Rotor Safety Guide
Maximizing the safe operational life of your centrifuge rotors
Introduction

We all appreciate that regular care and maintenance is critical to keeping lab equipment running properly and extending its life. One item that’s often overlooked for regular maintenance is the centrifuge rotor. These substantially built and carefully designed components experience stress, wear and damage that can not only shorten their bench life, but pose a safety hazard in the lab.

With even the best-designed, most advanced rotor, its safety depends largely on those who operate it, maintain it and decide when it should be retired. This guide will walk you through the basics of rotor safety and maintenance so you can maximize the life of your rotor and minimize risk in your lab.

Why Rotors Fail

To help prevent rotor failure, it’s important to understand its causes. Misuse or abuse of equipment is often a culprit. Be sure to take steps to avoid damage and check your rotor for these possible issues.

Stress

The centrifugal force created by high rotational speeds creates load or stress on the metal of the rotor. This actually causes the metal to stretch and change in size. Figure 1 shows the typical stress against this dimensional change for a typical rotor alloy.

Beckman Coulter designates maximum speeds and sample density ratings for each rotor. These designations are intended to prevent this type of stress damage. Always observe these designations.

Metal fatigue

After a certain number of stress cycles, any metal structure will eventually suffer fatigue. When a rotor is repeatedly run up to operating speed and then decelerated, the cyclic stretching and relaxing of the metal causes changes in its microstructure. Depending on how close the rotor is operated to the elastic limit of the metal and how many alternating stress cycles it experiences, these small changes will eventually become microscopic cracks. With continued use, the cracks will enlarge and the rotor will ultimately fail.

This is why rotors found in lower-speed centrifuges (such as the Beckman Coulter high-performance and benchtop instruments) often have longer useful lifetimes. Rotors used in very high-speed centrifuges (such as Beckman Coulter ultracentrifuges) are designed to operate very close to the elastic limits of their alloys and thus have a shorter useful lifetime. The table at the end of this guide provides an overview of the warranty period and retirement recommendations for each class of rotor.

Stress corrosion

Corrosion is an aluminum rotor’s worst enemy and the most common cause of failure of aluminum rotors, especially as they age. Corrosion happens when a metal surface is attacked by moisture, chemicals or alkaline solutions like cesium chloride or other salts. Corrosive substances eat away at the metal, forming pits. This means there’s actually less metal available in the rotor to handle the stresses of operation. When corrosion occurs in a highly stressed area, like the bottom of a cell hole in a fixed-angle rotor, the increased load on the remaining metal creates what’s called a stress concentrator. Repeated use will cause cracks to develop and the rotor will fail (Figure 2).

Stress corrosion will cause failure sooner and at a much lower level of stress than if the rotor were undamaged by corrosion. The next section will share some ways to prevent this common form of rotor damage.

Safety Starts with Design

Beckman Coulter designs rotors to meet the diverse needs of research, medical, industrial and bioprocessing laboratories. We rely on feedback from our customers to determine the rotor needs for various applications, and design products to fulfill them. Our engineering process is precise and meets rigorous standards to ensure both performance and safety. The basic steps of our engineering process include:

- Create solid modeling concepts and use finite element analysis (FEA) to simulate rotor stresses that will occur in daily use.
- Conduct dynamic characterization of the rotor, drive and centrifuge to ensure total system stability.
- Select ideal materials and geometry to optimize size, weight and required strength of the rotor.
- Fabricate prototype rotors and subject them to an extensive testing regimen.
- Subject rotor to repeated “cycle ups” to maximum speed.
- Conduct single-cycle burst tests to verify robustness of design and fragment containment.
- Perform laboratory protocols to verify motor will achieve desired particle separations.

Only after a rotor meets all design criteria is it released to manufacturing for production. Rotors undergo stringent inspection at each stage of production, from forging to finished product. Beckman Coulter then precisely balances each rotor and confirms its stability. The final step is a “high-stress test” that ensures the rotor will have a long, safe life in your laboratory.

Stress, psi

**Figure 1.** Stress/Strain Plot of a Typical Rotor Alloy.

- If stresses become too great, the elastic limit of the alloy will be exceeded. The rotor will not return to its original size and shape at the end of the run. This damage may initiate a failure of the rotor at some point.
- At this stage, the rotor alloy is elastic. It will return to its original dimensions after the load is removed.

Strain, in/in

**Figure 2.** Corroded Aluminum Rotor.

- Corrosion is an aluminum rotor’s worst enemy and the most common cause of failure of aluminum rotors, especially as they age.
1. **Observe load and speed recommendations**

All rotors are designed to carry a maximum load at a specific maximum speed, so be sure to follow all operational specifications in your rotor manual. Even one run made under conditions of excessive stress may significantly reduce the useful life of a rotor.

We continue to leverage the power of the platform:
- Prevent over-speeding by setting the proper run speed each time.
- Follow required speed reductions for:
  - Running high-density precipitated solutions
  - Plastic adapters
  - Half-filled, uncapped thick-wall plastic tubes (in fixed-angle rotors)
  - Stainless steel tubes
- Run swinging bucket rotors with all buckets present and ensure sample leads are balanced.
- For rotors used with carbon-fiber composite canisters, use all canisters at all times, even if there is no bottle inside.

**If using a Beckman Coulter ultracentrifuge**

Each Beckman Coulter ultracentrifuge rotor has an overspeed disk or magnets that prevent it from exceeding its maximum-rated speed through operator error or instrument malfunction. Operators should make sure:
- Correct disk is on the bottom of the rotor
- Disk is in good condition
- Speed-derating disk is installed (when required by warranty)

Rotor logging is not required by warranty except for Zonal and Continuous Flow Ultracentrifuge rotors. However, rotor logging is recommended as part of good laboratory practices.

**If using a Beckman Coulter Avanti J Series centrifuge**

Rotors are protected from dangerous single-cycle overspeed condition by magnets, windage, or by the power speed-derating disk. If using a Beckman Coulter Avanti J Series centrifuge:
- Prevent over-speeding by setting the proper run speed each time.
- Follow required speed reductions for:
  - Running high-density precipitated solutions
  - Plastic adapters
  - Half-filled, uncapped thick-wall plastic tubes (in fixed-angle rotors)
  - Stainless steel tubes
- Run swinging bucket rotors with all buckets present and ensure sample leads are balanced.
- For rotors used with carbon-fiber composite canisters, use all canisters at all times, even if there is no bottle inside.

2. **Guard against corrosion**

Most rotors are made from titanium or aluminum alloys, which have high strength-to-weight ratios. Aluminum rotors and components are particularly vulnerable to corrosion.

**Titanium rotors**
- Resist corrosion
- Recommended if rotor will be used frequently with corrosive salt solutions (e.g., cesium chloride, potassium bromide)
- Will still include components made from aluminum and susceptible to corrosion, such as:
  - Lids
  - Spacers
  - Caps
  - Knobs
  - Plugs

Be sure to follow the aluminum rotor care recommendations outlined below for these aluminum components.

**Aluminum rotors**
- Less expensive than titanium
- More susceptible to corrosion, especially from alkaline solutions

Beckman Coulter aluminum rotors are anodized with a thin coat of aluminum oxide for protection. If this layer is scratched or damaged, corrosion will occur.

**Cleaning and caring for aluminum rotors**
- Clean only with special plastic-coated brushes (available from Beckman Coulter).
- Do not use ordinary bottle brushes with sharp wire ends—this could damage the anodized coating, creating a site for stress corrosion to begin.
- Wash components in a mild detergent* such as Beckman 555, which will not affect the anodized coating.
- Do not use alkaline detergents or cleaning solutions, which may remove the anodized coating.
- Note: Most commercially available solutions designed for radioactive decontamination are highly alkaline.
- If corrosive materials have been run or spilled on the rotor, wash it immediately.
- Be sure to wash buckets (from swinging bucket rotors) or aluminum fixed-angle rotors when they have been used with uncapped tubes containing cesium chloride or other salts.
- Any salt crystals not carefully washed away will corrode the metal.
- Never immerse the body of the rotor.
- Only wash the buckets of a swinging bucket rotor.
- Take care cleaning and drying hanger mechanisms, which can rust.
- After the rotor has been cleaned and dried thoroughly, air-dry with buckets or cavities upside down.

3. **Store rotors properly**

Any moisture or other contamination present during storage is a potential source of corrosion.
- Store all fixed-angle vertical tube and near-vertical tube rotors upside down.
- Store swinging bucket rotors with bucket caps removed.
- Store all rotors in a dry environment, not in the centrifuge.

4. **Check rotor classification**

Before running a rotor, check the classification of your instrument to be sure it matches that of the rotor selected.

Rotor/centrifuge compatibility is a function of:
- Rotor chamber size
- Type of overspeed protection
- Kind of chamber door
- Barrier ring

For Beckman Coulter floor-model ultracentrifuges, the classification is stamped on the lid or top. These ultracentrifuges are classified according to the rotors that can be safely used in them.

5. **Don’t use past expiration**

Some rotors and components are permanently marked with an expiration date. **Do not use a rotor or component beyond its expiration date under any circumstances.** Components that carry an expiration date are highly stressed and there is a strong possibility the component could fail with prolonged use.
- Record the purchase date of each rotor and keep it on file.
- Note that the purchase date may be different from the manufacturing date shown in the rotor serial number.
- Carbon fiber canisters, carriers and some labware may carry expiration dates, usually engraved or molded into the component.
- Refer to individual rotor manuals for specific information on expiration dates.

**Components that carry an expiration date**
- Carbon fiber canisters, carriers and some labware may carry expiration dates, usually engraved or molded into the component.
- Refer to individual rotor manuals for specific information on expiration dates.
The Field Rotor Identification Program (FRIP) is available to all owners of Beckman Coulter ultra- and high-performance centrifuges and was created to help labs:

1. Prevent premature failures by detecting stress corrosion, metal fatigue, wear or damage to anodized coatings
2. Educate laboratory personnel about the proper care of rotors

Through FRIP, a specially trained Beckman Coulter representative will come to your lab at your request and examine all your rotors. Using non-destructive methods such as fiber optics borescopy, the representative will inspect your rotors for signs of corrosion or other damage. If issues are found, repair or replacement may be recommended to help you avoid costly rotor failure.

During a FRIP visit, the Beckman Coulter representative will also give a formal presentation to your staff about maintenance procedures, rotor damage and what can happen when rotors are compromised. This information helps reinforce good laboratory practice to reduce stress corrosion, especially for aluminum rotors. Contact your local Beckman Coulter Field Service Office to arrange a FRIP session.

Not sure if your rotor is damaged?

Sometimes rotor corrosion is easily visible with the naked eye (Figure 2), but other times, it’s less apparent. If you have doubts about the condition of any Beckman Coulter rotor, you may return it to the factory in Indianapolis, Indiana, where it will be inspected free of charge. Before shipping the rotor, please contact the nearest Beckman Coulter office for specific instructions. A written statement must accompany each rotor, indicating that it is free of any pathogenic or radioactive contamination and is safe to handle.

Guard against corrosion

<table>
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<tr>
<th>Ultracentrifuge rotors</th>
<th>Warranty years*</th>
<th>Retire after years</th>
<th>Retire after runs</th>
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<tbody>
<tr>
<td>Swinging Bucket</td>
<td>5</td>
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<tr>
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<td>Aluminum Fixed Angle</td>
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<tr>
<td>Zonal &amp; Continuous Flow</td>
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<table>
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<th>Retire after runs</th>
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<tr>
<td>Allegra Series</td>
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<tr>
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</table>

*This warranty is valid for the time periods indicated from the date of shipment to the original buyer by Beckman Coulter or an authorized Beckman Coulter representative.

Please note: Beckman Coulter warrants our rotors and centrifuges against defects in materials and workmanship. However, each warranty is based on the concept of a Beckman Coulter designed and tested rotor/centrifuge system in which the characteristics of the rotor, drive, instrument and containment have been carefully matched to ensure safe operation. Beckman Coulter does not warrant its rotors when operating in other centrifuges and does not warrant its centrifuges when used with other manufacturers’ rotors.
We hope this guide helps you better maintain your rotors, and understand when rotors should be retired and replaced. With some simple care, attention and good practices, you can expect a useful and safe life for every rotor in your lab.

If you have any questions about the care and condition of your rotors, or wish to schedule a Field Rotor Inspection Program visit, please contact your Beckman Coulter Representative or go to info.beckmancoulter.com/FRIP

“A list of suitable detergents is given in the “Appendix A: Chemical Resistances” in the following publications. This information is also available in Chemical Resistances, IN-175. This list of common laboratory chemicals and their effect on rotor and tube materials should always be consulted if the possible interaction is in doubt.

Rotors and Tubes for Preparative Ultracentrifuges, publication LR-IM-24
Rotors and Tubes for Tabletop Preparative Ultracentrifuges, publication TLR-IM-9
Rotors and Tubes for J2, J6, and Avanti J Series Centrifuges, publication JR-IM-10