3.3 Centrifuges and Electrical Motors

3.3.1 Use and Principles of Operation

If a liquid contains particles, the particles will eventually sink to the bottom under the force of gravity. A centrifuge more rapidly separates particles from liquid by rotating a liquid to simulate a higher force of gravity. Either a liquid/liquid or a liquid/solid mixture can be separated with the substance of higher density migrating towards the outer part of the centrifuge. Centrifuges vary in size, in speed of the rotation, how long they will run, temperature and angles of rotation of the samples.

A small, table-top, electric centrifuge is common in the developing world. However, smaller clinics may have only a hand-cranked centrifuge.

A centrifuge consists of a base and an inner spinning cylinder in which the substance to be separated is placed. Some centrifuges have timers that automatically turn off after a set period of time and some also have high precision speed regulators to control the speed with which the centrifuge spins. Centrifuges can be used to prepare a substance for analysis or to analyze the particle content. There are two types of preparative centrifuges: mechanical and electrical. Of the analytical centrifuges, the only one used in medicine is the microhematocrit, used for separating plasma from the blood suspension.

With the lid of this centrifuge tipped back, you can see the four tubes where the specimen or dummy tubes would be placed. When the rotor turns, the tubes will tip out at an angle. The small round dot just beyond the white interior (center bottom) is an interlock that prevents the unit from spinning if the lid is open

The simplest centrifuges have a single speed motor, a mechanical timer and a rotor that holds the samples at a preset angle of 20 to 40 degrees. For user safety, the lid of the centrifuge should have an interlock on it so that the unit will not spin with the lid in the up position.

A simple rotor is made from metal with 4, 6 or 8 holes drilled into it at an angle where the samples are placed. Balancing the rotor is very important. If the user has only a few samples to be spun down they may have to use "dummy tubes" to properly balance the load. Since the motor shaft is attached to the rotor, uneven loads can cause motor damage and uneven speeds. Another type of rotor has sample carriers that are vertical at rest but when spun move out to 20 to 40 degrees.

The simplest centrifuges have a single speed ranging from 2,500 to 10,000 RPM. Low speed centrifuges have RPM rates up to 12,000 RPM, high speed units go up to 35,000 RPM and the ultrahigh speed can reach 125,000 RPM. The simplest variable speed centrifuges will have a rheostat speed control, which may be non-linear. Most of the newer variable speed centrifuges have built in tachometers that provide the users with a speed indication. More sophisticated speed control systems can involve SCR's, stepper motors and servo systems.

Most high speed and all ultrahigh speed units are refrigerated because the friction caused by the air on the samples will dry them out and change the results.

Centrifuges have a timer that is either electronic or mechanical built into the controls. Depending upon the centrifuge, the time can be set from seconds to days. If no time is selected the centrifuge will probably not run. Also, the centrifuge may have a time delay on the start where it will not start to spin for several seconds after the RPM rate and timer are set and the start button pushed.

3.3.2 Common Problems

Any part of the centrifuge may cause a problem. However, not every part of the centrifuge can or should be repaired. After eliminating the timer, rotor and most of the rest of the machine, the only repairable part of the centrifuge which needs much further explanation is the motor.

If the timer is at fault, often the only practical solution in the field is to bypass the timer (so the centrifuge always turns when switched on), and instruct the staff to use manual timing. As personnel are generally plentiful in the developing world hospital, this solution is typically well accepted by the staff, especially if they have been attempting to operate without any centrifuge at all.

If the rotor is cracked or bent, it should not be repaired. There are tremendous forces developed in a centrifuge. If the rotor is weakened or off balance by being bent, the machine could be destroyed and the staff injured in the process.

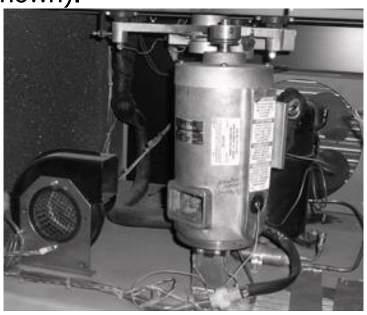
Mechanical centrifuges typically only need lubricating and cleaning to return them to use. If a piece is broken, it often cannot be repaired.

All centrifuges produced after 1990 are required to have an interlock system that does not allow the rotor to spin unless the cover is closed. Some of these interlock systems are very simple; a solenoid that pushes a rod through a hole in the cover latch is common. Others are more complicated and may involve several solenoids, flexible cables and a clock. The clock can be tied to the RPM indicator and will not release the solenoids until a set time has elapsed after the speed drops to zero. These timed units may give the appearance of failure because the operator cannot immediately open the lid. Check the manual, if available, to confirm both the delay and if that delay is adjustable.

There is always a temptation to defeat a broken interlock system. This should only be done for clinical laboratory departments that have no alternative centrifuge and then only after careful consultation with the technician who will be using the machine. Affix a picture on top of the machine showing a damaged finger and an open lid so that all future users will know about this danger.

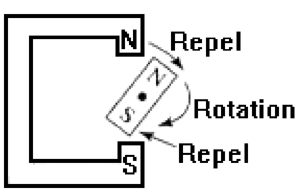
3.3.3 Motors

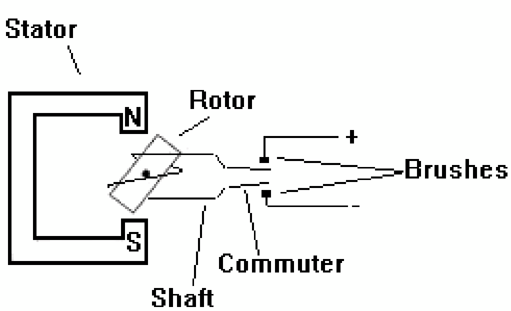
The inside of a simple centrifuge is nothing more than a motor and a few switches. This more sophisticated centrifuge includes two fans (additional motors) and a small bit of electronics (not shown).



The heart of the centrifuge is the motor. Almost all variable speed electrical motors in the developing world work on the same principle, whether they are in a centrifuge or any other piece of equipment (fixed speed motors, such as pumps and compressors are often of the induction type, not discussed here). The motor works by passing electrical current through electro-magnets attached to a rotating shaft. Stationary, permanent magnets attract or repel the electro-magnets depending on the orientation of the magnetic fields. The fields' orientations are switched such that the electro-magnets are progressively attracted to the permanent magnets around the circle, bringing the shaft of the motor around with them.

If a magnet is placed within another magnet, it can be made to rotate around a shaft by aligning the magnets to repel each other. If the polarity of the rotating magnet is then switched, the shaft and magnet will continue to rotate, and the device will be a motor. In order to switch the polarity, brushes contact commuters, the brushes and commuter forming switches. As the shaft rotates, the brushes contact different commuter parts, alternating the polarity of the rotating magnet.





In general, the engineer in the field will not be called upon to rebuild an electrical motor. Almost every major city in the developing world has a shop that can accomplish this task. However, most motors use carbon brushes to make electrical contact with the electro-magnets on the rotating part of the motor. These brushes wear down over time and need to be replaced. The brushes can be replaced by the field engineer.

Brushes should only be replaced with brushes of the same size. Do not use undersize brushes as they may wear unevenly and score the shaft of the motor. Brushes are held against the shaft via spring pressure, if the spring weakens, breaks or is missing the motor may not spin. If the caps holding the brushes in place become loose or cracked, that can also cause the brushes to lose contact and the motor will not run at all or will not run consistently.

Brushes that are installed properly and with the correct tension make the brushes wear evenly and have a bright almost shinny look on the contact end. If the brushes are defective or not making good contact the contact face of the brush will be dull and not smooth. Both brushes should be removed from the unit and compared when troubleshooting.

The shaft is held in the center of the permanent magnets by bearings. These are not often the cause of the problem, but in certain cases they can cause noise as the shaft rattles instead of being held in place. Bearings can be removed and replaced. Most developing world cities have motor repair shops which can replace or repair the bearings.

Besides the brushes and the motor bearings, many motor systems, including centrifuges, will have braking systems. If the rotor of a centrifuge, for example, was left to stop on its own, it could take a long period of time for the rotor to drop from 100,000 RPM to zero. To cut the time most units have a brake. The brake is not a mechanical device, as on your car. In some systems, the brake is a resistor that is temporarily placed across the motor. The motor is essentially operating as generator, with the mechanical energy coming from the spinning rotor and the electrical energy dumping into the resistance.

Motors are sometimes used in a 50 Hz country, despite being designed for 60 Hz use. In general, this causes few problems in centrifuges. In other applications, it can cause overheating. If possible lower the voltage about 10% on these motors to reduce heating.

In more sophisticated systems, the brake reverses the electrical field in the electro-magnets to make them attempt to spin the rotor in the opposite direction. The operator has to energize the switch and should only hold the switch in the reverse or stop position for a few seconds at a time.

3.3.4 Suggested Testing

The centrifuge creates tremendous forces inside the vessel when in use. If the rotor were to break or become dislodged, it could damage the machine or injure the user. Therefore, you should perform some safety testing before releasing the device for use.

First, check that the lid cannot be opened when the rotor is turning. Never release a centrifuge which can be opened while the rotor is turning without a thorough discussion of the dangers with the staff. If this is the only centrifuge that the hospital has at its disposal, you may have to release the device for use without a safety interlock.

Second, you should insure that the device can spin up to speed and brake without excessive noise. Be sure to balance the rotor (with equal amounts of water-filled vials on each side) before turning it on. Check the rotor for cracks or bends before starting the centrifuge. Particular attention has to be paid to centrifuges that have rotors that can be changed out. The users have been known to not fully tighten down the knob securing the rotor to the motor shaft causing severe damage to the device and lab when the rotor broke loose while spinning.

The ideal test for a centrifuge is a tachometer used to verify the rpm. However, you can make an approximate measurement of the centrifuges speed without one. Under light from a fluorescent bulb that runs on 60 Hz. current, the gage shown below will give you an accurate reading when you are running at one of the speeds on the gage. The "flashing" of the fluorescent bulb at 120 Hz will cause one of the bands to appear to stop moving at the RPM indicated by that band. The gage will not work with an incandescent light bulb.

To use the gage, photocopy it, cut it out, and place it on the spindle. You may need to cover it in clear packing tape to make it stiffer. Spin up the centrifuge until one of the bands has stopped, mark that spot on the speed control knob. Count the bands from the inside to note which band has stopped. You can increase the speed and find the next time that this same band stops. This speed corresponds to twice the marked RPM. Likewise, you can find speeds which are three, four or more times what is marked by counting the number of times the bands stop as you increase the RPM's. To determine the RPM, stop the centrifuge, read the band, and multiply by the number of times it stopped as you were increasing the rotation. You'll need to try this a few times before getting consistent results.