will cool slowly. Glass-sealed ampoules and plastic containers can be sterilized in this type of autoclave. Cooling stops when the solution inside the container reaches around 75°C, thus helping to dry the exterior of the container when stored outside the autoclave.

Autoclave with Superheated Water Spray (Water Cascade)

After loading this type of autoclave, the lower circular sector of the autoclave is filled with purified water. At the beginning of the process, no air in the chamber is removed. Water is circulated in the heat exchanger, then sprayed onto the load. This process provides excellent temperature uniformity and very small F_0 excursions, thus minimizing the sterilization time. The circulation water continues to circulate after the sterilization phase. Cold tap water flow into the plates of the heat exchanger to replace the steam and then cools the load. During all phases of the sterilization cycle, sterile air counterpressure is maintained inside the chamber so that no thermal or pressure shock occurs. This autoclave is used to sterilize flexible containers that cannot withstand sudden changes in temperature and pressure together. One major disadvantage of this process is the obvious fact that the load cannot be dried inside the chamber.

Autoclave with Air Over Steam Counter Pressure

This autoclave is similar to the water cascade autoclave in many respects. For example, the air in the chamber is not initially removed before steam enters the chamber. Partial air pressure of this mixture of air and steam is adjusted during the entire process with fans and flow deflectors in the chamber assuring a homogeneous steam and air mixture. Pressures inside the chamber of this kind of autoclaves are much higher than conventional pure saturated steam autoclaves. The cooling phase consists of air feeding into the chamber to condense the steam while maintaining the sterilization phase pressure. Cold tap water is then fed into the heat exchanges. The load is cooled while maintaining a constant controlled pressure. This autoclave also is used to sterilize flexible containers with the advantage of being able to dry the containers during the cycle. However, this type of autoclave has a cooling phase that takes much longer than the superheated water spray autoclave.

Sterilization-in-Place (SIP)

When this term is used, it is always referring to steam sterilization of large equipment items such as mixing tanks, vessel-filter-filler systems, and even complete isolator units. The same steam sterilization principles apply in that effective air removal must occur first, followed by adequate time–temperature exposure of all surfaces for overkill sterilization to take place. SIP is preceded by effective clean-in-place (CIP) procedures, so for both effective and successful CIP and SIP, equipment design and construction must be able to achieve the following (3):

- Withstand pressures required for steam sterilization
- Adequate air venting using microbial retentive filters
- Condensate must be trapped
- No leaks
- No inner surfaces that cannot be exposed to water and steam.

Dry Heat Sterilization

Dry heat destroys microorganisms by oxidation (basically exploding the cells) because of the very high temperatures employed, at least 170°C. Materials typically sterilized by dry heat include glassware, metal parts, oils, and dry powders. The process of dry heat sterilization is quite simple—heat with filtered air with blower fans enabling heat to be uniformly distributed in the sterilizer. Besides simplicity, the main advantage of dry heat sterilization is its effectiveness in destroyed endotoxins. In fact, dry heat is perhaps the most effective method to destroy endotoxins although temperatures required to validate the depyrogenation process for glass containers are a minimum of 250°C. Thus, dry heat depyrogenation requires higher temperatures and longer exposure times than that required by sterilization. Other advantages of dry heat sterilization are materials being dry at the end of the cycle and corrosion of materials is not an issue.

Disadvantages of dry heat sterilization include the fact that the process is difficult to control within precise temperature limits. The USP states that "a typical acceptable range in temperature in the empty chamber is ± 15°C when that unit is operating at not less that 250°C." Dry heat