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Centrifuge Safety and Security

by Tammy Goodman

For laboratories around the world, increasing health and safety legislation requires that equipment be operated and maintained so that every step is taken to maximize safety and security. For capital equipment, such as centrifuges, this is of paramount importance due to the sheer physical forces involved and the possible hazard associated with the centrifugate. It must be noted, though, that centrifuges are inherently safe, with far fewer catastrophic failures than most people believe. This is due to the extensive research and development work conducted by the manufacturers, and the introduction of easy-to-use features that make centrifugation safe, intuitive, and trouble-free.

Safety and security: teamwork

Ultimately, safe centrifuge use is the responsibility of the end users, who should always ensure that they follow any established safety procedures. Many safety concerns have been addressed in modern centrifuges through a range of features. Therefore, users and manufacturers can work together to provide a safe and secure centrifuge facility.

Catastrophic failure

Catastrophic failures are extremely rare, even with ultracentrifuges, but when an event does occur, it generally means the loss of the sample; bottles; potentially the rotor; and, in a worst-case scenario, the centrifuge. In even rarer cases, it could pose a risk to other equipment and personnel in the immediate vicinity. For this reason, centrifuge, rotor, and tube manufacturers have taken steps to greatly reduce the amount of damage caused by tube or rotor failures.

1. *Compliance standards*. Centrifuges purchased today should be compliant with International Electrochemical Commission (IEC) standard 61010-2-020. IEC standard compliance means that the centrifuge not only meets the electrical regulations in place, but also indicates that the unit has been tested for containment in the event of a catastrophic rotor failure. Centrifuge manufacturers are responsible for determining the most damaging rotor failure possible and then performing the actual failure. In order to pass containment testing, neither the centrifuge nor any of its contents can exit a 30-cm square around the original position of the centrifuge.
2. *Flexible drive shafts*. Flexible drive shafts allow enough movement at the time of a bottle failure to dampen the massive imbalance. This significantly reduces and even prevents damage to the rotor, centrifuge chamber, and drive shaft (rigid shafts can be completely sheared off in the event of a severe imbalance).
3. *Rotor materials*. New materials, such as carbon fiber, do not fatigue or corrode, as do the aluminum rotors; thus the useful life of a carbon fiber rotor greatly exceeds that of an aluminum rotor. Moreover, in the event of a failure of the material, the energy release is much less due to their light weight and the unique way the carbon fibers are wound. This results in less damage to the rotor and centrifuge. Also, carbon fiber material can extend the life of laboratory consumables.
4. *Tubes and bottles*. New, disposable, single-use consumables are becoming more widespread and are now even available for ultracentrifugation; they ensure that failures are extremely rare and are therefore beneficial for all processes. For both reusable and disposable products, the end user needs to adhere to manufacturer's guidelines that are developed based on optimum testing of the product before it is brought to market.

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Rotor safety

It is an unavoidable fact that rotors age and become fatigued with repeated use. For the highest-speed centrifuges, ultracentrifuges, rotors must be "derated" (their maximum rpm reduced gradually over time) and then eventually retired after a period of continuous use. This is due to the high stress on the titanium or aluminum from the ultrahigh gravitational forces, which will eventually lead to failure. Further, equipment that lasts 10–15 years can have multiple users, and rotors are often passed down over the life of the centrifuge. It is therefore important to manage all the rotors; modern centrifuges have many built-in features that assist in this process, even for multiple-user environments:

1. Rotor-life management allows end users to manage ultracentrifuge usage by either rotor serial number, total number of hours used, or total number of cycles. This enables the centrifuge to alert the end user when it is time to derate or retire a rotor. Furthermore, once a serial number is denoted as derated, the centrifuge will not allow the rotor to be used in excess of the new reduced speed.
2. Automatic rotor ID prevents the running of nonspecified rotors

in a given centrifuge. Rotor ID is achieved in a variety of ways, such as a magnet configuration on the bottom of the rotor, which is read by a sensor in the bottom of the chamber. Sometimes rotors are identified by inertia readings taken during acceleration, which compare the amount of energy being used to turn the rotor by the motor to the on-board database, which is programmed with the correct amount of energy required for all rotors usable in that unit.

3. Overspeed protection and rotor ID are closely related. During an inertia check, the on-board system confirms that the programmed speed does not exceed the maximum rpm for the specified rotor. In the case of ultracentrifugation, speed disks on the bottom of the rotor are read by an optical eye, which limits the maximum speed by the number of black segments on the disk.
4. Rotor inspection/clinics can be conducted in the laboratory by most service technicians. Trained service technicians can inspect and educate laboratory staff on warning signs to look for that indicate imminent rotor failure.

Biohazard safety

There are a huge number of centrifuge tubes on the market today ranging from single-use tubes, such as 1.5-mL conical microtubes, to 2-L multiuse sealing bottles, but they all have one thing in common, i.e., they can break. The major concerns when a tube breaks are that the centrifuge system contains any biohazardous sample, and whether the sample can be retrieved. Generally, samples will remain in the rotor, and the appropriate action can be taken to recover the contents and decontaminate the rotor. However, many hazards require more robust assurances:

1. *Optional HEPA filters*. If a tube fails in a centrifuge that runs under vacuum and the seal on the rotor is compromised, the sample will be pulled out of the chamber due to the vacuum. To prevent the sample from being sent into the laboratory atmosphere, HEPA filters can be installed between the vacuum pump and the air outlet to clean all exhaust of contaminants.
2. Biocontained rotors and accessories are now offered that are tested and certified by the Centre for Applied Microbiology & Research (CAMR, Porton Down, U.K.) to contain all aerosols that could potentially be released if a tube fails.
3. *Closed removal*. Some rotors are designed to be removed from the centrifuge without needing to be opened (see *Figure 1*); thus they can be moved to a safety cabinet and then opened under safe conditions.

Figure 1 Some rotors can be removed without being opened, meaning they can be moved to a safety cabinet and opened under safe conditions.

User training

Centrifuges, as with most capital equipment, are generally shared in a multiuser environment, creating a different set of safety issues around traceability and access by multiple users. It is essential that every user is fully trained on the equipment and that new users know to whom they can speak about the issues. Manufacturers also provide features that make this process as efficient as possible:

1. *Manufacturer's training*. Most centrifuge manufacturers have factory-trained sales and service representatives who will train the end user on the proper use of the instrument at the time of installation or at a future date.
2. *Controlled access*. Software can be used to limit access so that only those with passwords can use the centrifuge. This is a great way to enforce that proper training is provided before a person can use the equipment.
3. *Traceability*. The increasing introduction of stringent GMP procedures makes traceability software an effective option when many users share the same equipment. It is increasingly important in all laboratory settings to ensure that every action of each process is recorded precisely. Centrifuge software can now be tasked to record and collate all run data into a database, so that searches by user ID, rotor, or date can be performed and then either printed or downloaded onto a PC.

Conclusion

Over the years, centrifuges have grown significantly to meet the demands of the end user, and manufacturers continue to look for designs or features that will make the end user's life simpler and safer. All of the features mentioned in this article are available on centrifuges from leading manufacturers. The combined options result in a centrifuge that is both safe and secure in any laboratory setting, making the capital investment a long-term partnership.

Ms. Goodman is Sample Preparation and Separations Applications Product Manager, ***Thermo Fisher Scientific Inc.,*** *275 Aiken Rd., Asheville, NC 28804, U.S.A.; tel.: 828-365-1348; e-mail: tammy.goodman@thermofisher.com.*