

Our guide to choosing an Autoclave

Choosing an Autoclave

An informal Guide to Laboratory Autoclave purchasing, with some advice and suggestions from Priorclave Ltd.

For many years the laboratory autoclave has been an essential item in any laboratory where microbiology work is carried out. However, spiralling amounts of justifiable but suffocating regulations over the last 25-30 years have changed the way they are specified, installed and used.

All of this makes buying, specifying, installing and running a laboratory autoclave more difficult than it used to be. Gone are the days when you could look through a catalogue to pick one out and once it was delivered, plug it in with a bucket behind to catch the drips, or a pipe running into the nearest drain or through the wall, set it to 15 minutes at 121oC and empty it out again once there was no pressure inside.

The addition of safety systems such as thermal or cooling locks, and the increased requirement to ensure that the load is sterilised so as to meet various laboratory quality standards has extended cycle times dramatically.

This has led to the development of accessories and systems becoming available on laboratory autoclaves to assist in optimising their performance for particular load types. Vacuum air removal, venting systems and accelerated cooling options are now more commonplace than before, and as in all walks of life, microprocessor control is everywhere.

The vacuum and free-steaming systems fitted to many laboratory autoclaves to improve performance, along with increasing concern about what is carried over in the exhaust steam from autoclaves, have also led to the formulation of standards and regulations, requiring most of them to be connected to sealed and vented drains.

Microprocessor control systems can be a nightmare to the technophobes amongst us, so it is important to consider who is likely to be using the equipment and how often the settings may need to be changed. Some systems are as easy to set up as the timer and temperature gauges on 'older' autoclaves, whereas others require a manual and passwords to make even a small adjustment to the set time or temperature. Both are equally valid but they must be applied in the right environment. For instance a level of security in setting the autoclave that is essential in a hospital or pharmaceutical production facility with fixed and validated cycles and with non-technical operators would be extremely frustrating to experienced laboratory scientists wishing to run a variety of sterilising cycles.

These would include factors such as electricity or steam used the cost of water for cooling systems and vacuum pumps, if applicable, and also the cost of servicing and maintaining the autoclave. Generally speaking the more complex the equipment is the more maintenance and parts that will be required. As a general rule of thumb, the more moving parts the more things there are to go wrong, especially over the lifetime of the autoclave. In many cases it might pay to 'keep it simple' as much as possible.

It is also worthwhile taking into consideration the lifetime costs of the equipment when deciding what to buy.

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 that the autoclave that you buy has the right specification to process it effectively and efficiently, especially if you are going to have to prove this to a certifying body later on.

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 you in narrowing down your choices a little. With this information you should at least be armed with some informed questions to ask of prospective suppliers and manufacturers.

Which type of autoclave is most suitable?

Top or front loading?

Top loading

- + Smaller 'footprint' – They usually do not require much additional width and depth outside of the chamber space and therefore use less laboratory space. Top loading models only increase in height with increased capacity.
- + Accommodate 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 Health and Safety issues involving lifting of possibly heavy baskets and containers. Fitting a load-lifting hoist can reduce the risk.
Choosing lower loading height models to decrease the lifting distance 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 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 and has less metal to heat up. It therefore weighs less and costs less to manufacture 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. If the steam cannot get to the load or the air cannot escape then sterilising will not be effective.
- Less useable space than rectangular section autoclaves for a given volume in front loading versions because of the circular profile. This is a trade off against the improved steam circulation.

Rectangular chamber

- + Larger chamber capacity for a given footprint compared to cylindrical autoclaves.
- + Less wasted chamber capacity as a rectangular load is being fitted into a rectangular chamber.
- More careful and skilled loading is required to ensure that steam circulation is not restricted by overfilling the autoclave chamber. If the steam cannot get to the load or the air cannot escape then sterilising will not be 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. This makes them more expensive to build and heavier than cylindrical models.

They require more heating and will cool more slowly because of the additional weight of metal and so, in the long term, can be more expensive to run as well as to purchase.

Double door (Pass through) models

Ideal for containment or sterile areas where items can be sterilised 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.priorclave.co.uk/downloads/DoubleEndDatasheet.pdf>

How should the autoclave be heated?

To some extent this will depend upon what you have available in your laboratory. However there are three principle methods:

1. 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 requires less servicing.
- 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 out to improve cooling times, although this would require an automatic filling system to re-fill before the next cycle.
- Slower chamber heat up time than with steam heated autoclaves, but with bulky liquid loads, the load heat-up time is actually not very much slower.

2. Steam Heated from an external steam source

- + Faster chamber heat-up times 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 '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.
- A reliable supply of **dry** steam is required. Some in-house supplies can be unreliable. An autoclave requires good quality 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 down 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 equipment but on many models they will be an additional installation cost.
- With the faster chamber heating of steam heated models the lag between chamber and load temperature must be taken into account when setting up the autoclave. What is saved in the heat-up time can end up being added to the sterilising time with bulkier liquid loads
- Condition and possible chemical contamination of the steam should be considered if autoclaved items are intended for re-use.

3. Dedicated Steam Generators. - There are three main types available:

i) Stand-alone steam generators. Electrically or gas heated

- + 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.
- Relatively expensive to purchase, especially for smaller autoclaves where the cost might be near to or greater than the cost of the autoclave.
- Water treatment systems are often needed for these units, along with suitable drains and other ancillary equipment, adding further to the cost.

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

iii) Built in electrically heated high pressure 'on demand' type 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 'standalone' 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 'standalone' 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. They are therefore more expensive and require 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.

What type of door will you require?

Manual door with hand bolts

- + Less complex, and so requires less servicing and is 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 door with single action closure

- + Less complex than powered door closures, and so requires less servicing and is 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 operation.

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.

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 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 it. Regular maintenance is essential.
- Requires a steam supply. -If water-cooling is required a large amount of water is used or an external re-circulation and cooling system is required.
- When cooling liquid loads 'Air Ballasting' is required to protect the load from damage by rapid falls in chamber pressure.

What will be sterilised 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.
Free steaming	+	Allows time for the load temperature to 'catch-up' with the autoclave temperature.
Load Sensed Process Timing	+	Guarantees sterilising times by starting process time when the load reaches sterilising temperature.
	-	Not advised for growth media, which can be 'overcooked' whilst the whole load gets up to process temperature.
Rapid Cooling	+	Reduces time 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 sterilising 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 specialist staff and equipment can take several days, depending on the number of load sizes and types to be tested
	-	To be effective as an assurance of sterilisation, consistent loads must be run.

Glassware, Equipment and Porous Loads (Textiles and wrapped instruments)

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 pressurising and depressurising 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.
Air Intake Filters	+	Air drawn into the autoclave as it cools is filtered with a microbial filter to protect the contents from contamination.
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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.
Free steaming	+	By venting the autoclave at low pressure turbulence is created within the autoclave helping to remove air to be replaced by steam.
Pulsed Free steaming	+	Assists with steam penetration. Repeated pressurising and depressurising 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 sterilising 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	+	Combats the odours generated when autoclaving waste materials.
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Installation

For a detailed look at the issues surrounding the correct installation of autoclaves we suggest the following the downloadable PDF data sheet: <http://www.priorclave.co.uk/downloads/installation.PDF>

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 if possible. Small and medium sized autoclaves are often castor mounted and with flexible connections can be moved to enable service work to be carried out.

Around the Autoclave.	At least:	Sides - 1 metre
		Rear - 300mm
		Front - 2 metres 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 maintain a limited service?

What services are required?

Electrical supply	<ul style="list-style-type: none"> 400 Volt 3 Phase 230 Volt Single Phase 	<ul style="list-style-type: none"> Most larger autoclaves and steam generators. 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	<ul style="list-style-type: none"> Mains Water Softened Water RO Water 	<ul style="list-style-type: none"> For drain condensers, water jackets and vacuum pumps. These items have quite high water usage. Do you want to flush expensive treated water down the drain? In hard water areas may be required for electrically heated autoclaves or steam generators. For specialist “clean steam” applications. Often requires adaptation of the autoclave as it is corrosive to copper piping and conductivity based water level detectors do not work with it.
Drains, are they:	<ul style="list-style-type: none"> Heat resistant? Over 35mm diameter? 	<ul style="list-style-type: none"> Not just the material of the drains but any joint seals etc. should be capable of withstanding 134+oC. For heat sensitive drains a water cooled condenser can often be fitted to cool the autoclave exhaust to a suitable temperature. To allow adequate venting
Steam	<ul style="list-style-type: none"> Vented at a high level outside of the building? Plant Steam or Clean Steam? Is the line pressure acceptable? What is the life of the boiler house? 	<ul style="list-style-type: none"> To prevent pressure build-up when the autoclave is vented Certain applications where the sterilised items are reused require high quality clean steam, which can be expensive to install A supply pressure of at least 1 Bar above maximum autoclave operation pressure is required for proper operation. 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		<ul style="list-style-type: none"> 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.

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 sterilising conditions if air remains in the autoclave.
Other Methods		With the sophisticated microprocessor controls now available an alternative system for controlling sterilisation 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 sterilising time.
	+	Useful for laboratory waste as it reduces the time required for sterilisation.
	+	Useful for growth media as it reduces cycle time and the likelihood of 'overcooking'
	-	Not widely accepted in the NHS
	-	Requires thorough performance qualification and consistent loads

How do you prove sterilisation?

Methods of recording the cycle include:

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 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 sterilised 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.
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 specialist 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 rectification, 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 logged data will be inaccurate too. In such a case improperly sterilised 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.

Chart Recorders & Data Loggers

- The record produced as proof of sterilisation (or at least the source data for it) must be unable to be altered so that records cannot be falsified.
- + 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 require the installation and placing of additional probes and sensors which operate only with the recorder or logger.
- + Tried and tested and simple for operators to place and use
- Not always an indicator of full sterilising conditions i.e. both temperature and steam.

Servicing and Maintenance?

1. Take the time to consider your options. The working life of an autoclave is upwards of 5 years and with the capital expenditure involved you may not be able to replace what you have chosen for some time to come.
2. Look at what you have already
3. Discuss it with 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 quite enough budget for all that you want, you can still upgrade inexpensively at a later date.
5. Get some budget prices from manufacturers, the product selector section of www.priorclave.co.uk (<http://www.priorclave.co.uk/prodSearch.asp>) will help you to get budget prices and select suitable options.
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 sterilised. 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 that 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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