# Capacitor Information for HVAC&R Technicians

- Capacitors are devices that store an electric charge.

- Many types of single-phase, alternating current motors require capacitors to operate properly.

- Both batteries and capacitors store electric energy (charges). The major difference between a battery and a capacitor is that a battery stores energy due to internal chemical differences, **actively** producing direct current (DC) voltage until the chemical differences have reached equilibrium. A capacitor is a totally **passive** device that relies on an outside voltage source to give it a charge.

- Capacitors consist of two metal **plates**, separated by an insulating material called a **dielectric**. A simple capacitor can be constructed with two sheets of aluminum foil (plates) that are separated by a slightly larger sized sheet of wax paper. The foil sheets must not be allowed to touch each other, if they do, the “capacitor” becomes a conductor.

- The larger the surface area of the plates, the greater the charge-holding capacity of the capacitor. Also, the smaller the distance that the plates are separated by the dielectric, the greater the charge-holding capacity of the capacitor.

- Charge-holding capacity is measured in units called micro-Farads, symbolized by the Greek letter “mu” followed by a capital letter F. Because most keyboards don’t have access to the Greek alphabet, a lower-case “u” is often placed before the capital F to substitute for “mu” (example uF).

- In the HVAC&R industry, technicians use two types of capacitors: **Start** and **Run**.

- **Start capacitors** have one purpose – to give the motor a “kick” to start the rotor turning. Once the rotor comes up to 75 to 80 percent of its rated RPM, the start capacitor is electrically disengaged from the **start** winding of the motor. This electrical disconnection process is accomplished with the use of an electro-mechanical **switch** or an electronic equivalent. Isolating switches include: centrifugal switches, potential relays and current relays.

- Most start capacitors are recognized by their black Bakelite plastic containers, although one manufacturer has been producing a start capacitor with an electronic relay housed in a steel container.

- Since the black plastic start capacitors use distilled water as a component of the dielectric, any capacitor with a crack in the shell should be discarded, even if it tests with the correct uF value.

- A black plastic start capacitor has a round relief disc in the top plate, near the male spade terminals. If the disc looks like a miniature volcano, the water inside has turned into steam and has ruptured the disc. If this characteristic has been noticed, the capacitor should be replaced.

- A “hard start” device consists of a start capacitor and a potential relay that is often installed as an after-market kit. Hard start kits are wired in parallel with the compressor’s run capacitor and may be employed when a customer complains that house/office lights go dim when the A/C comes on.

- This writer installed a hard start kit on his 5-ton condensing unit and measured a reduction in Locked Rotor Amps from 150A (before) to 100A (after). It is possible that the routine installation of hard start kits could increase the operational life of compressors by many years.

- **Run capacitors** have two purposes: 1) to give a motor a small “kick” to get the rotor turning and 2) to improve the efficiency of an operating motor.

- For their physical sizes, run capacitors have lower uF ratings than start capacitors.

- Run capacitors exist in many shapes, sizes and colors. Currently, run capacitors are housed in silver-colored steel shells and may be round, oval or box shaped.

- When possible, install a run capacitor in the vertical position, with the spade terminals facing upward.

- Some run capacitors have been housed in gray plastic containers and some capacitors made for foreign markets look like the small black plastic “fan” relays used in residential furnaces.

- Run capacitors improve the efficiency of a motor by bringing voltage and current, as observed on an oscilloscope, into phase with each other.

- An alternating current motor causes current to **lag** (start after) the voltage supplied by the utility. This out-of-phase condition is measured in electrical degrees, ranging from 1 to 90. The greater the numerical value of the lag, the less efficiently the motor will run and the hotter it will run.

- Run capacitors, on the other hand, cause current to **lead** (start before) the voltage supplied by the utility. This out-of-phase condition is also measured in electrical degrees.

- Run capacitors are chosen by the manufacturer as follows: if the inductive (magnetic) properties of a motor cause current to lag voltage by 30 electrical degrees ($-30^o$), then a run capacitor is chosen that creates a lead of 30 electrical degrees ($+30^o$). Plus 30 added to minus 30 equals 0; therefore voltage and current have been brought into phase with each other.

- Motors that are designed to operate with run capacitors are called **PSC (permanent split capacitor)** and **CSR (capacitor start, capacitor run)**. Both types of motors use run capacitors that are energized throughout the entire duty cycle of the motor.

- Motors that are designed to use start capacitors are **CSIR (capacitor start, induction run)** and **CSR (capacitor start, capacitor run)**.

- **Replacement run capacitors should be of the same uF value as the number listed on the motor nameplate/sticker or manufacturer's literature.** Any lower or higher value will cause the motor to draw excessive current, causing the motor to run hotter than intended, thus reducing the longevity of the motor.

- It is important to note that capacitors (both start and run) in an alternating current circuit, store energy as direct current as soon as the A.C. power source has been removed. A charged capacitor can be safely discharged by attaching a digital multi-meter set to D.C. volts and watching the display or by connecting a 2 watt resistor with a 15k ohm value across the spade terminals.

- Capacitor labels show both a uF rating and a voltage rating. Exceeding the voltage rating may compromise the capacitor by causing an arc across the dielectric.

- Capacitors follow rules that are opposite the rules for resistors. When capacitors are wired in **parallel**, the resulting uF value is **additive**; thus, $C_T = C_1 + C_2 + C_3$. When capacitors are wired in **series**, the resulting value follows the **reciprocal rule**; thus, $1/C_T = 1/C_1 + 1/C_2 + 1/C_3$. Examples: two 5 uF capacitors wired in parallel give a value of 10 uF; two 5 uF capacitors wired in series give a value of 2.5 uF.

- **A common service call:**

  A customer complains that the A/C system is not cooling and "that big thing" (condensing unit) in the back yard is making funny noises. You arrive and verify the customer's complaint. Although the compressor appears to be energized and noisy, the condenser fan motor is not spinning the fan blade. You note the direction that the blade should spin and carefully use a long-shank screwdriver to quickly assist the fan's rotational motion. The blade promptly speeds up to its operating RPM and soon, cool air is felt coming from the supply registers.

If the technician were to remain at the job site until the thermostat cycled the cooling system off, at the next “call-for-cooling” command, the compressor would energize and the condenser fan motor and blade would shudder rapidly but not spin.

A quick check of the run capacitor would likely show a loss of greater than 10% of its rated uF value. In most cases, replacement with a new and correctly sized run capacitor solves the problem.

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