

Orbital shaker benchmarks: best practices for use and maintenance

Authors: Mary Kay Bates, Senior Global Cell Culture Specialist and Sara Livingston, Global Product Manager, Thermo Fisher Scientific

Key words: *Orbital shaker, HEPA filter, cleaning, orbit diameter*

INTRODUCTION

Most life science labs have an orbital shaker—often more than one—because these versatile workhorses are used in many applications including chemistry, biochemistry, molecular biology, microbiology, environmental and food sciences, clinical diagnostics, and eukaryotic cell culture. Usage extends from basic research all the way up to bioproduction. Shakers come in a wide range of sizes and formats (Figure 1), including open air, heated, or refrigerated. Choosing among these many options can be confusing, and your application may require a specific shaker style¹.

Regardless of the models used, this application note contains valuable information which applies to all orbital shakers. We offer helpful tips to properly install your shaker, guidelines for best operation, proper usage and cleaning, and a general



Figure 1. Orbital shakers are available in a wide variety of sizes and formats.

maintenance schedule. In all cases, the manufacturer's recommendations for each model take precedence and should be followed.

INSTALLATION

Upon delivery of your new shaker, inspect the shipping carton and ask the carrier to specify and sign for any damage on your delivery receipt, to ensure that any damage to the components can be properly documented and addressed. When unpacking any laboratory equipment, carefully match parts to a packing list and ensure everything is accounted

for before discarding any packing materials; some small parts can be accidentally discarded.

Recognize that orbital shakers, regardless of size, can be heavier than you may think. Take care when lifting the shaker, ensure you have at least one other person to help you, and that the shelf or bench designated to hold the shaker will be strong enough.

Also confirm that the shaker will not wobble or tip. Orbital shakers can vibrate if not properly supported or while experiencing an uneven load. Vibration can have additional adverse effects on the mixing motion created, impacting cell growth and the end product.

LOCATION

Because shakers vary so much in size, the required clearance around the particular model will also vary. But all shakers should have some space around them to allow for proper ventilation. In general, this space should be 1 inch (2.5 cm) for smaller units, up to 4 inches (10 cm) for the largest models. Also, because the shaker is working to establish a set temperature, it is important to position the shaker out of areas of direct sunlight or drafts. The shaker's temperature control can also be influenced by nearby equipment, especially any that generate heat, such as ultra-low freezers or ultracentrifuges.

If you have a refrigerated shaker, it may need access to a drain for evacuating condensed liquid. Some shakers have a sealed chamber with a drain for convenience when cleaning with liquids. This drain may be hidden behind an access panel. If you plan to use this drain, consider its location when positioning the unit.

INITIAL SETUP

The shaker may have a switch next to the power cord receptacle to toggle between 115 or 230 volts. Set the switch appropriately for the voltage used in your region. Do not connect

the shaker to a power source until it is completely set up and ready for use. With larger shakers we recommend setting up each unit on an independent circuit to provide stable power to the unit and avoid power fluctuations that may affect the electronics of the shaker system.

For best operation, use a level and adjust turn screws on the unit feet to ensure the shaker is level (including front to back as well as side to side). Tighten the locking nuts to secure the position.

Depending on your shaker make and model, you may have to install the shaker platform next. Before progressing too far, however, know that some shakers require the flask clamps to be manually secured onto the platform before installing the

platform. Consider a shaker which offers platforms which are easily installed and removable to allow for easy cleaning (Figure 2). In general, a shaker platform will have integrated points to aid in alignment of the platform over the drive mechanism. Install all screws before tightening them, to ensure proper seating of the platform. Once installed, never lift the shaker by the platform, but only by the bottom and sides. Use only the manufacturer provided screws, tools, and clamps. Establish a clear, organized and well labeled area, ideally a clear plastic divided box, to store these parts near the shaker.

Before installing flask clamps, check whether a flexible spring must first be installed. If your clamps require a spring, it must be used, because without it the flask will not be secured



Figure 2. Removable platforms are recommended for all orbital shakers for greater flexibility and to facilitate regular cleaning and disinfection. A universal platform will accept a wide variety of clamps.

and there is a great risk of the flask breaking, spilling, or accidentally releasing from the clamp. After attaching the springs, install the clamps onto the platform using the manufacturer provided instructions and parts. Different shakers and flask clamps require 1–5 screws, and some require nuts and/or washers, so be sure to use all of the necessary components for your model. Using fewer than the recommended number of screws and nuts will increase the risk of the flask clamp dislodging from the platform, causing damage to your flask and samples.

If you are connecting a data monitoring and remote alarm module, now is a good time to set that up. This is also time to become familiar with the different alarms indicated by the shaker and how to correct them. If your shaker allows, you can change the alarm setpoints and triggers—such as high and low temperature



Figure 3. A shaker should offer a clear display which allows viewing of all parameters simultaneously and allows individual, precise control.

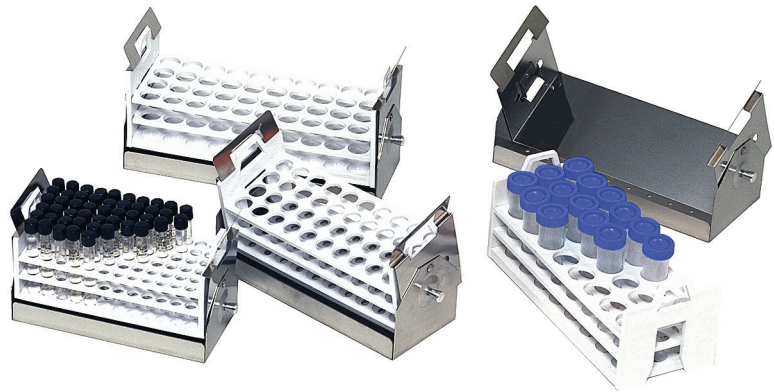


Figure 4. Clamps are available that are designed to fit Thermo Scientific™ Universal Test Tube Racks. The clamps can rotate to allow incubation at a desired angle. Different rack models fit a variety of commonly used culture tubes. The racks easily pop into and out of the clamps.

alarms—to more closely match your most common settings.

Ideally, the shaker will have a display that shows all parameters simultaneously (Figure 3) and allows precise individual adjustments. Refer to the user manual for proper management of settings, and become familiar with any specific tips for routine parameter entry.

TIPS FOR BEST OPERATION AND CELL PRODUCTION

When placing a flask into a spring clamp, use your free hand to pull the clamp open enough to easily insert the flask. This will increase the service life of the clamp and spring, and prevent accidental breakage of the flask. Reverse the process to remove the flask, again using one hand to pull the spring and clamp open before pulling the flask out.

For shaking culture tubes, consider using a specialized test tube rack holder (Figure 4) which will secure the rack and tubes at a specified angle. You can remove the rack from the

holder and take the entire rack and cultures with you to and from the shaker, eliminating the need to transfer tubes to a new rack for transport. These are so easy to use, save time, and eliminate the waste and risk of using laboratory tape to secure test tube racks to the shaker platform.

We recommend establishing a standard procedure to check the platform and flask clamp screws monthly and tighten if necessary, to prevent failure and breakage.

Load flasks and tubes into clamps and racks carefully and securely, making sure all are firmly seated before startup. When using multiple vessels, ensure that they are evenly distributed on the platform for best operation and to reduce the chances of vibration, uneven wear on mechanics, and uneven shaking.

Always begin with the shaker set to “0” RPM (revolutions per minute). Increase the shaking speed gradually to the desired speed, monitoring to ensure you get a “swirl” action as

the speed increases. While this will take longer than simply switching the shaker on and allowing the speed to increase as fast as possible, it is the best approach because increasing the speed too quickly can create a “slosh” rather than the gentle swirling that is ideal for best mixing and cell viability. This is most critical for animal and insect cells which do not have a cell wall; however, this procedure will aid in protecting all cell types and liquid solutions. Often, you can use a slower speed once you have achieved a good swirling motion around the flask perimeter. In addition, by personally monitoring the shaker until it reaches the set speed, you will be there to stop the shaker if any problem occurs during acceleration, and to correct the situation.

If the above procedure does not give you the cell viability or productivity you need, experiment with a new flask with a different aspect ratio (the ratio between the height of the flask compared to its diameter), or one with baffles. Also, test different culture volumes; this is especially important for scale up because the volume to flask physics play a significant role in cell health. Best mixing and aeration are achieved when the liquid is 10–25% of the flask volume².

Shakers are available with various orbital diameters; however, with the appropriate speed, flask size and volume, any size orbit will provide sufficient aeration for proper cell growth. Remember that shakers with different orbit sizes will affect the speed required, according to the following equation:

$$r_2 = \sqrt{\left(r_1^2 \times \frac{d_1}{d_2} \right)}$$

Here, d_1 = the orbital diameter for the first shaker, d_2 = the diameter for the new shaker, r_1 = the RPM for the first shaker and r_2 = the RPM for the new shaker³.

Different speed, temperature, flask size and shape, liquid volume, cell types, and growth media components all have effects on cell growth. In most cases any negatives you experience with cell growth will require some empirical testing and comparison of different variables. To best maintain the conditions inside an incubated or refrigerated shaker, try to limit the frequency and duration of shaker lid or door openings.

Never operate the shaker at maximum speed without a load, or overload the systems weight limits. The stated maximum weight for a shaker will be the combined weight of the platform, clamps, vessels, and samples.

CLEANING AND DISINFECTION

Clean up any spills immediately using a lint free cloth dampened with a noncorrosive cleaner or 70% ethanol, or as instructed by the manufacturer. This is important to keep liquids from entering the shaker mechanism or electronics cabinet. In addition to attending to sudden spills, regular cleaning is also important, for best shaker operation and to protect your cultures from contamination. We recommend cleaning and manually disinfecting your laboratory shaker at

least once each month. Normal indoor air contains thousands of circulating microorganisms which can take up residence in your shaker, putting your cultures at risk.

At a minimum, take a good look at the shaker parts and remove any spilled growth media or dirt using a microfiber cloth moistened in water with mild dish soap. Rinse with clear water. Using a spray bottle, wet all parts and areas with 70% ethanol and allow to air dry. Do not spray any areas with exposed electronics.

Remember that spills can seep under the platform. Orbital shakers which offer easily removable platforms ease cleaning of this often neglected area. Larger models may offer a drain to facilitate the process. For large incubated/refrigerated floor models, HEPA filtration is a feature that automatically purifies the air, saving you time and protecting your cultures from contamination. Filters are generally good for 12 months, can be autoclaved with other biological lab waste and are easy and inexpensive to replace.

Some laboratory shakers offer ultraviolet (UV) light as a mode of decontamination. We do not recommend using this option because we do not believe it is effective enough for standard use in an orbital shaker environment. UV light is easily blocked by even dust and dirt, rendering it ineffective. Areas not directly reached by the light—such as on the shadowed side of clamps—are not disinfected. In practice, UV light efficacy decreases as the bulb ages

and in many cases those using UV light are unaware that it is no longer adequate. In contrast, HEPA filtration is continuously working and becomes more efficient over time as the filter collects particles. The HEPA filter will capture all particle sizes, although it is least efficient—99.97%—at 0.3 μm .

REGULAR PREVENTIVE MAINTENANCE

Like most laboratory equipment, your orbital shaker will perform at its best when it is properly maintained. Refer to the user manual for your model to ensure you are following the manufacturer's recommendations. Here are some general guidelines:

Monthly

1. Unplug the unit and clean inside and out using a mild dish soap and wipe dry. You may follow with 70% ethanol as a disinfectant. Do not allow detergent or disinfectant to make contact with any electrical systems. Remove and clean under the shaker platform if possible. If you require a stronger disinfectant, we recommend a quaternary ammonium based product such as Lysol™ No Rinse sanitizer, Conflikt, or Fermacidal D. Quaternary ammonium is safe for stainless steel, plastic and glass, and will not leave harmful fumes which could affect your cultures.
2. For cleaning an acrylic shaker cover you can use any plastic cleaner; be aware that some glass cleaners can cause clouding of acrylic, so make sure to use one recommended for plastic. Use only a soft cotton or microfiber cloth; never use a scouring compound or pad. You may use a polish specifically recommended for

- plastic to protect the cover surface.
3. If your shaker has a touch screen display, use a dry microfiber cloth. Use liquid cleaners only as approved by the manufacturer.
4. If your shaker has an air filter (Figure 5), remove and inspect it for dust and dirt. It may be cleaned with mild soap in water, and dried between two lint free towels.
5. Inspect under the shaker unit and clean up any dust, dirt or debris.
6. Ensure that the shaker platform and all clamps are properly seated and secured.

Quarterly

1. If your shaker offers refrigeration, cleaning the condenser coil and air filter is recommended every 3 months. Generally these can be cleaned using mild dish soap in water and thoroughly dried with a lint free cloth.
2. Verify the proper operation of the circulating fan.
3. If your shaker has a belt based mechanism, visually inspect the drive belt for signs of wear. Refer to your user manual for specific instructions on maintaining and replacing belts.

Yearly

1. Test and document the accuracy of the temperature calibration, speed, time and alarms. Also check the calibration of CO_2 (if applicable). Use secondary probes and sensors that have been themselves calibrated in the last year to eliminate any variability. Position the secondary probe in the center of the shaker chamber and allow the unit time to equilibrate to the setting.
2. If applicable, change the HEPA

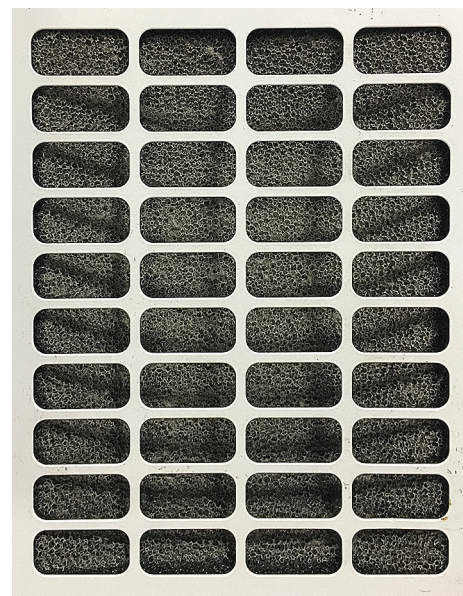


Figure 5. A typical air filter and cover for a refrigerated shaker.

filter. This may be required more frequently depending on the usage of the unit and surrounding ambient conditions.

More specific recommendations can be found in the user manual for your model. Contact a qualified service professional for questions or service of shaker belts, probes, fans or electronics. In general, shakers available today should not require any oiling. Thermo Fisher Scientific factory trained service professionals are available in most areas and can be found at www.unitylabservices.com.

CONCLUSIONS

Orbital shakers are found in most laboratories and despite their frequent usage are often overlooked in terms of standard maintenance. With proper installation and care, they should provide years of trouble free service. An ideal shaker is easy to use and program and is easily assembled and disassembled to allow user-friendly maintenance.

REFERENCES

1. O'Bryan J, Goodman T (2001) Choosing the right orbital shaker for your application. Thermo Fisher Scientific ANSHKSELECTOR 0611.
2. Hensler H-J and Schedel M (1991) Suitability of the shaking flask for oxygen supply to microbiological cultures. *Bioprocess Engineering* 7, 123–131.
3. Bates MK, Phillips DS, O'Bryan J (2016) Shaker agitation rate and orbit affect growth of cultured bacteria. Thermo Fisher Scientific ANSHORBGR 0816.

Table 1. Typical maintenance list and schedule for an orbital shaker. Refer to the user manual for each model for specific recommendations.

Maintenance schedule summary for orbital shakers			
Action	Monthly	Quarterly	Yearly
Manually clean and disinfect the shaker.	●		
Inspect the condenser air filter. Clean as needed.	●		
Inspect underneath the shaker and remove any dust or debris.	●		
Check that the shaker platform and clamps are properly seated and secured.	●		
Clean refrigeration condenser coil and air filter.		●	
Verify proper fan operation.		●	
If applicable, inspect the drive belt for signs of wear.		●	
Test accuracy of temperature, speed, time and alarms.			●
If applicable, change to a new HEPA filter.			●

Find out more at thermofisher.com/shakers