

Autoclaves on House Steam: Metering Results of Electricity, Steam, and Water Usage

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Learning Objectives

- ▶ Learn about the different ways steam is produced and used by autoclaves.
- ▶ Learn about the metering set-up used on **two house steam autoclaves** to better understand the consumption of these units.
- ▶ Learn the steam, water, and electric power usage numbers of two models of autoclaves on house steam.
- ▶ Understand the impact of cycle variations and operating conditions on steam, water, and electricity usage for two different models of autoclaves on house steam while maintaining passing sterilization tests.

Inside an Autoclave

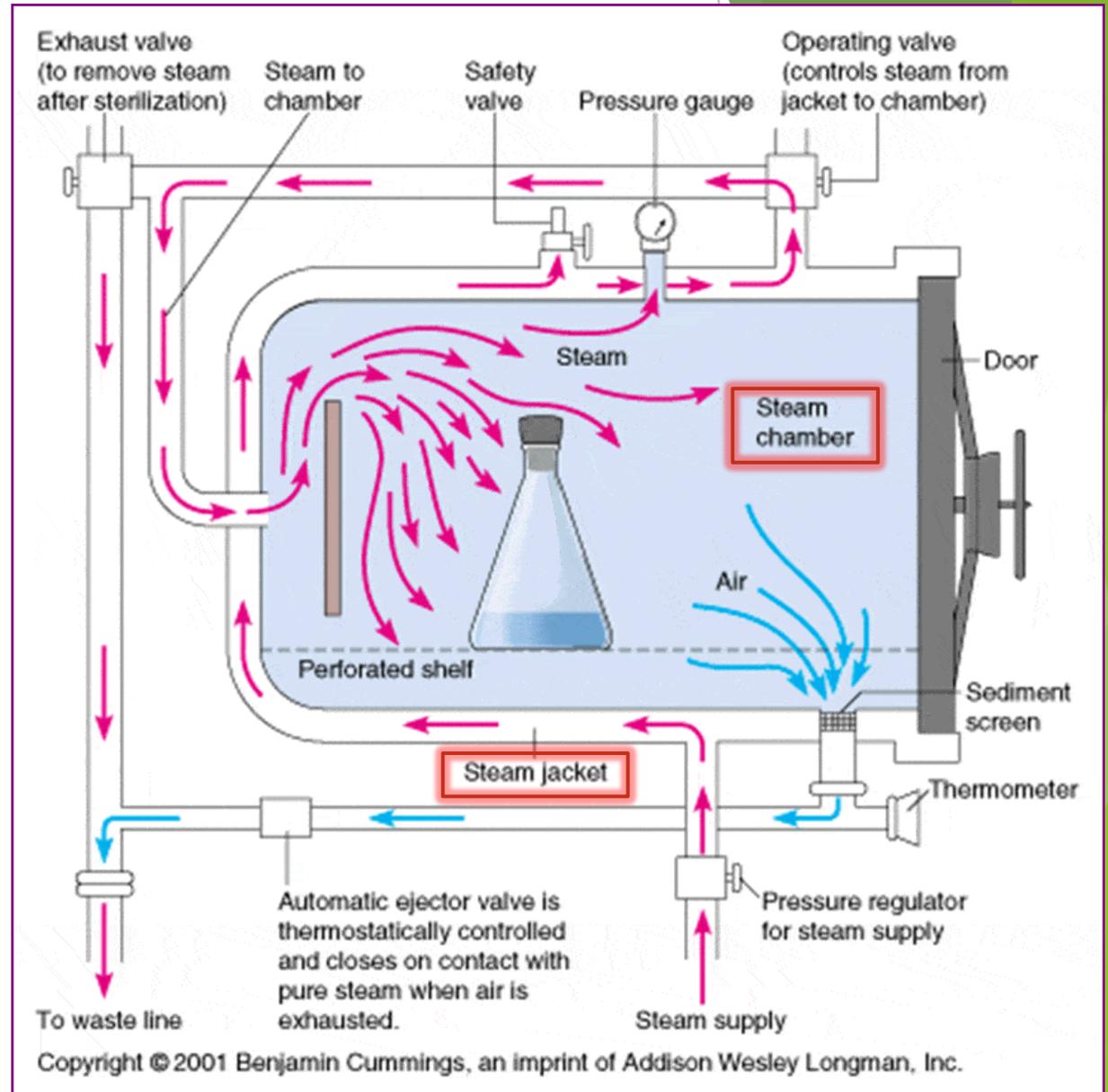
- ▶ Two elements are used to form a high pressure/high temperature environment:

- ▶ The **autoclave chamber** is where the items-to-be-sterilized are placed.

Here, steam is pumped in and air is pumped out until the desired pressure and temperature is reached. Then, a valve regulates the pressure so it remains constant.

- ▶ The **jacket** has steam running through it in order to keep the chamber at the desired temperature.

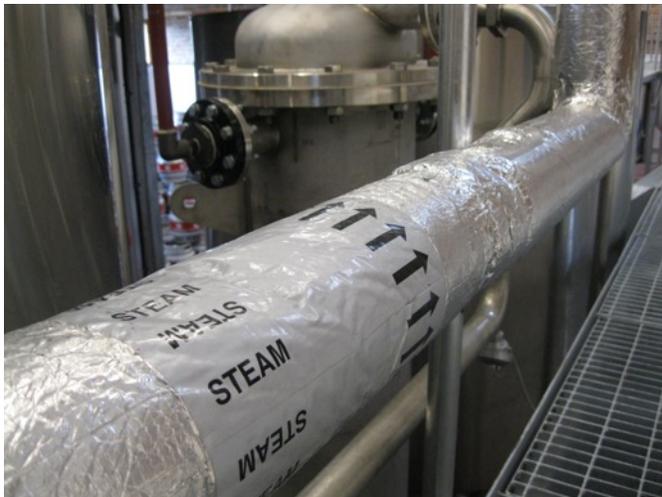
This then leads to effective sterilization of items after 30 minutes to over an hour.



Steam Usage in Autoclaves

In general, there are 3 types of steam autoclaves:

- 1.) The kind that generates steam from water (sometimes distilled) to be used in the chamber and jacket.
- 2.) A hybrid that generates steam *only for the chamber* while using house steam for the jacket.
- 3.) The kind that uses house steam for **BOTH** the chamber and jacket.



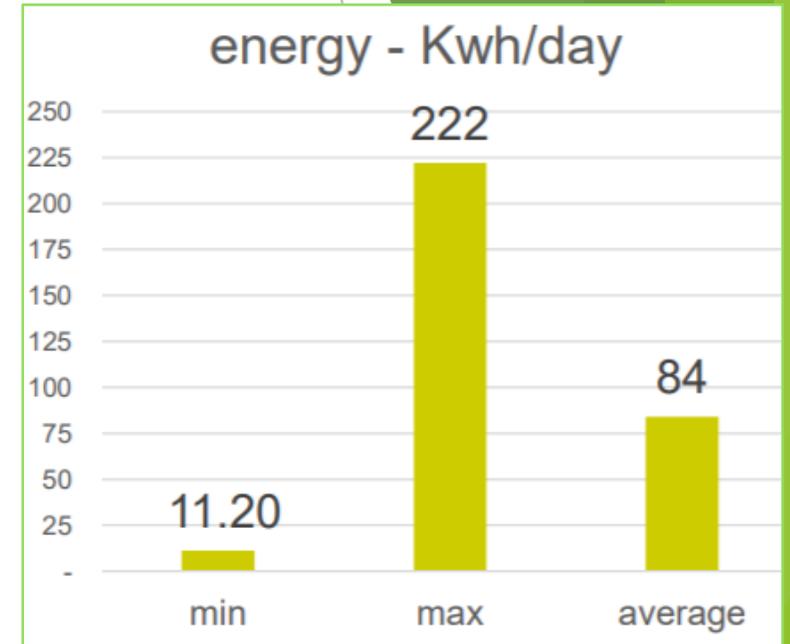
In a different category, there are also autoclaves that do NOT employ a jacket.



UC Riverside Study vs. CU Boulder Study

A previous study was performed by the University of California Riverside to analyze the energy consumption of electric steam generators in autoclaves.

- ▶ Some types of autoclaves were proven to be very energy intensive.
- ▶ Of course energy consumption varies by usage.



Our study seeks to complement this study by comparing the energy consumption of electric steam generation vs. house steam.

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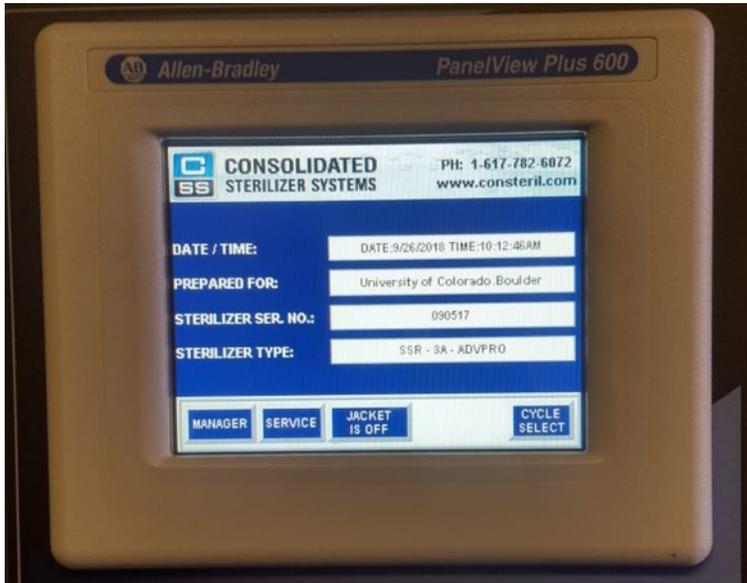
Considerations for this Study

The Chemistry building on campus needed a new autoclave:

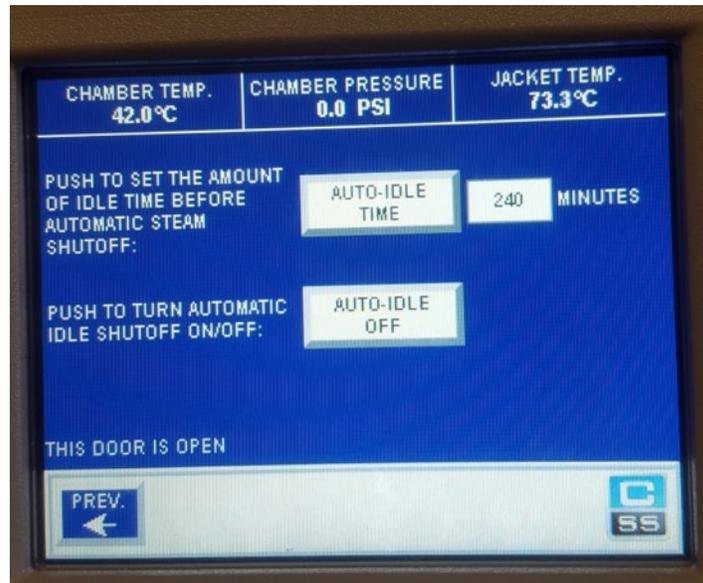
- ▶ Green Labs worked on this project with the building manager and a scientist.
- ▶ In the process we interviewed 3 autoclave companies with energy efficiency claims. Two of the companies did have energy and water efficiency efforts related to their autoclaves.
- ▶ Chose the *one* the building manager wanted the most.
- ▶ This proved to be a model from **Consolidated Sterilizer Systems**.



CSS Autoclave Features



✓ Easy to Program



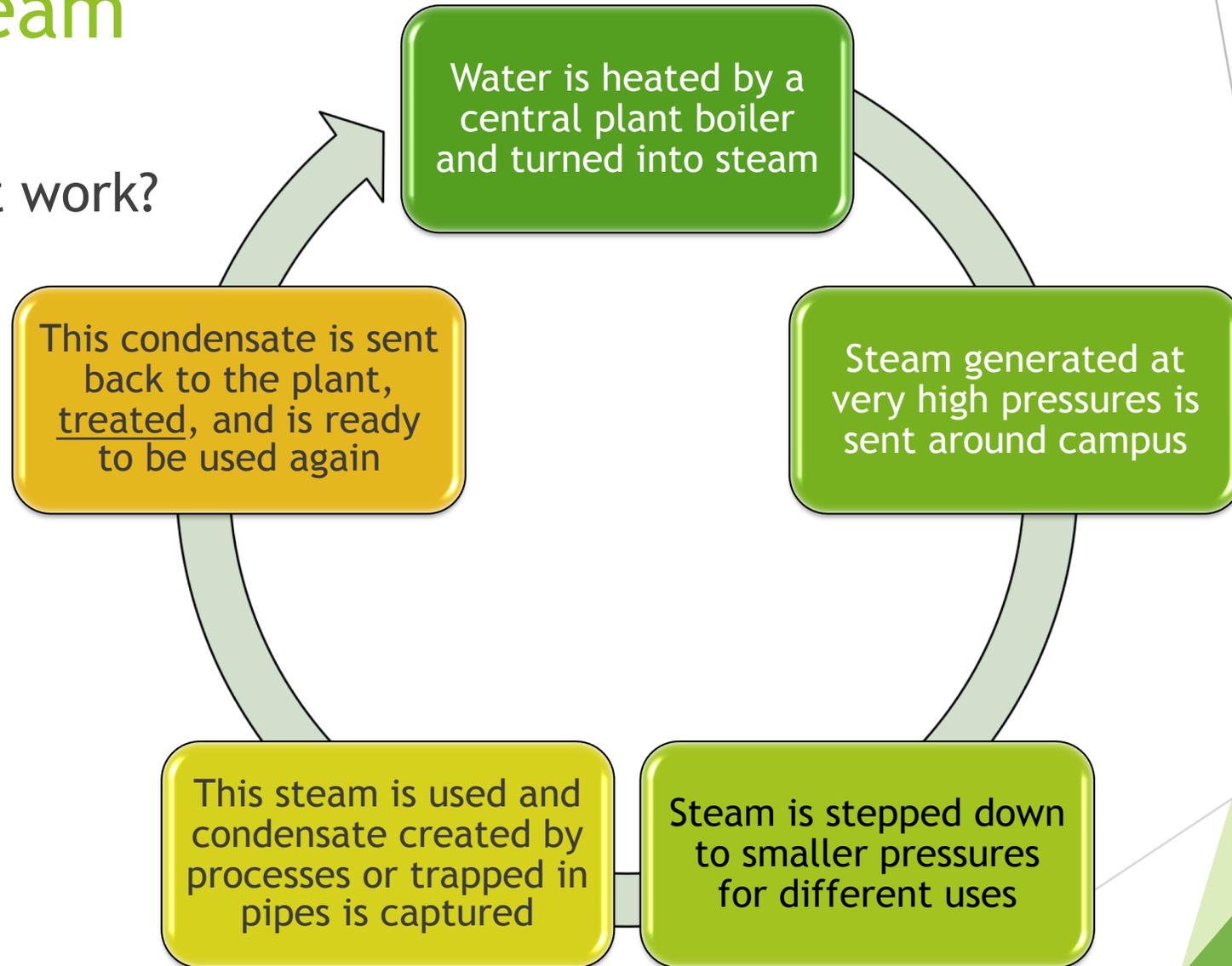
✓ Efficiency Features



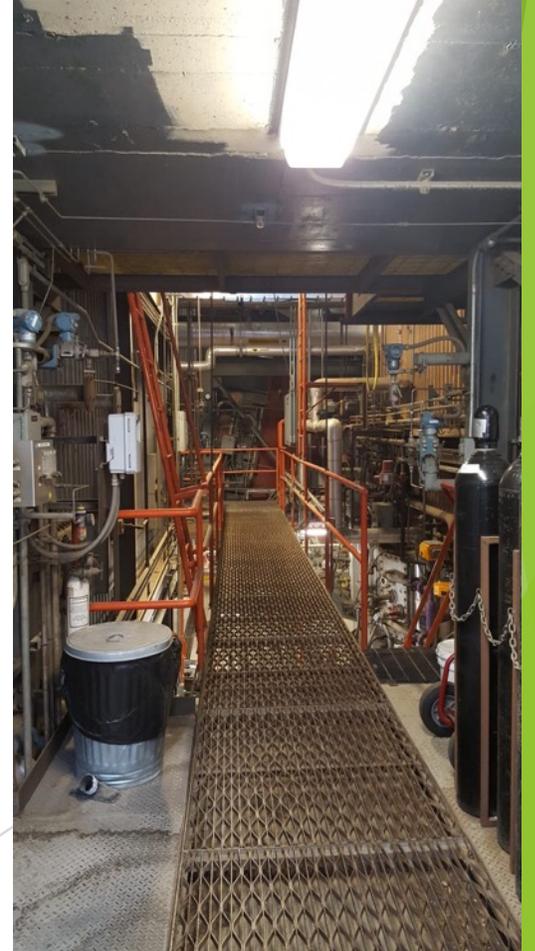
✓ Recycles Jacket House Steam

House Steam

► How does it work?



House Steam at CU Boulder



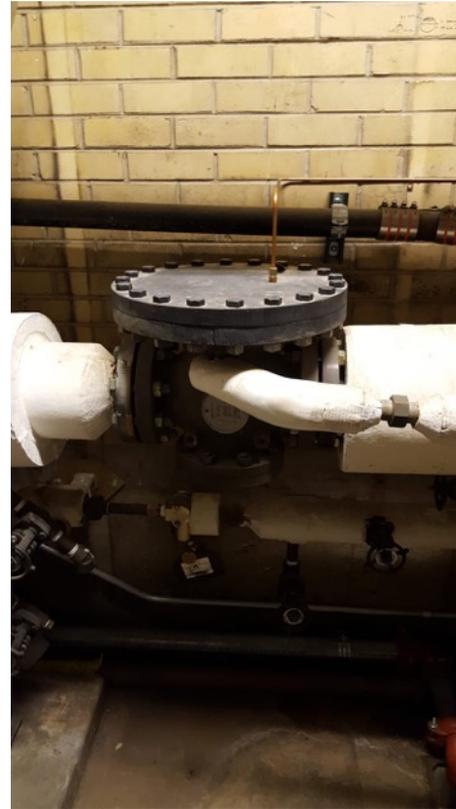
House Steam at CU Boulder



Here are the pipes that change pressure into 50 PSIG.



These tanks help normalize condensate temperature before it is re-injected.



A steam velocity/pressure transformer.



The house-steam pipes that run in tunnels throughout campus. 10

End Note on House Steam

- ▶ Both autoclaves use house steam to perform sterilization.
- ▶ Only the CSS has the ability to recycle this house steam.
- ▶ **House steam is a convenient and efficient energy source** with which to power autoclaves if steam pipes are already used within the building for other uses such as building heating.

Autoclave Study Details



Primus

VS



CSS

Very similar:

- *Both autoclaves use water misers*
- *Both use house steam for chamber and jacket*
- *Same chamber and jacket size*
- *Both exhaust chambers using an “air flush” method which creates a ~0 PSI environment*

Different:

Primus:

- ▶ Installed in 1996
- ▶ Uses house steam to keep jacket at a constant 250°F/121°C temperature
 - ▶ Does NOT recycle this steam
- ▶ Retrofitted with water miser 12 years ago
- ▶ Retrofitted with an electric time-out meter 12 years ago

CSS:

- ▶ Installed 2018
- ▶ Came with water miser
- ▶ Very programmable in comparison
- ▶ Jacket can turn on or OFF

Water Meters



- ▶ These water meters are installed on the water pipelines for CSS (left) and Primus (right) and measure gallons of water used. Both meters can measure up to 1/10th of a gallon usage.

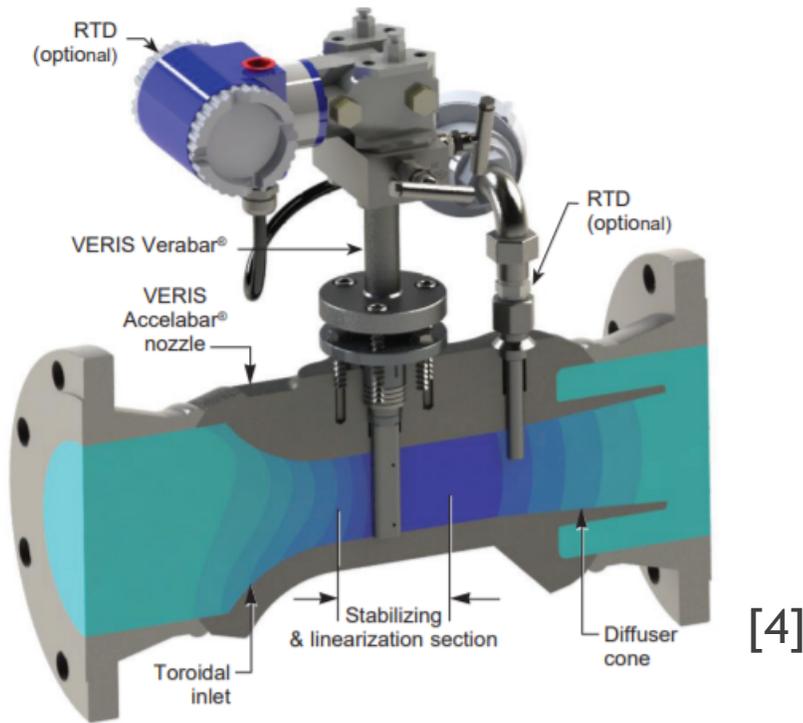
Steam and Electric Meters



- ▶ The steam meter has high resolution down to 1/1000th of a pound and is comprised of:
 - ▶ An analog meter (left)
 - ▶ A digital display (right)
- ▶ It will be used to measure steam consumption of individual autoclaves and the aggregated steam of both.

- ▶ While there are power meters installed per autoclave, these readings are measured in whole kWh; each autoclave cycle only consumes a fraction of a kWh.

VERIS Accelabar® Flow Meter



- ▶ Low-flow steam meter.
- ▶ Steam meters typically measure the flow of entire buildings.

Test Methodology

- ▶ The methodology to test each autoclave's performance will be:

Gravity	
Keep sterilization time constant	Vary dry time
Vary sterilization time	Keep dry time constant
Liquid	
Vary sterilization time	
Idle	
Measure idle consumption of steam/water	

Preliminary Results:

- ▶ Eleven tests were performed and averaged on each autoclave (with minimal repetition at this point).

Gravity:

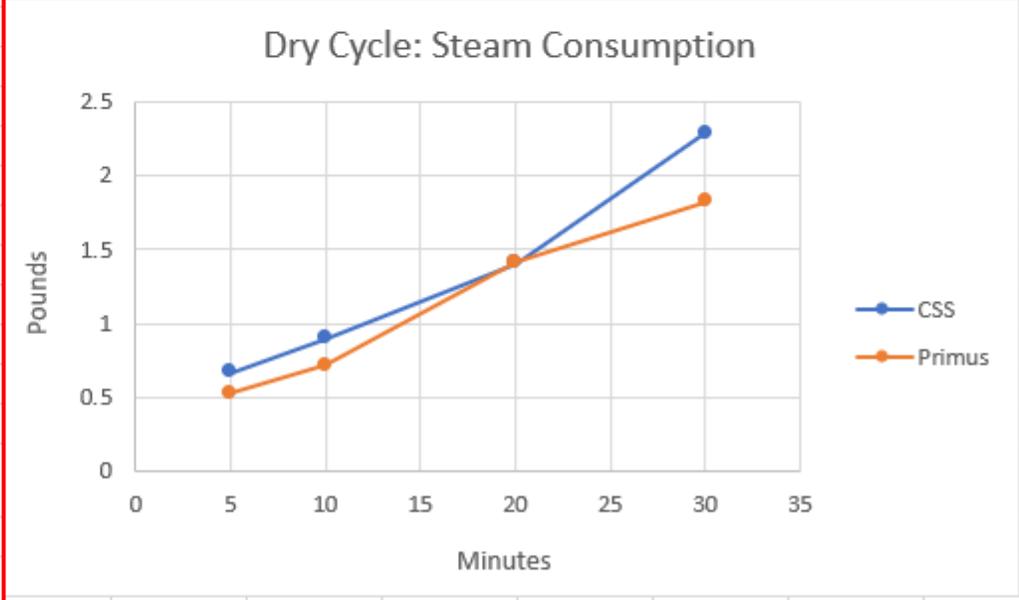
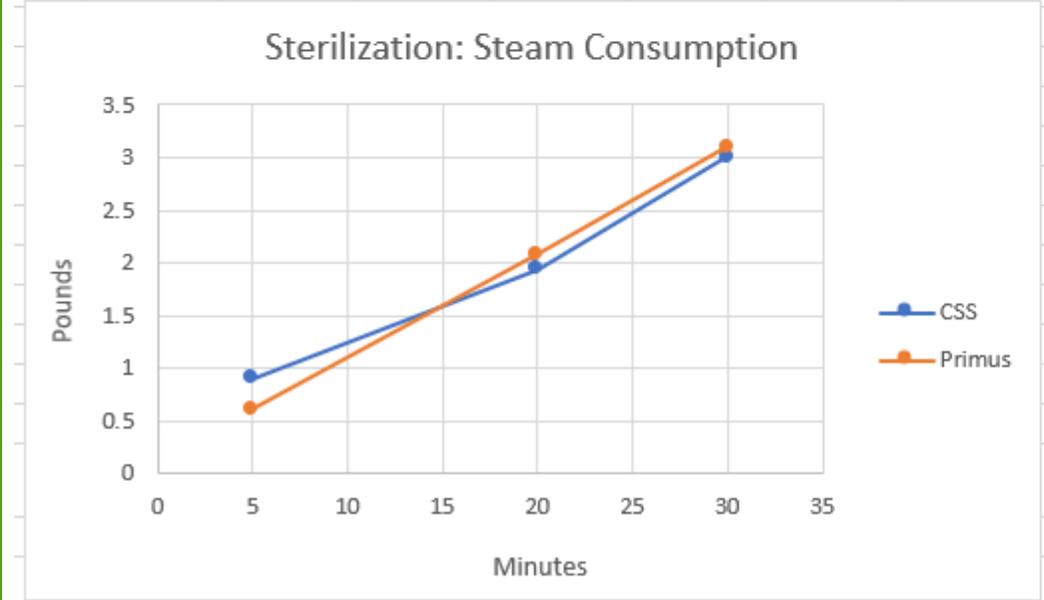
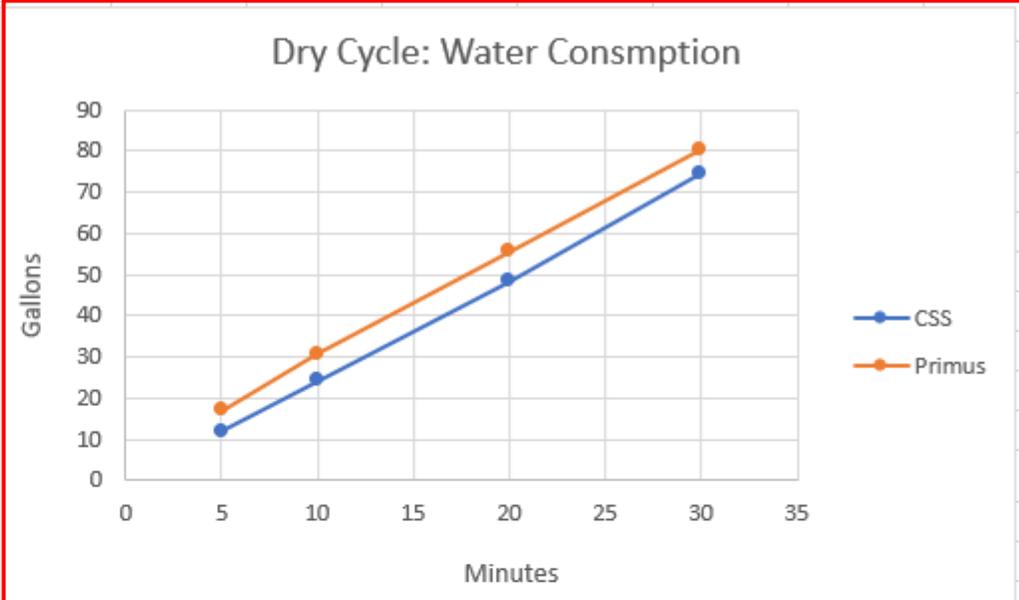
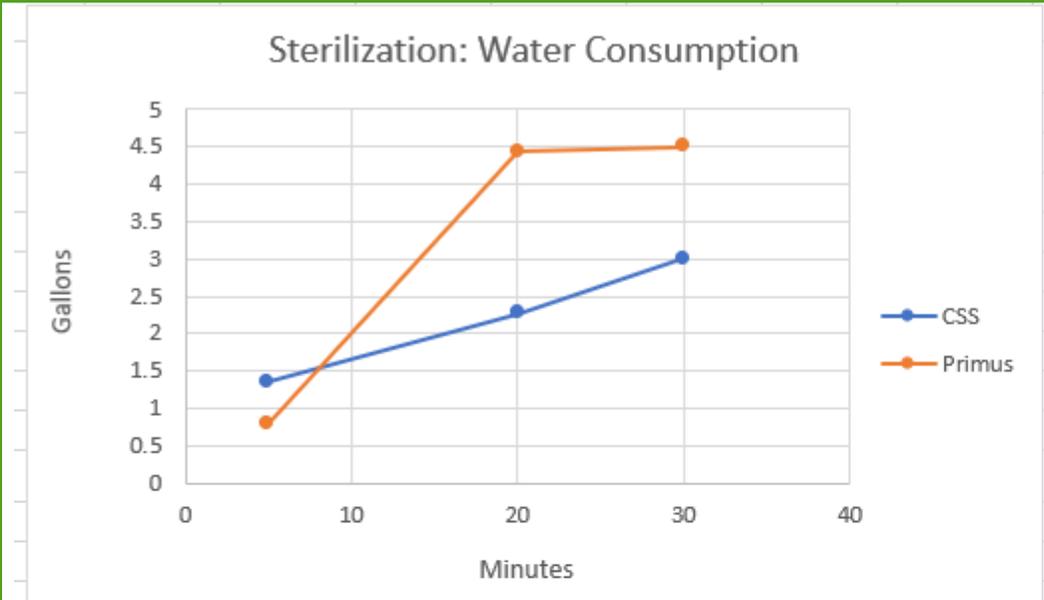
- ▶ 5 min Sterilization, 5 min Dry Time
- ▶ 20 min Sterilization: 5, 10, and 20 min Dry Times
- ▶ 30 min Sterilization: 5, 10, 20, and 30 min Dry Times

Liquid:

- ▶ 20, 30, and 40 Sterilization Times

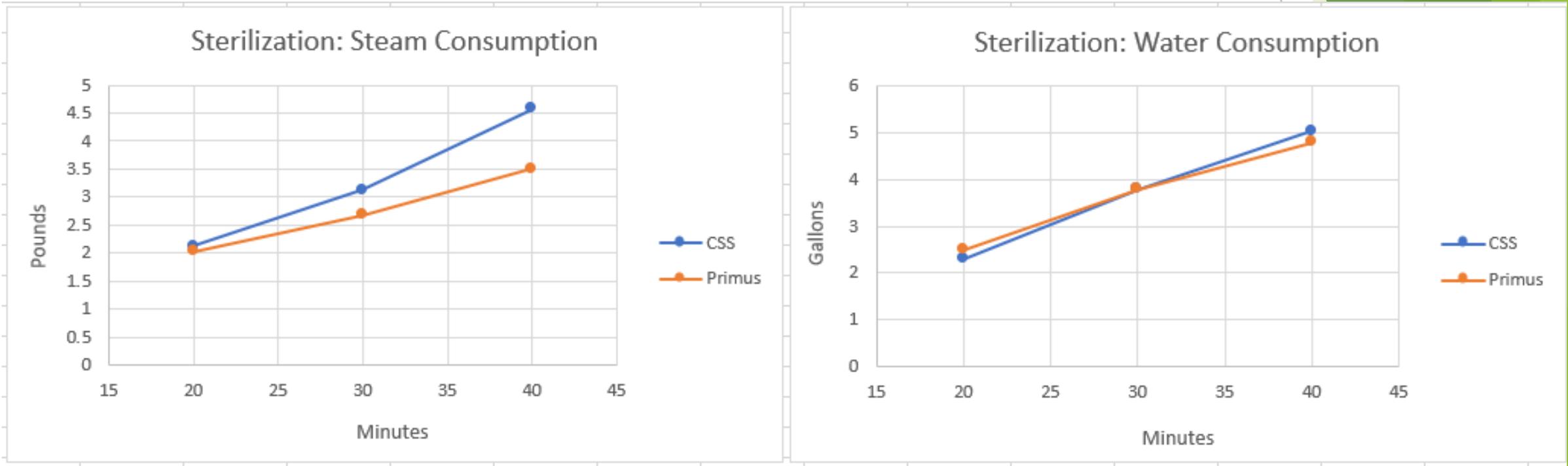
Comparison Graphs: Gravity

NEW Autoclave
OLD Autoclave



Comparison Graphs: Liquid

NEW Autoclave
OLD Autoclave



Idle Data

- ▶ The CSS's jacket uses more steam because it is programmed to retain a tighter margin on jacket temperature (centered around 120 degrees C) and thus requires steam intake more frequently.
- ▶ The Primus requires less as it has a wider margin by default which can swing from 118 to 123 degrees C.

CSS Jacket Consumption		Primus Jacket Consumption	
Jacket ON	.06 lb/min	Jacket ON	.03 lb/min
Door Closed		Door Closed	
Jacket ON	.09 lb/min	Jacket ON	.053 lb/min
Door Open		Door Open	
Jacket OFF	0 lb/min	Jacket OFF	0 lb/min

Overall Consumption Comparison with Pre-Cycle Conditioning Included: Gravity

	Primus				
5 min, 5 min	Air Purge	Heat Chamber	Sterilization	Dry	Total
Water (gal)	7.9	1.5	0.8	18	28.2
Steam (lbs)	1.75	1.67	0.61	0.74	4.77
20 min, 20 min	Air Purge	Heat Chamber	Sterilization	Dry	
Water (gal)	8.5	1.3	4.5	56.1	70.4
Steam (lbs)	1.79	0.87	1.93	1.26	5.85
30 min, 30 min	Air Purge	Heat Chamber	Sterilization	Dry	
Water (gal)	7.9	1	4.3	80.4	93.6
Steam (lbs)	1.66	1.12	3.3	1.82	7.9

*uses on average 9 gallons of water and 3 pounds of steam to purge air and heat chamber.

	CSS				
Jacket Usage	Cond. Usage	Sterilization	Dry	Total	
0.35	2	0.2	12.85	15.4	
5.45	1.53	0.93	0.677	8.587	
Jacket Usage	Cond. Usage	Sterilization	Dry		
0	2.1	2.25	48	52.35	
0	0.53	2.03	1.406	3.966	
Jacket Usage	Cond. Usage	Sterilization	Dry		
0	2.25	3.1	74.55	79.9	
0	0.68	3.25	2.292	6.222	

*uses on average 2.3 gallons of water and 0.65 pounds of steam to purge air and heat chamber.

Energy Analysis

From Ellen Edwards, an Energy Manager at CU Boulder:

- ▶ Natural gas is purchased in millions of Btus - \$4.10 per MMBtu.
- ▶ One boiler here in EDEP uses 963 lbs per hour of NG, roughly 0.05 lbs to make 1 lb of steam.
- ▶ Using standard weight and running numbers, natural gas comes to **\$0.004 per pound per hour.**

With this information we can estimate cost per run- using longer runs (typically gravity) as an example- and possible savings due to recycled jacket steam.

CSS Gravity Cost									
Sterilization	Dry	Ster Rate	Dry Rate	Consumption	\$/lb	Total Cost	Recycle Rate	Total Recycled	Savings
5	5	0.126192	0.077294	1.017427083	0.004	\$0.004	0.06	0.6	\$ 0.002
20	5	0.126192	0.077294	2.910302083	0.004	\$0.012	0.06	1.5	\$ 0.006
20	10	0.126192	0.077294	3.296770833	0.004	\$0.013	0.06	1.8	\$ 0.007
20	20	0.126192	0.077294	4.069708333	0.004	\$0.016	0.06	2.4	\$ 0.010
20	30	0.126192	0.077294	4.842645833	0.004	\$0.019	0.06	3	\$ 0.012
30	5	0.126192	0.077294	4.17221875	0.004	\$0.017	0.06	2.1	\$ 0.008
30	10	0.126192	0.077294	4.5586875	0.004	\$0.018	0.06	2.4	\$ 0.010
30	20	0.126192	0.077294	5.331625	0.004	\$0.021	0.06	3	\$ 0.012
30	30	0.126192	0.077294	6.1045625	0.004	\$0.024	0.06	3.6	\$ 0.014
minutes	minutes	lb/min	lb/min	lb	\$/lb	\$	lb/min	lb	\$

Takeaways

- ▶ Similar steam and water consumption between two autoclaves
- ▶ However, CSS is a higher performing unit with tighter temperature margins and more consistent data

It has features that help with consumption already as part of the unit

- ▶ Auto shut down of jacket
- ▶ Recycling of jacket steam
- ▶ Much faster conditioning at beginning requiring less consumption

Employs an excellent human-machine interface (HMI)

- ▶ Easy to read/use display
- ▶ WiFi abilities

Suggestions

If you cannot buy a new unit with energy conservation features, you can still modify your old unit:

- ▶ Add water misers for water savings
- ▶ Add timers to turn steam off at night/weekends or try to program the unit to do this
- ▶ Make 5 minute dry times a standard

If you can buy a new unit, look for a unit that has features for energy and water efficiency already programmed in (and possible opportunities such as jacket steam return to house system) and has a good online internet system.

If your building already has a house steam system in place for heating purposes, utilizing this steam for autoclaves is an efficient option- especially when compared to the energy intensive process of electric steam generation.

Future Plans

More tests will be performed in which:

- ▶ Tests will be repeated to get a more accurate understanding of variation
- ▶ Spore tests will be placed in cycles to make sure both autoclaves are sterilizing
 - ▶ This is a key feature as the older autoclave model has grown more **unreliable** over the years
- ▶ Benefits of recycled steam will be more closely analyzed
- ▶ CSS jacket steam will be switched over to the miser as opposed to being recycled in order to have a more 1:1 comparison
- ▶ House Steam vs. Electric Steam Generation Comparison
- ▶ Carbon Footprint
- ▶ White Paper

References

- ▶ [1] <https://microbeonline.com/moist-heat-sterilization-definition-principle-advantages-disadvantages/>
- ▶ [2] <https://tuttnauer.com/autoclave/steam-generator>
- ▶ [3] <https://www.westlab.com.au/equipment/equipment-a-l/autoclaves/050119-0004-autoclave-steam-electric-24lt>
- ▶ [4] <https://www.armstronginternational.com/sites/default/files/resources/files/479-EN.pdf>
- ▶ [5] Ellen Edwards

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