Priorclave North America

An informal guide to laboratory autoclave purchasing, with some advice and suggestions from Priorclave North America.

For many years the laboratory autoclave has been an essential item in any laboratory where microbiology work is carried out. However, a spiraling amount of regulation over the past 25-30 years has changed the way sterilizers are specified, installed, and used. All of this makes running an autoclave more difficult than it used to be. Gone are the days when you could look through a catalog to pick one out, and once it was delivered, simply plug it in.

Safety systems such as thermal or cooling locks, along with additional laboratory quality standards, have extended cycle times dramatically. This has led to the development of systems and accessories to assist in the optimization of performance for specific load types. Vacuum air removal, venting systems, and accelerated cooling options are now common on many sterilizers.

The vacuum and free-steaming systems fitted to many autoclaves to improve performance, along with increasing concern about what is carried over into the exhaust stream, has led to the establishment of standards and regulations requiring most autoclaves to be connected to sealed and vented drains.

Sophisticated microprocessor control systems can be a nightmare to the technophobes among us, so it is important to consider who is likely to be using the sterilizer, and how often the settings may need to be changed. Some systems are as easy to set up as a timer and temperature dial, whereas others require a manual and passwords to make even a small adjustment. Both may be valid, but each apply to separate applications. For instance, a level of security in setting the sterilizer that is essential in a pharmaceutical production facility with fixed and validated cycles, and with non-technical operators, would be extremely frustrating to experienced laboratory scientists looking for spontaneous flexibility.

It is also worthwhile taking into consideration the lifetime cost of the equipment. These would include factors such as electricity or steam, the cost of water for cooling systems and vacuum pumps, if applicable, and the cost of servicing and maintaining the autoclave. Generally speaking, the more complex the equipment, the more maintenance will be required. As a rule of thumb, the more moving parts, the more things will go wrong, especially over the lifetime of the sterilizer.

As always, when specifying or purchasing an expensive and complicated piece of equipment, it is essential to be able to ask the right questions in order to get the right answers. It is important to think about what you are going to put into the autoclave to make sure the device you buy is configured properly to process it effectively and efficiently, especially if you are going to have to prove this to a certifying body.

The following questions and comparisons may help you in making your decision. They are not intended to give a full explanation of all the issues and technicalities, but they should help in narrowing your choices - with this information you should at least be armed with informed questions to ask prospective suppliers and manufacturers.

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Which type of autoclave is most suitable?

Top or Front Loading?

Top Loading	+	Smaller 'footprint' - usually does not require much additional width and depth outside the chamber space, and therefore uses less laboratory space. Top loading models typically only increase in height with increased capacity.
	+	Accommodates taller items such as fermentation vessels, which otherwise would require a much larger and more expensive front-loading autoclave.
	-	Recently becoming less popular due to ergonomic issues involved in the lifting of possibly heavy baskets and containers. Fitting a load-lifting hoist can reduce this risk. Choosing lower loading height models to decrease lifting height can also help.
Front Loading	+	Easier loading and unloading, especially if a loading trolley is used.
	-	Larger 'footprint' - larger capacities will require more floor space, unlike top loading models, which typically only increase in height with increased capacity.

Cylindrical or Rectangular Chamber?

Cylindrical Chamber	+	Pressure inside the chamber naturally attempts to make the chamber round. A cylindrical chamber can have thinner walls since it requires less steel to support the chamber, which must be heated (and then cooled). It therefore weighs less, and costs less, to manufacture, deliver, and operate.
	+	Better steam circulation on front loading models. Because of the circular profile of the working chamber and the 'square' profile of most autoclave loads there will normally be space around the sides of the load for steam circulation. This prevents inexperienced users from 'overloading' the chamber.
	-	Because of the circular profile, front loading cylindrical models have less 'useable space' than their rectangular counterparts for a given volume. This is a trade off against improved steam circulation. (this does not apply to top loading autoclaves, as most loads naturally adapt to a cylindrical profile, and can also be stacked)
Rectangular Chamber	+	Larger chamber capacity for a given footprint compared to cylindrical autoclaves.
	+	Less 'wasted' chamber capacity as a rectangular load is more readily fitted into a rectangular chamber.

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Rectangular Chamber (continued)

- More careful and skilled loading is required to ensure steam circulation is not restricted by overfilling the autoclave chamber. If the steam cannot get to the load, or the air cannot escape, the cycle will be less effective.
- In order to prevent the chamber from becoming round under pressure rectangular autoclave chambers must be built with much thicker walls than cylindrical ones. They also require substantial bracing around the outside of the chamber at regular intervals, resulting in up to 3x the mass. They therefore require substantially more energy to heat, and without sophisticated systems (which require more energy, water, and maintenance), can cool more slowly. They not only cost more to build and deliver, but also to operate, than their cylindrical counterparts.

Double Ended (Pass-through) models

Ideal for containment or sterile areas where items can be sterilized into or out of the room via an autoclave sealed into the lab wall.

For more detail on the issues surrounding this type of autoclave please refer to our downloadable pdf data sheet:

http://www.priorclavena.com/autoclaves/double-ended

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How should the autoclave be heated?

To some extent this will depend upon the utilities available to your laboratory. However there are three principle methods:

Electrically Heated (by heaters inside the chamber)

+ Simple and easy to maintain and service as the heaters are visible and accessible within the chamber.
+ Less complex and therefore less expensive and requiring less service over time.
- Longer cooling times, as there is a reservoir of hot water in the bottom of the autoclave which must be cooled down along with the load. On some models this can be emptied to improve cooling times, although this would require re-filling the chamber before the next cycle.
- Slower chamber heat-up time than steam heated autoclaves (not as significant for large liquid loads, as their heat-up time is also slow).

Steam Heated (from an external steam source)

+ Faster chamber heat-up time as high temperature steam is instantly available inside the autoclave.
+ Because steam is injected into the chamber at pressure there is better circulation and penetration of steam than with electrically heated models.
+ Faster cooling than some electrically heated models - there is no reservoir of hot water in the bottom of the autoclave to be cooled down along with the load.
- A reliable supply of dry steam is required. Some in-house supplies can be unreliable. An autoclave requires good quality 'dry' steam to function correctly. Some manufacturers can supply autoclaves with 'back up' electrical heating to cover for when the steam supply is not available.
- Unless you are replacing an existing steam heated autoclave, a reducing valve will be needed to reduce the steam line pressure to a pressure suitable for the autoclave. Condensate-return equipment to dry the steam before delivery to the autoclave may also be necessary. On larger, more expensive autoclaves, these items are often fitted as part of the autoclave but on many models they will be an additional installation cost.

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Steam Heated (from an external steam source) (continued)

- Faster chamber heating of steam heated models means the lag between chamber and load temperature must be taken into account when setting up the autoclave cycles. What is saved in heat-up time can end up being added to sterilizing time with bulkier liquid loads.
- Condition and possible chemical contamination of the external steam source should be considered if autoclaved items are intended for re-use.

Steam Heated (from a dedicated steam generator)

Stand-Alone Steam Generator

Electrically or gas heated steam generator.

+ All the advantages of in-house steam supplies and unaffected by other items connected to the same steam supply. 'Clean Steam' and other types are available if required.
- Expensive to purchase, maintain, and operate, especially for smaller autoclaves where the cost might be near to or greater than the cost of the autoclave itself.
- Water treatment systems are often needed for these units, along with suitable drains and other ancillary equipment, adding further to the cost.

Built-In Steam Generator

Electrically heated steam generator. This system has many similarities to mounting the heaters in the bottom of the chamber. The heaters are fitted into a separate chamber directly attached to the main autoclave vessel. As with the 'in chamber' system, steam generation is controlled by the autoclave temperature controller.

+ Slightly faster heat up times and slightly better steam penetration than 'in chamber' electrically heated models.
+ Faster cooling than 'in chamber' electrically heated models. There is no reservoir of hot water in the bottom of the autoclave to be cooled down along with the load.
- Can be affected by spillage and breakage of certain load types, especially growth media.
- Expensive to purchase and maintain - heaters and other parts are more difficult to access for service and examination than 'in chamber' electrically heated models.

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Steam Heated (from a dedicated steam generator) (continued)

Built-In Steam Generator — **Electrically heated high pressure 'on demand' steam generator**

+ This type of generator maintains a high-pressure steam supply available on demand and is generally comparable in performance with an external steam supply or a 'stand alone' steam generator.

+ Faster cooling than 'in chamber' electrically heated models. There is no reservoir of hot water in the bottom of the autoclave to be cooled down along with the load.

+ Because the steam generator is physically closer to the autoclave chamber, and the generator steam pressure is lower than a 'stand alone' type generator, reducing valves and condensate-returns are not usually required.

- Heaters and other parts are more difficult to access for service and examination than 'in chamber' electrically heated models.

- More complex than 'in chamber' electrically heated models, requiring a control system, water pump, and separate safety valve - expensive to purchase, requiring more frequent servicing.

- More expensive to run as the heaters will be operating all day to maintain the supply of readily available steam. During a 10 hour day they will be running for 2-3 times longer than the heaters in a comparable electrically heated model and even longer if the generator is left running overnight.

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What type of door will you require?

Manual — **Manual door with hand bolts.**

+ Less complex, requiring less servicing, and less expensive.
- Requires opening space at the front and side of the autoclave.
- Less convenient to open and close than single action or push-button operation.
- Slower to open and close than single action or push-button operation, however, the extra time required is small when compared to total cycle time

Manual — **Manual door with single action closure.**

+ Less complex than powered door closures, requiring less servicing, and less expensive.
+ Faster and easier to operate than hand bolt doors.
- Requires opening space at the front and side of the autoclave.
- Less convenient to open and close than push-button powered doors.

Power — **Power door, vertical or horizontal opening.**

+ Simple and fast push-button operation.
+ No 'door swing' space required.
- Many types rely on 'moving door seals,' which can require frequent and expensive changing.
- More complex and expensive due to the controls and mechanisms required to move the door into position and then seal it. Regular maintenance of these systems is essential.
- On horizontal closing versions the door requires space for at least the width of the autoclave chamber on one side.
- On vertical closing versions the door requires space for at least the height of the autoclave chamber below at the front. This tends to reduce the chamber heights available so as to avoid high loading heights.

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What about steam jackets - will you need one?

Steam/Water Jackets are available on many autoclaves. These are effectively another pressure vessel surrounding the main autoclave vessel around which steam or cold water is run to heat or cool the outside of the autoclave chamber. Full and partial jackets are available.

+ Faster cooling times when cold water is run around the external jacket.

+ Still the best system for achieving the maximum dryness in porous and textile loads. Heating the outside of the chamber wall reduces condensation onto the load during heat up and drying. Some alternative and less costly systems are available, however, which can achieve an acceptable level of dryness in many cases.

- More complex and expensive to build. The jacket requires additional valves and control gear to operate. Regular maintenance is essential.

- Requires a steam supply.

- If water-cooling is required, a large amount of water is used.

- When cooling liquid loads 'Air Ballasting' is required to protect the load from damage by rapid decreases in chamber pressure.

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What will be sterilized and which options will help to make autoclaving more effective?

Bottled Liquids - Bottled Growth Media, Buffers, or Bottled Waste

Thermal/ Cooling Lock	+	Prevents the autoclave from opening before the load inside has cooled to a safe temperature.
Freesteaming	+	Allows time for the load temperature to 'catch-up' to the autoclave temperature.
Load Sensed Process Timing	+	Guarantees sterilizing times by not starting the process time until the load reaches sterilizing temperature.
	-	Not advised for growth media, which can be 'overcooked' whilst the whole load gets up to process temperature.
Rapid Cooling	+	Reduces cooling time before the thermal lock allows the door to open.
Air Ballasting	+	For sealed or semi-rigid containers where very rapid cooling, i.e. spray or water jacket, is used. Requires a supply of compressed air.
Load/ Performance Qualification Testing	+	Recording of cycle temperatures with multiple recording probes ensures that the autoclave settings will achieve sterilizing conditions in all parts of the load. After initial testing regular calibration of the autoclave is required to confirm the continued correct operation of the autoclave.
	-	Testing requires specialized staff and equipment and can take several days, depending on the number of load sizes and types to be tested.
	-	To be effective as an assurance of sterilization, consistent loads must be run.

Glassware, Equipment, and Porous Loads - l Zmi ^aZhdVcYd gVeeZYdchi gj b Zci h

Pre-Cycle Vacuum	+	Improved air removal as repeated vacuum pulses draw trapped air out from difficult loads to be replaced by steam.
Pulsed Freesteaming	+	Assists with steam penetration. Repeated pressurizing and de-pressurizing of the chamber during heat-up creates turbulence, helping to remove air, to be replaced by steam. Often used in conjunction with a vacuum system.
Post-Cycle Vacuum Drying	+	Helpful with removal of residual moisture in the load. Traditionally this requires a steam jacket, but other methods are now available.

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Glassware, Equipment and Porous Loads (continued)

Air Intake Filters	+	Air drawn into the autoclave as it cools is filtered with a microbial filter to protect the contents from contamination.
Load/ Performance Qualification Testing	+	Recording of cycle temperatures with multiple recording probes ensures that the autoclave settings will achieve sterilizing conditions in all parts of the load. After initial testing regular calibration of the autoclave is required to confirm the continued correct operation of the autoclave.
	-	Testing requires specialized staff and equipment and can take several days, depending on the number of load sizes and types to be tested.
	-	To be effective as an assurance of sterilization, consistent loads must be run.

Plastic Discard and other Laboratory Waste

Pre-Cycle Vacuum	+	Improved air removal as repeated vacuum pulses draw trapped air out from difficult loads to be replaced by steam.
Freesteaming	+	By venting the autoclave at low pressure, turbulence is created within the autoclave, helping to remove air, to be replaced by steam.
Pulsed Freesteaming	+	Assists with steam penetration. Repeated pressurizing and de-pressurizing of the chamber during heat-up creates turbulence, helping to remove air, to be replaced by steam. Often used in conjunction with a vacuum system.
Post-Cycle Vacuum	+	Available on some autoclaves. Repeated post sterilizing vacuum cycles can be used to rapidly cool the load contents, improving cycle times.
Load Sensed Process Timing	-	**Not** advised for plastic wastes. Remote probes can become encapsulated in melting plastics and are often damaged on removal.
Exhaust Filtration	+	Where high category pathogens are being autoclaved, prevents pathogens from leaving in the autoclave exhaust.
Discard Containers	+	Protection from spills and leakage when plastic containers and dishes melt during autoclaving.
Deodorants, Room Air Extraction	+	To combat the odors generated when autoclaving waste materials.

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Plastic Discard and other Laboratory Waste (continued)

Load/ Performance Qualification Testing	+	Recording of cycle temperatures with multiple recording probes ensures that the autoclave settings will achieve sterilizing conditions in all parts of the load. After initial testing regular calibration of the autoclave is required to confirm the continued correct operation of the autoclave.
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Installation

For a detailed look at the issues surrounding the correct installation of autoclaves we suggest the following downloadable pdf data sheet:

http://www.priorclavena.com/downloads/AGuidetoAutoclaveInstallation

How much Space is required?

Although many people do not have the luxury of a large amount of available space around the autoclave the following dimensions are advised. Small and medium-sized autoclaves can be castor mounted and with flexible connections can be moved to enable service work to be carried out.

		At least
Around the Autoclave:	Sides	3.5 feet
	Rear	12 inches
	Front	6.5 feet or twice the length of the Loading Trolley
Other Considerations:		Room size?
		Room access to fit the proposed autoclave in?
		Which floor?
		How do you get to that floor?
		Floor loading weight?
		Is there an existing autoclave or other equipment, and if so, how are you going to get it out?
		Do you need to schedule the removal of the current autoclave so that you can maintain a limited service?

What Services are Required?

Electrical Supply	480 Volt 3 Phase	Most larger autoclaves and steam generators.
	240 Volt 3 Phase	Smaller autoclaves. Sometimes available on 100-200L sizes with reduced heating power. If only single phase is available, manufacturers may be able to accommodate this.
Water	Mains Water	For drain condensers and vacuum pumps
	Treated Water	In hard water areas may be required for electrically heated autoclaves.

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What Services are Required? (continued)

Drains, are they:	Heat resistant?	Not just the material of the drains but any joint seals, etc., should be capable of withstanding 134C+ (273F+). For heat sensitive drains a water cooled condenser can often be fitted to cool the autoclave exhaust to a suitable temperature.
	Over 1.5 inches in diameter?	To allow adequate venting.
	Vented at a high level outside of the building?	To prevent pressure build-up when the autoclave is vented.
Steam	Plant Steam or Clean Steam?	Certain applications where the sterilized items are re-used require high quality clean steam, which can be expensive to install and maintain.
	Is the line pressure acceptable?	A supply pressure of at least 1 Bar above maximum autoclave operation pressure is required for proper operation.
	What is the life of the boiler house?	Will the autoclave 'outlive' its steam supply? Some manufacturers can supply autoclaves with 'back up' electrical heating to cover for when the steam supply is not available.
Compressed air		Required for door seals and control valves on some autoclaves and for air ballasting systems. On many autoclaves an air compressor may already be built-in.

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Control and Measurement

How will the Cycle be controlled?

Pressure and Time - No longer common with the advent of more reliable temperature systems. Can lead to under-temperature cycles if air remains in the autoclave

Temperature and Time + Ensures adequate temperature sterilizing conditions if air remains in the autoclave.

Other Methods With the sophisticated microprocessor controls now available an alternative system for controlling sterilization has been devised, known as **F0**. F0 is a lethality calculation used extensively in Food Processing and in Pharmaceutical applications. It takes into account the time spent by the load at elevated temperatures during heat up and cool down and includes this as part of the total sterilizing time.

+ Useful for laboratory waste as it reduces the time required for sterilization.

+ Useful for growth media as it reduces cycle time and the likelihood of 'overcooking.'

- Not widely accepted in the UK National Health Service.

- Requires thorough Performance Qualification and consistent loads.

How do you Prove sterilization?

Methods of recording the cycle:

Integral Data Printers_ + Inexpensive and uses the same sensors as the autoclave. Some printers use a thermal printing process. These can be faster and quieter than other systems but the paper can be affected by the heat. Care should be taken with the handling and storage of records on thermal paper in the hot environment around an autoclave.

- Although very uncommon with modern control systems there is the possibility that if there is a fault in the control system, making it inaccurate, then the printer will be inaccurate too. In such a case improperly sterilized loads could be produced and the fault not picked up by normal monitoring. However modern microprocessor systems are more reliable than before and, in addition, many manufacturers can include internal systems to 'self-validate' the control system and detect and indicate it.

Methods of recording the cycle (continued)**:**

Built in Logging Systems	+	Many modern microprocessor autoclave control systems have the ability to download a detailed cycle log to a computer, either with a direct link or via a memory card. This data can then be processed with specialized software or with a standard spreadsheet to provide a complete record of cycle progress.
	+	Log data can be sent directly to the manufacturer to aid in fault diagnosis and resolution, often saving the expense of an engineer callout.
	-	Although very uncommon with modern control systems there is the possibility that if there is a fault in the control system, making it inaccurate, then the printer will be inaccurate too. In such a case improperly sterilized loads could be produced and the fault not picked up by normal monitoring. However modern microprocessor systems are more reliable than before and, in addition, many manufacturers can include internal systems to 'self-validate' the control system and detect and indicate it.
	-	The record produced as proof of sterilization (or at least the source data for it) must be unable to be altered so that records cannot be falsified.
Chart Recorders & Data Loggers	+	Independent of the autoclave control system. In the unlikely event that there is a fault in the control system, making it inaccurate, then the independent recorder or logger will show this.
	-	More expensive and requires the installation and placement of additional probes and sensors which operate only with the recorder or logger.
Chemical Indicators	+	Tried and tested and simple for operators to place and use.
	-	Not always an indicator of full sterilizing conditions, i.e. both temperature and steam.

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Servicing and Maintenance?

Once your autoclave has been delivered and installed it is easy to forget that it is there, until it breaks down, and the work starts to build up. It can often be the case that a food manufacturing plant can be brought to a halt if the lab autoclave is not working for a few days. At minimum, work may have to be expensively out-sourced while the autoclave is waiting to be repaired.

On-going maintenance and service should be considered as part of the purchasing process, after all, you wouldn't buy a new car and expect it to run forever without service. Make sure you're not saving a few dollars on the initial purchase only to wind up with inconvenient 'down time' afterwards.

Find out whether preventative maintenance is available, who will conduct the work, what is covered by different packages and warranties, and how well they perform in terms of call-out times and the ability to fix the equipment when they arrive.

What else should you do?

1. Take the time to consider your options. The working life of an autoclave is upwards of 10 years, and with the capital expenditure involved, you may not be able to replace what you have chosen for some time.
2. Look at what you have already.
3. Involve the people who will use the autoclave, and find out what they want. An operator who feels left out of the specifying process can often be the cause of many unnecessary service visits and 'faults.'
4. Discuss with the Finance Department how big the budget will be. Some manufacturers' options and accessories are easily fitted to the autoclave at a later date, so if there is not enough budget for all that you require, you can still upgrade at a later date.
5. Get some budget prices from manufacturers.
6. Take into consideration aspects of hygiene and cross contamination when specifying and installing your autoclave. After all it is only the stuff that finds its way inside the autoclave that gets sterilized. Anti-microbial surface coatings and materials are available with some equipment to assist with this aspect.

Any reputable supplier will be able to provide assistance, advice, and information on these questions. Often you will be able to arrange a site survey to make sure everything is going to fit.

In the end it's your choice. Of course price is an important factor, but sound research and reliable backup to ensure trouble free installation and operation may very soon turn out to be a wise investment.

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