

Autoclave training module

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Autoclaving

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<https://www.steris.com/healthcare/knowledge-center/sterile-processing/everything-about-autoclaves>

Everything About Autoclaves

What is an autoclave?

Autoclaves are also known as [steam sterilizers](#), and are typically used for healthcare or industrial applications. An autoclave is a machine that uses steam under pressure to kill harmful bacteria, viruses, fungi, and spores on items that are placed inside a pressure vessel. The items are heated to an appropriate sterilization temperature for a given amount of time. The moisture in the steam efficiently transfers heat to the items to destroy the protein structure of the bacteria and spores.

In healthcare, the term "autoclave" is typically used as the nomenclature to describe a Steam Sterilizer. ANSI/AAMI⁴, which provide standards and guidelines for the processing of medical devices, refers to autoclaves for healthcare specifically as Steam Sterilizers.

[Explore our Steam Sterilizers](#)

Who invented the autoclave machine?

The steam digester, a prototype of the autoclave that is better known now as a pressure cooker, was invented by French-born physicist Denis Papin in 1679.¹ It wasn't until 1879 that the French microbiologist Charles Chamberland created a new version called the autoclave to be used in medical applications.

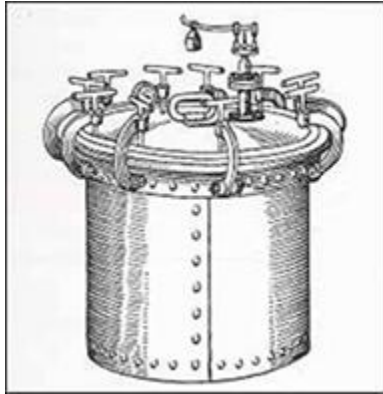


Figure 1 the first steam sterilizer built in 1880 by Charles Chamberland

The science of disinfection and sterilization began in 1881 with the research of Robert Koch on the disinfecting properties of steam and hot air. He demonstrated the greater power of penetration exhibited by moist heat (steam) compared to dry heat. Finally, in 1933 modern autoclave technology was introduced with the first pressure steam sterilizer that controlled performance by measuring the temperature in the chamber drain line (thermostatic trap). Prior to this date, pressure was the sole indication of control with no means to verify temperature or air elimination.

Over time, [new autoclave technology](#) has been developed including pre-vacuum cycles in 1958, and steam-flush pressure-pulse in 1987 allowing the science to evolve into the autoclaves, or steam sterilizers, used in hospitals today.

How does an autoclave work?

Autoclaves are commonly used in healthcare settings to sterilize medical devices. The items to be sterilized are placed inside a pressure vessel, commonly referred to as the chamber. Three factors are critical to ensuring successful [steam sterilization](#) in an autoclave: time, temperature and steam quality.

To meet these requirements there are three phases to the autoclave process:

1. **Conditioning Phase (C):** Air inhibits sterilization and must be removed from the chamber during the first phase of the sterilization cycle known as conditioning. In dynamic air removal-type steam sterilizers, the air can be removed from the chamber

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=====
===== PREVAC =====
=====
CYCLE START AT 15:14:55
ON 8/11/09

CYCLE COUNT 8675
OPERATOR MY
STERILIZER: 421
CYCLE TYPE PREVAC
CYCLE NO. 4

STER TEMP = 132.2C
CONTROL TEMP = 133.3C
STER TIME = 4 MIN
DRY TIME = 40 MIN

- TIME T= C P=psig V=InHg
-----
C 15:15:17 35.3 0.0P
C 15:16:18 107.6 12.1P
C 15:17:43 85.5 11.1V
C 15:19:19 129.1 26.0P
C 15:21:05 92.7 14.0V
C 15:22:24 130.2 26.1P
C 15:24:09 94.5 15.0V
C 15:25:26 130.2 26.1P
C 15:27:11 95.6 16.0V
S 15:29:45 132.2 28.3P
S 15:30:45 133.5 29.3P
S 15:31:45 133.1 29.1P
S 15:32:45 133.2 29.0P
E 15:33:45 133.2 29.1P
E 15:34:34 105.6 3.6P
E 16:14:35 40.2 28.1V
Z 16:16:11 40.9 1.9V

LOAD 081106

TEMP MAX=133.5C
TEMP MIN=132.2C

CONDITION = 0:14:28
STERILIZE = 0:04:00
EXHAUST = 0:42:26
TOTAL CYCLE = 1:00:54

=====
= READY TO UNLOAD =
=====

```

Figure 2 Example Cycle Tape Printout, Showing the three phases of the process.

using a vacuum system. It can also be removed without a vacuum system using a series of [steam flushes and pressure pulses](#). Gravity-type sterilizers use [steam](#) to displace the air in the chamber and force the air down the sterilizer drain.

2. **Exposure Phase (S):** After the air is removed, the sterilizer drain closes and steam is continuously admitted into the chamber, rapidly increasing the pressure and temperature inside to a predetermined level. The cycle enters the exposure phase and items are held at the sterilization temperature for a fixed amount of time required to sterilize them.

3. **Exhaust Phase (E):** During the final phase of the cycle, exhaust, the sterilizer drain is opened and steam is removed, depressurizing the vessel and [allowing the items in the load to dry](#).

Quality steam is vital to a successful autoclave sterilization process. The steam used for sterilization should be composed of 97% steam (vapor) and 3% moisture (liquid water). This ratio is recommended for the most efficient heat transfer. When the steam moisture content is less than 3%, the steam is described as superheated (or dry). Superheated steam is too dry for efficient heat transfer and is ineffective for steam sterilization.²

What is the autoclave temperature range?

Commonly recommended temperatures for steam sterilization are 250° F (121° C), 270°F (132°C) or 275°F (135° C). To kill any microorganisms present, the items being sterilized must be exposed to these temperatures for the minimum time recommended by the manufacturer of the device being processed.

What is the autoclave cycle time frame?

The exposure time is the time necessary to sterilize the device and does not include the entire cycle time. There is a time/temperature relationship for proper steam sterilization which has been developed by scientific testing and is used in all sterilization methods to create what is known as the total exposure phase. Exposure periods for steam sterilization vary with size, shape, weight, density and material composition of the device being sterilized, among other factors.

How big is an autoclave?

The size of the sterilizer will vary based on the capacity needed for the area where the autoclave will be used. For example, in a dental office a small autoclave may simply sit on the countertop where the equipment only needs to sterilize small packs of instruments. An [immediate-use small sterilizer](#) is typically needed near an operating room, and may only need to process 1-3

trays of instruments at a time. Most healthcare facilities, however, have medium or [large autoclave machines](#) in their [Sterile Processing Department](#) (SPD) which can process 15-20 trays of instruments per cycle or even up to 625 lbs of instruments per cycle depending on size.

Industrial sized autoclaves for manufacturing processes can be very large, some comparable to the size of a semi-truck or airplane.

What is Autoclavable?

Devices must be compatible with the autoclave process. Autoclavable items must be compatible with conditions of high heat and moisture and should be processed per the manufacturer's written instructions for use. Medical devices that have contact with sterile body tissues or fluids are considered critical items. These items may include surgical instruments, implanted medical devices and surgical drapes and linens. These items should be sterile when used because any microbial contamination could result in infection transmission. Steam is often the sterilant of choice for sterilization of heat and moisture stable items because it is reliable, consistent, and lethal to microorganisms while being safe for staff who operates the autoclave.²

How much does an autoclave cost?

The costs of an autoclave can vary greatly because of the various uses and applications of this technology. Industrial and pharmaceutical autoclaves are customized and manufactured for a specific use and therefore costs are likely to differ compared to autoclaves you find in a hospital or dental office.

In healthcare applications, the costs of an autoclave can range by capacity and installation method. Beyond the initial cost of the autoclave, the maintenance and cost of [sterility assurance and monitoring products](#) should be considered. Depending on the autoclave manufacturer, the costs per cycle, utility consumption and maintenance costs could vary over time and should be evaluated to compare your total-cost-of-ownership over time.

Industrial autoclaves vs. medical autoclaves

Autoclaves may be used in a variety of industrial and medical applications. Industrial autoclaves are used in manufacturing environments to process parts and materials using heated steam and pressure: for example, in the manufacturing of pressure treated woods and specialized rubbers used in the tires of your car. Autoclaves are also used in the scientific research and pharmaceutical industries – beyond sterilizing equipment used in laboratory research most autoclaves come equipped with a liquid cycle to sterilize liquids used in laboratory environments.

Medical steam sterilizers are used in healthcare environments for the sterilization of heat and moisture-stable items such as surgical instruments, implanted medical devices and surgical drapes and linens. The [cycles](#) used in medical steam sterilizers are developed and validated according to recognized industry standards. In the United States, steam sterilizers used in

healthcare must be cleared for use by the Food and Drug Administration for the sterilizer manufacturer's stated intended use.

1 <https://www.britannica.com/technology/autoclave>

2 <https://university.steris.com/course/understanding-steam-sterilization/>

3 <https://archive.cdc.gov/#/details?q=disinfection%20sterilization&start=0&rows=10&url=https://emergency.cdc.gov/han/han00382.asp>

4 (ANSI) American National Standards Institute Inc./ (AAMI) Association for the Advancement of Medical Instrumentation

Additional References

Association for the Advancement of Medical Instrumentation. (2017). *ANSI/AAMI ST79:2017 comprehensive guide to steam sterilization and sterility assurance in health care facilities*.

Association of periOperative Registered Nurses. (2016). *Guidelines for perioperative practice*.

International Association of Healthcare Central Service Material Management. (2016). *Central Service Technical Manual* (8th ed.). McDonnell, G. (2007). *Antisepsis, disinfection, and sterilization types, action, and resistance*.

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Safety considerations

Modern autoclaves are very safe and have mechanisms that prevent them from operating if there is a malfunction. The biggest risk is that you could get burned from steam, hot metal, or hot items. Following the proper procedures and wearing the right protective equipment will reduce the risk injury.

Preparing to autoclave

When preparing items for sterilizing, ensure the materials you are sending to autoclave are compatible with steam and heat treatment. You should choose packaging that allows steam to penetrate, or that is specifically designed to be used in an autoclave. Vessels that are tightly sealed will not get the expected heat transfer and may not be sterilized following the cycle. Loosening lids and foil coverings will allow for steam movement and heat transfer.

When loading the autoclave, you need to make sure there is enough air space around each item to allow steam to pass over everything efficiently. We recommend you aim to leave 2cm on all sides. It's not advisable to stack items directly on each other. This effectively makes your items thicker and increases the time needed to sterilize. Stacking also creates surfaces where steam can get trapped, which, at the end of the run, will leave your items wet. It's better to use a wire shelf or spread the contents over multiple loads.

Use caution when loading the autoclave, the chamber surfaces are hot and you could get burned. It is best to wear heat resistant gloves that protect your hands and forearms. Never put your head in the autoclave to reach to the back, there is a real chance that you could hit your head on the hot metal. Instead of reaching in, pull out the rack to bring the items closer to you. You also need to be careful around the autoclave hatch, make sure your hands are clear of the door and hinges when closing the door.

Once your autoclave is loaded, you are ready to seal the chamber. Most of our autoclaves have a wheel on the door which is turned in a clockwise direction until the chamber is sealed. The more modern autoclaves are controlled by a foot pedal. Depressing the pedal will raise and lower the door and the autoclave will seal itself.

The basic steps of running an autoclave cycle are: loading the autoclave, sealing the door, selecting your cycle, collecting your items at the end of the cycle, and cleaning any equipment you use. There are a few key differences when it comes to cycle selection for processing liquids and solids, which we'll review below.

Dry materials – Gravity cycle

Dry goods are run on the GRAVITY cycle. If gravity isn't written on the control keys, you can press the number keys once and the display will show what cycle is connected to that key. Our standard gravity cycle is 20 minutes long at 18 psi, providing heat treatment at 121°C. Note that additional time is needed to charge the chamber, evacuate the chamber, and allow your items to cool, so you should expect the process to take around 30 minutes.

At the end of the gravity cycle, pressure is rapidly released from the chamber until the pressure drops to ambient. Once the pressure has reached 0 PSI you are safe to open the door. As a safety feature, the door will not open until the autoclave has settled to 0 PSI. When opening the door, stand back to avoid the rush of steam that will come from the chamber. It's best practice to wait 10 minutes with the door slightly open before collecting your materials. The wait time will allow steam to fully evacuate the chamber and the temperature of your materials to come down to a safer level. Waiting also aids in evaporating moisture off the surface of your items. It isn't always possible to completely dry items this way, particularly deep vessels or vessels with narrow opening (flasks). These items will often need to be moved to a drying oven.

Liquids

There are a few key differences between processing liquids and dry goods in the autoclave. Unlike with dry goods, you must use secondary containment. The cycle times are different depending on the volume of liquid you want to sterilize. Lastly, unlike the fast pressure release in the gravity cycle, a slow release of pressure is used.

Before you autoclave your liquid, ensure all the components in your mixture are compatible with autoclaving. You'll find, for example, that certain proteins and sugars can change chemically at the temperatures we use, so they should be filter sterilized instead. Liquids need to be in an appropriate vessel that can hold your liquid, withstand dramatic temperature change, and tolerate the high temperatures of autoclaving. When choosing your vessel, it's recommended that at least 1/3 of the volume is left empty to allow space for your liquid to boil. Fully filled vessels will boil over and could damage your vessel. The chances of a boil over are exacerbated if your contents are prone to foaming, in which case they will require even more head space.

You must place your bottles or containers of liquid in one of the metal pans that are provided. It's recommended that you add water to the pan to cover the bottom 2 - 3 cm of your vessel to shield it from thermal shock due to the quick heat transfer from the metal. Sometimes glass bottles will break in the autoclave, this could be from uneven heating, a crack in the glass, or the bottle becomes over pressurized. Having the bottles in the secondary containment pan makes it easy to clean up if an accident happens.

Our department autoclaves are preprogrammed with 3 liquid cycle lengths: 20, 25, and 30 minutes. Our general recommendation is that less than 500mL is 20 minutes, over 500mL up to one liter is 25 minutes, and one to two liters is 30 minutes. We don't recommend autoclaving more than two liters in a single vessel. As with the gravity cycle, you can press the control buttons once to have the autoclave display the type and length of the cycle and press a second time to start the run.

The end of the liquid cycle allows steam to release gradually to avoid large pressure changes that would cause hot liquids to flash boil. Flash boiling could damage the vessel or lead to a boil over and you will lose some (or a lot of) your liquid. You should expect this slow pressure release to take 10 minutes. Once the pressure has been released, you can open the autoclave and allow the door to stay open 1/3 for 10 minutes to allow the temperature to come down to a safer handling zone.

You must wear appropriate heat resistant gloves when handling hot items from the autoclave. It's recommended that you transfer bottles and pans directly to a cart and use the cart to move the pan and vessels to the sink.

Transfer your hot items to an appropriate bin or cart to get them back to your lab. Take an extra minute to rinse out any pans that you used and set them aside so they are ready for the next person to use.

Biohazardous waste

Biohazardous waste should be separated into three streams: dry, liquid, or sharps. Chemicals must not go in the autoclave. Be sure that you are collecting chemical waste separately and disposing of it through the chemical waste stream. This includes chemical-soaked absorbent materials, such as paper towels with bleach, tubes with small amounts of Trizol, or tissue samples in formaldehyde. If the nature of your work creates biohazardous waste that contains chemicals, or sharps that contain liquids, you must use a different method of decontamination, such as incineration, which would be arranged through the department or Health and Safety Office. Contact either office for more details.

Dry waste should be collected in autoclavable bags. Not all biohazard-labeled bags are autoclavable. If you use the wrong bag, it will melt and the contents will spill out (see *Cleaning up after an unexpected event*). Autoclavable bags will be rated to withstand normal or ultra-high autoclave temperatures; be sure to verify this when you are ordering. Our autoclaves are set to run at normal temperatures when decontaminating waste. Bags should not be packed densely or filled beyond 2/3 capacity and should not exceed 6 kilograms. They need to be sealed loosely with tape so that steam can enter the bag, but objects won't fall out. There should never be any liquids in the bag, so there is no need to create a perfect seal.

You must label the bag with enough information that it can be traced back to the source in case there is an issue. As an example, a caretaker could unknowingly be cut while transporting a bag of waste, and being able to find out what it contained may be important in determining the appropriate care response.

Liquids are stored in an autoclavable vessel; usually a borosilicate glass bottle, beaker, or flask is used in our department. It should be covered with a lid or aluminum foil. The waste must be labeled sufficiently to trace it back to the source, and it should also include the principal hazard, such as the toxin name or genus of the hazardous organism(s), so that facility workers know what they are transporting. Labeling with "W" or "waste" is not sufficient.

Sharps must be stored in a puncture-resistant, autoclavable, single-use container. Most science supply vendors sell sharps disposal containers that are suitable. Your sharps should not contain liquids. If they do, autoclaving is not the correct method of decontamination.

Waste is run on a 60- or 90-minute liquid cycle, depending on the validated parameters for the autoclave being used. Following the cycle, the door to the autoclave should be opened slightly to allow steam to escape and the contents to cool to a safer temperature before handling. After 10 minutes, the materials should be safer to handle. Using gloves, you can remove the bags or vessels from the autoclave. Once fully cooled, the bags can be placed in a double-lined garbage bag. The bag should be sealed and labeled with a white and green “Treated Waste” sticker that includes the source details and date. Liquid waste can be poured down a sink once it is no longer hazardous.

Cleaning up after an unexpected event

Sometimes spills happen. If a liquid spills in the autoclave and you followed the correct loading steps, your materials will be caught in the metal pan. If only liquid has been spilled, clean up is quite simple. Remove items from the pan and then dump the content into the sink and flush with water. Rinse the pan thoroughly with water and then leave it inverted to dry.

If there is broken glass involved in the spill, you will need to wear puncture resistant gloves to provide a layer of protection. Before getting started, give the contents time to cool to a safe handling temperature. Collect the large pieces of glass and transfer them to the glass waste container; there should be one in every room that houses an autoclave. The remaining small pieces of glass and the liquid should be poured through a colander or strainer. Rinse the pan thoroughly and let the runoff go through the strainer to catch any remaining glass. Dump the collected glass into the glass waste container. Rinse the pan thoroughly and invert and leave on the counter to dry.

If you didn't follow the instructions and you simply put your bottles directly in the autoclave, you could have a bigger cleanup job. You will need to report the spill to the autoclave technician so they can help you clean appropriately. We want to avoid having items clog the internal drain or getting baked to the chamber interior.

If solid items have spilled, like tubes or pipette tips, you will need to pick them out of the autoclave carefully while wearing safety gloves. If you can reach your items by only reaching your arm in the autoclave, you are safe to do so. If the contents have spilled too far into the autoclave to reach with just your arm, you will need extra support. Contact the area autoclave technician for help.

General remarks

You **MUST** wear insulated gloves when handling the hot items coming from the autoclave.

Please remember that autoclaving is not a substitute for proper handling of materials. Enzymes, certain spores, chemicals, and debris may remain active and contaminate your sample after autoclaving.

If your vessel breaks, it's your responsibility to know the proper method of clean up and disposal. Glass should be collected after it has cooled. You **MUST** wear puncture resistant gloves when collecting broken glass. Place all broken glass in the marked waste bin provided in the facility.

The treatment cycle times used are very general and you may find that they don't meet your requirements. It is ultimately the responsibility of the labs and users to determine their cycle time needs. If your required processing time is different from those programmed into the system you will need to speak with the department operations manager to explore options.

Troubleshooting

The autoclave door won't close.

If this is a wheel style closure, spin the wheel counter clockwise all the way, open the door and inspect the hinge. If the hinge is straight and there are no signs of damage, try closing the door and make sure it seats firmly. Now spin the wheel clockwise to seal. If the door still will not seal, the autoclave will need to be serviced. Report the malfunction to the autoclave technician.

If this is a pedal activated door, first check for obstructions. The wire shelf may be sticking out further than you think and is preventing the door from closing. If the door isn't obstructed, you can attempt to manually lift the door to the closed position. The autoclave will latch and begin the cycle. Report the malfunction to the autoclave technician. If the door will not latch, the autoclave will need to be serviced. Report the malfunction to the autoclave technician.

Steam escapes after the door is closed and the cycle starts

If steam escapes from wheel closure autoclave, attempt to tighten the hatch a little more by pulling firmly clockwise. If steam still escapes you will need to abort the cycle and retry. Follow the direction for the case where the door won't close and re-attempt running the cycle. If steam is still escaping, abort the cycle. The autoclave will need to be serviced. Report the incident to the autoclave technician.

If this is a pedal style autoclave, abort the cycle and push the pedal to open the door. Inspect the sealing surface to ensure there are no objects preventing the door from making

a tight seal. If all is clear, use the pedal again to close the door and run your cycle. If steam is still escaping, abort the cycle and report the malfunction to the autoclave technician.

Abort a cycle

To abort a run, you must press the abort button once and allow the autoclave to print out the entire warning message. Once the message finishes printing, press the abort button again to cancel the cycle.

Thank you for completing this department training module.

Please follow the link or use the QR code to access the quiz so your training can be registered.

<https://forms.office.com/r/7iVGY1ujCY>

