3.7 Autoclaves

3.7.1 Use and Principles of Operation

An autoclave is a device used to sterilize medical instruments and equipment. It uses steam and pressure in the absence of air to assure sterile conditions. The small, table-top autoclave uses heat to boil water into steam. The steam continues heating and the pressure continues to increase. Bacteria cannot survive in these conditions. However, not all viruses and spores are killed. Exposing materials to a single heat cycle is somewhat effective, but sterilizing them 3 times over a period of 3 days will kill most vegetative spores.

Inside and outside of a small, electric autoclave.

Most hospitals have electric, steam autoclaves, but you will also find an autoclave like the "All American" distributed by UNICEF. It uses an open fire as its source of heat.

The small open fire autoclave is still common in the developing world.

An autoclave is a fairly simple instrument to operate but could be dangerous if operated improperly. It is important to wait until the chamber is completely depressurized before opening! If it is opened under pressure, large quantities of steam could escape causing severe burns! Most modern hospitals have automated autoclaves. These devices go through the steps of operation without intervention. If the machine is not going through its steps correctly, there is little that can be done to change the sequence of steps.

Manual machines, such as the All American, must be operated correctly to insure sterilization. The automated machines follow the same steps, though automatically.

Start by making sure that the water reservoir is filled to proper level with distilled water or filtered rain water. Well water will, in time, leave a scaly deposit on the instruments and autoclave. An indicator strip should be used with each pack being sterilized. However, in the developing world, this practice is not followed. Place the instruments into the chamber and close lid securely. Open the air outlet valve. Automated machines may use several cycles of vacuum to remove the air. The manual machines depend on the steam to push the air out of the chamber.

Now, the machine is ready to begin its cycle. Turn on or light the heating element. During this part of the cycle, the manual machine is evacuating the air. Therefore, it is important to wait until there is a steady stream of steam exiting from the autoclave. If the air release valve is

spitting and sputtering, it should remain open. Air left in the chamber will lead to cold spots, and poor sterilization.

When the air is completely evacuated from the machine, either by vacuum in the automated machines or by steam in the manual machines, the air outlet valve must be closed. The steam pressure will begin to rise. At this point, it is sufficient to monitor the temperature and time to insure sterilization. Do not open the chamber or valves, as the pressure of the escaping steam can be dangerous.

The sterilization cycle and sometimes the cool-down cycle can be timed. The proper time and temperature is shown below for unwrapped surgical instruments. Allow 30 minutes more at the holding temperature and pressure if the instruments are wrapped.

Sterilizing Temperature (C)	Appropriate pressure (kPa)	Appropriate pressure (psi)	Minimum holding time (min)	Overall time (min)
115	75	11	30	50
122	115	17	15	40
128	150	22	10	30
136	225	33	3	20

After the specified holding time, the sterilization cycle is complete. Turn the heating element off completely. Now the cool-down cycle begins. The progress of cool-down can be followed by time, temperature, or simply by dropping water on the outside of the vessel. If it boils off, the vessel is still too hot. When cool down is complete, the chamber can be opened. If a sterilization tape was used, check to see that it is completely black.

3.7.2 Common Problems

There are a number of different types of problems you may encounter. However, the manual autoclave is a very reliable instrument. It rarely fails when properly operated and maintained.

The most common problem in the developing world is a buildup of a scale due to the use of non-distilled water in the sterilization cycle. The scale can usually be scraped off the machine and simply thrown away. On manual machines, the scale may cause the air release valve and the over-pressure relief valve to be clogged. Both of these systems are difficult to scrape clean. If they can be removed from the machine and forced or left open, then simply soaking them for several days in pure distilled water should dissolve any deposits. It may be best to run a few dozen cycles with distilled water, where the air release valve is intentionally left open (steam will escape through the valve the entire cycle). This will help to dissolve any remaining the scale. If the relief valve cannot be opened and cleaned, it is best to replace this component.

Automated machines with scale build up may also see clogs in the vacuum lines and associated valves. If the machine is still operable, the best procedure may be to remove any visible build up, then run many cycles with pure distilled water until the remaining scale dissolves. If the valves have become blocked, remove them all and clean them all (not just the clogged one). If only one is clogged, it is certain that the others are close.

The second most common problem for autoclaves in the developing world is clogging of filters due to the use of dirty water, such as non-filtered rain water. This primarily plagues the automated autoclaves which often have inlet filters between the water storage and the main vessel. Some of these filters can be removed and back-flushed (run water backwards through the filter) to clean and restore them. Be sure to clean the tank of any particles that have settled to the bottom. In other cases, the filter must be replaced.

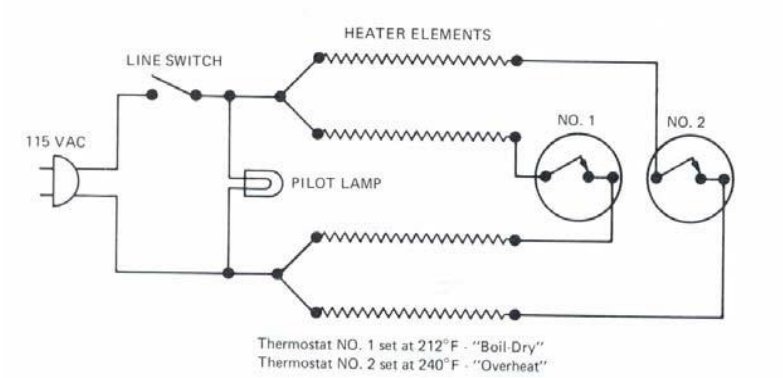
If you hear a hissing noise, then there is a leak in the pressure vessel or valve. Try to isolate the problem by looking for steam escaping and by using your ear. If the problem is a valve, it will probably be necessary to replace the valve. If the problem is the vessel, it is impossible to fix and the autoclave should be discarded. The seal on the vessel is also a common source of leaks. Check to see that there are no obstructions (dirt, or scale build up) along the seal. In some cases, the seal can be reground, but often, replacing the seal is required.

Some machines use a plastic or rubber seal. For these machines, run your fingernail into the seal. It should be pliable. If the seal is hard, or worse cracked, then it must be replaced. In larger cities, you may be able to find an automobile repair shop that can cut you a replacement gasket. Silicone sealant can be used to seal cracks in door gaskets until a replacement gasket can be located and installed.

If the seals are working and there are no leaks or clogs, the manual autoclave should work. The automatic autoclave may still not reach the proper temperature. The cause may be the thermostat or the heating element. In the most sophisticated autoclaves, the controller can be suspected.

If there is no heat generated, it could be the heating element or the thermostats. The typical heating element consists of two coils of nickel-chrome resistance wire, each of which has approximately 14 ohms of resistance. If the resistance across a coil is significantly higher, it is probably broken. These heaters are paralleled and the combination is placed in series with the on/off switch and one or both of the thermostats. Nicrome wire is common and can usually be found in the developing world. Match the resistance and length as closely as possible.

Circuit of a simple, electric autoclave.



There are often two thermostats. One is a boil-dry safety thermostat connected in series with one of the elements and set to open at 212 degrees F. This will reduce the violence of boiling once 212 is reached. The second thermostat, often called the overheat relay, is set to turn off the electricity going to the nicrome elements when the temperature is excessive, usually meaning that the water has boiled away. Both thermostats for this instrument are usually of the bimetallic-switch type. They rarely degrade themselves, but the device which holds them in place often deteriorates.

3.7.3 Suggested Testing

Autoclaves are like centrifuges in that there is a safety issue associated with their use. The device can injure the operator or leave the equipment undetectably contaminated. Therefore, some testing should be performed before releasing the device for use.

Before releasing an autoclave back to the floor, check the gaskets and check for scaling. You can prevent future clogging by removing any scale or dirt now. If the gasket for the vessel breaks, it

may leak steam, which can be dangerous. If the autoclave has an interlock that prevents opening during a cycle, check this again for safety.

If possible, check the temperature inside the vessel during sterilization. Most US hospital users put test strips with each sterilization pack. These strips verify that the temperature reached the required level for the required time and that humidity was present. However, in the developing world, these test strips are rarely used. It is nevertheless, possible to test the autoclave.

A complete test of an autoclave includes a Bowie-Dick test (to see that all the air was being removed) and either a temperature or a pressure test to see if the temperature and pressure reached the needed levels (since PV=nRT, and the chamber is only filled with steam, it is not necessary to measure both temperature and pressure). The time of the sterilization cycle can be measured with a watch. The Bowie-Dick test for air removal can be approximated by placing a standard Time-Temperature test strip on a sheet of paper in the center of a stack of 100% cotton towels and placed in a metal dressing can. The dressing can is placed in a warmed pre vac sterilizer and a short cycle is run using the tape on the cotton towels as a check. If there is any air left in the sterilizer chamber, then it would be trapped in the towels. Because the air would not allow the steam to touch the tape, the color change would not be uniform around the strip. In order to pass the test, the entire tape must change colors, not just the edges. This procedure will test both the temperature and the air removal process.

If test strips are not available, then it is not possible to reliably test the autoclave for both air removal and temperature/pressure. You will have to settle for a pressure measurement. At the present time, there is no reusable alternative to the test strips readily available in the developing world.

Check the safety valve on the vessel. If it is dirty or corroded, attempt to replace it. If you cannot replace it, it is possible to test the safety valve by bypassing the overheat limit switch. This should only be attempted by experienced technicians wearing proper safety gear. Furthermore, you can only test the safety valve on autoclaves with working pressure gages. The safety valve is factory set to open at 30 psi. To test this valve, short out the thermostat with a clip lead, operate the autoclave as in starting a normal cycle. Be ready to pull the plug from the wall very quickly, should the safety valve fail and the pressure rise above 31 psi. If the safety valve fails to operate at this upper limit, it must be replaced. If you cannot find a replacement, discuss the danger with the administration. Although not having a safety valve is a severe danger to the operator, not having an autoclave is a severe danger to the patients.