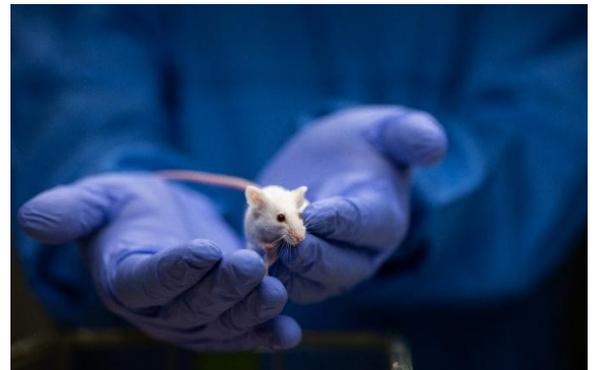
# Dry Heat Sterilization & Sustainability

**BOB DAVIS**

Animal lab sterilization has recently seen a demand for greener technologies. This puts the pressure on equipment engineers to develop innovative ways to approach sterilization. While traditional steam autoclaves use water more efficiently, dry heat sterilization provides an alternative to steam that uses no water, less energy, and requires less maintenance. The incumbent technology in today's bulk sterilization marketplace for animal cages utilizes steam as the heat transfer method to raise the temperature of the product load to the level needed to sterilize the cages. However, over the last 18 years, bulk sterilizers that use dry heat have been gaining ground.

## BACKGROUND

Physics tells us that the heat transfer rate of steam is greater than that of air, which seems to imply that steam is more efficient. But is it? Compared to steam sterilizers, dry heat sterilizers eliminate water usage, water waste discharge, steam usage and have significantly lower rejected heat. With that in mind, we, along with our customers at the University of Edinburgh, wanted to determine which technology was more efficient and which had a lower carbon footprint.



## Why It Matters to the University of Edinburgh

Under UK law, the country must achieve net zero greenhouse gas emissions by 2050 while needing to achieve meaningful reduction milestones along the way. The University of Edinburgh's target is even more aggressive with the goal to emit net zero carbon by 2040. The university has been implementing a plan that includes significant reductions in direct emissions (heating, vehicles) and through energy efficiency and electrification, reducing travel, and the like. Additionally, the university has also implemented other programs such as restoring Scottish peatland and forest restoration. Today, the university has reduced emissions by over 50% from 2007/08 levels. In order to meet the net zero goal by 2040, more large steps need to be taken.

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For more information, go to:

<https://www.gruenberg.com/products/vivarium-dry-heat-sterilizers>

## Are Dry Heat Sterilizers More Efficient?

But is dry heat sterilization more efficient than steam? While there was data from units tested in the Gruenberg manufacturing facility and one tested at a Gruenberg customer's facility, the data was old. The purpose of our study was to test and acquire energy usage data and compare that to a similar size autoclave used in the same facility. Once we had that data, we would calculate the carbon footprint of each technology for a better understanding of which method of sterilization has the lower footprint.

## How Do Dry Heat Sterilizers Work?

First, it would be helpful to understand how dry heat sterilizers work. In short, dry heat sterilizers are convection ovens, albeit highly engineered ones. Air is drawn in through a HEPA filter into a plenum. Heat is generated and mixed with the incoming air and chamber return air in the plenum. The air is then recirculated down duct walls and across and throughout the chamber, heating the contents. As the air is recirculated and reheated, the load is heated up. A small portion of the air is also exhausted through a HEPA filter to help with temperature control and uniformity. At the end of the sterilization phase, the heat is shut off and the on-board exhaust blower speeds up, bringing in more make up air which cools down the load. All of the heat required is generated electrically and aside from the exhaust, there are no other utilities required.

## TEST EQUIPMENT

### Dry Heat Sterilizer Tested

The dry heat sterilizer we used for the testing was Gruenberg model VST40H357.8SS-2D-KY and was purchased and installed at the University of Edinburgh's Bioresearch and Veterinary Services Department in 2022. It is a bulk dry heat sterilizer with dual chambers which are 1066mm x 2336mm long x 2082mm high. each and has a 357 cubic foot/10135 litre capacity. The sterilizer is used to sterilize cages on transport trollies and IVC racks. For the testing, we loaded the sterilizer with (4) logistics trollies with a grand total of (320) assembled cage setups.



### Steam Sterilizer Tested

The steam sterilizer we used for the testing was purchased and installed at the University of Edinburgh in 2010. It is a bulk steam unit with a 1194mm wide x 2082mm long x 2082mm high chamber and has a 182 cubic foot/5150 litre capacity. While the sterilizer is half the size of the dry heat sterilizer, this steam sterilizer is the largest we had to test, so it would have to be used. The sterilizer is used to sterilize cages on transport trollies and IVC racks.

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## MEANS AND METHODS

### Dry Heat Sterilizer

For the dry heat sterilizer test, we used a Fluke 1734 Energy Test Meter with current calibration certificate. The meter was used to monitor and record incoming voltage, amperage and hertz thus recording the total kWh electrical usage of the cycle. As for the rejected heat, manufacturer's engineering data was used.

The dry heat sterilizer parameters of the validated cycle were: Heat up to 140°C, hold for 120 minutes, cool down to 95°C and shut off. The total cycle time was a little over 2 hours.

### Steam Sterilizer

For the steam sterilizer test, we did not have the ability to record the various utility usage, so we were forced to rely on various manufacturers' data for steam, water and electricity usage, as well as rejected heat. For each utility, we used the lowest value published by each of the manufacturers.

The steam sterilizer cycle parameters were: (3) vacuum pulses, heat up to 121°C, hold for 20 minutes, exhaust and dry, end. The total cycle time was 1 hour.

## RESULTS AND COMPARISONS

### Utility Usage

The test data from the dry heat sterilizer showed that the energy electrical consumption was 77.76 kW/h. Using the utility usage numbers from various steam sterilizer manufacturers, we calculated that the steam sterilizer used 1,800 litres of water, 381 kg of steam, 9.3 kW/h of electricity and discharged 1,800 litres of water.

### Energy Usage Comparison

While the dry heat sterilizer appeared to use a lot of electricity, we wanted to compare the total utility usage on an annual basis. Understanding that the dry heat sterilizer had twice the capacity as the steam sterilizer, we assumed it would be run 260 times a year while the steam sterilizer would need to be cycled 520 times to achieve the same throughput. We took the data from each sterilizer and input it into a spreadsheet with the University's cost for each utility. The results are in Table 1 on the next page.

By changing just (1) bulk sterilizer with a dry heat sterilizer, the Bioresearch and Veterinary Services Department has saved the University of Edinburgh 936,000 litres of water, 936,000 litres of wastewater and £48,188 in electrical costs per year!

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**Table 1.**

<b>DRY HEAT vs STEAM STERILIZER Utility Cost Analysis</b>			
	<b>47x82x82 Steam Sterilizer 182 cu ft</b>		<b>Gruenberg Dry Heat Sterilizer 357 cu ft</b>
<b>Local Utility Costs</b>			
Cold Water	£ 0.0035336	per litre	£ 0.0035336
Steam by Nat Gas	£ 0.0528	per kW/h	£ 0.0528
Drain	£ 0.004100	per litre	£ 0.004100
Power	£ 0.324000	per kW/h	£ 0.324000
<b>Utilities Consumed Per Cycle</b>			
	<b>Steam</b>		<b>Dry Heat</b>
Cold Water	1800	litres	0
Steam by Nat Gas	263	KW/h	0
Power	9.3	KW/h	77.76
Drain	1800	litres	0
<b>Utility Cost per year***</b>			
Cold Water	£ 3,307.45		£ -
Steam	£ 7,220.93		£ -
Power	£ 1,566.86		£ 6,550.50
Drain	£ 3,837.60		£ -
Rejected Heat - BTU/hr	48,000		15,000
Rejected Heat - hours per year	8,760		780
kWh used to condition rejected heat	123,201		3,428
Total Cost to condition rejected heat	£ 39,917.01		£ 1,110.70
Total Utility Costs per year	£ 55,849.85		£ 7,661.21
<b>Utility Cost Savings per year</b>			<b>£ 48,188.64</b>
<b>***Based on 2 cycles a day for steam, 1 cycle a day for dry heat, 260 working days a year</b>			

Formula Used for Conditioning Rejected Heat:

$$\left( \frac{(\text{Operating Hours} * \text{BTU per hour}) * 0.293}{1000} \right) = \text{kWh} * \text{Electricity Costs per kWh}$$

### **Comparison of Carbon Footprint of the Steam Sterilizer to Dry Heat Sterilizer**

The overall goal of the study for the University of Edinburgh Bioresearch and Veterinary Services Department was to determine if the energy savings realized by the dry heat sterilization process could also help the university achieve their net zero goals.

Building on our model from the utility usage acquired during testing, we worked with the Estates Department at the university to determine what the carbon footprint impact was for steam and

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electricity generation. They provided us with the specific carbon footprint values for both steam and electricity generation used by the university. We populated those values into our model to determine the carbon footprint of each sterilizer cycle. The carbon footprint numbers can be seen in Table 2.

**Table 2.**

<b>DRY HEAT vs STEAM STERILIZER Utility Cost Analysis</b>			
	<b>47x82x82 Steam Sterilizer 182 cu ft</b>		<b>Gruenberg Dry Heat Sterilizer 357 cu ft</b>
<b>Local Utility Costs</b>			
Cold Water	£ 0.0035336	per litre	£ 0.0035336
Steam	£ 0.0528	per kW/h	£ 0.0528
Carbon Footprint Steam Generation - Nat Gas	0.18316	kg CO <sub>2</sub> e/kWh	0.18316
Drain	£ 0.004100	per litre	£ 0.004100
Power	£ 0.324000	per kW/h	£ 0.324000
Carbon Footprint Electric Generation	0.20229	kg CO <sub>2</sub> e/kWh	0.20229
<b>Utilities Consumed Per Cycle</b>			
	<b>Steam</b>		<b>Dry Heat</b>
Cold Water	1800	litres	0
Steam	263	KW/h	0
Carbon Footprint - Steam Generation	48.2	kg CO <sub>2</sub> e/kWh	0
Power	9.3	KW/h	77.76
Carbon Footprint - Electricity Generation	1.88	kg CO <sub>2</sub> e/kWh	15.73
Drain	1800	litres	0
<b>Utility Cost &amp; Carbon Footprint per year***</b>			
Cold Water	£ 3,307.45		£ -
Steam	£ 7,220.93		£ -
Power	£ 1,566.86		£ 6,550.50
Drain	£ 3,837.60		£ -
Rejected Heat - BTU/hr	48,000		15,000
Rejected Heat - hours per year	8,760		780
kWh used to condition rejected heat	123,201		3,428
Total Cost to condition rejected heat	£ 39,917.01		£ 1,110.70
Total kg CO <sub>2</sub> e	50,949		5,201
Total Utility Costs per year	£ 55,849.85		£ 7,661.21
<b>Utility Cost Savings per year</b>			<b>£ 48,188.64</b>
<b>Carbon Footprint Savings</b>		kg	<b>45,749</b>

\*\*\*Based on 2 cycles a day for steam, 1 cycle a day for dry heat, 260 working days a year

Formula Used for Conditioning Rejected Heat:

$$\left( \frac{(\text{Operating Hours} * \text{BTU per hour}) * 0.293}{1000} \right) = \text{kWh} * \text{Electricity Costs per kWh}$$

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## CONCLUSION

The purpose of the study was to establish the impact of each sterilizer on greenhouse gas emissions. Because each sterilizer heat source is indirect, i.e. electricity generated off site and steam generated campus wide, the impact of each was relatively easily attained from the local utility and university, respectively.

We were able to test for energy consumption of the dry heat sterilizer from a calibrated energy usage meter and heat loss data from Gruenberg to calculate the total operating costs and carbon footprint per cycle.

With the steam sterilizer, the data for steam and electrical costs as well as the carbon footprint impact of each were also well understood. Usage of steam by the autoclave was difficult to acquire from the manufacturer so we chose the most conservative consumption data from a variety of manufacturers and used the lowest value for each utility metric. To also ensure that we continued to be very conservative for this sterilizer, we did not calculate steam usage cost or carbon impact while the sterilizer was not being used, although it does use steam and water to keep the jacket warm. We did, however, calculate the HVAC operating costs to condition the rejected heat while the sterilizer was idle.

The study showed a 45,749 kg and 89.8% reduction in greenhouse gas emissions of the sterilization process when using dry heat sterilization for this one application. Additionally, the study also showed utility cost savings of more than £48,000.

The Bioresearch and Veterinary Services Department currently operates (10) steam sterilizers leaving more possibility for the department to help the university reduce carbon emissions through changes in their sterilization processes to dry heat. As the UK works towards net zero, opportunities to make significant impacts in carbon emissions will get more difficult. By using newer, yet proven, technologies in biomedical research such as dry heat sterilization, the bold changes needed to stay on track for 2040 net zero can be realized.

Understanding the importance of having accurate data, we will be doing more testing.

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## **ABOUT GRUENBERG**

Gruenberg, a division of Thermal Product Solutions, is a leader in dry heat sterilization technology in the pharmaceutical, medical devices, and laboratory industries, with an advanced line of sterilizers that eliminate harmful pathogens on animal habitat cages. In addition to the dry heat sterilizer technology, they offer a full line of standard and custom industrial ovens that accommodate temperatures up to 1200°F and are available in a variety of configurations, including cabinet, truck-in, and top-loading models. Gruenberg has more than 18 years of direct experience in the laboratory animal industry.

## **ABOUT THE AUTHOR**

Bob Davis has more than 30 years of experience selling industrial, research, laboratory animal, and pharmaceutical equipment, including washers, autoclaves, and dry heat sterilizers. Bob and his company have been pioneering the use of dry heat sterilizers in laboratory animal facilities since 2005.

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