

Capacitors: Identify, Discharge, Test Three Ways, Replace

YES Electric • Arc Workforce Academy HVAC Apprenticeship

Draft 1 (October 2026). This lesson is under review. Videos are made by other companies, not YES Electric; follow this lesson and your journeyman where they differ. Boxes marked "Shop photo coming" will get real photos from our shop in a later version.

Unit 3 • Electrical for HVAC I • Appendix A Competency 19 — "Identify and replace capacitors, contactors, and relays" (capacitor half) **Class time:** ~4 hrs (1 video + 3 bench)

1. What you'll be able to do

- **Discharge a capacitor safely** — the non-negotiable first move, every time, even on a "dead" unit.
- Read a capacitor's identity: **μF rating, voltage rating, run vs start, single vs dual (HERM/FAN/C).**
- Test three ways and rank them: **under load (best) $\rightarrow$ bench μF $\rightarrow$ visual** — and replace one start-to-finish with photos of the wiring before you touch it.
- Apply the **$\pm 6\%$ rule** and explain why a weak cap murders motors slowly.
- Pick the right replacement: exact μF , voltage equal-or-higher, and what's actually OK to substitute (440 V for 370 V: yes; 5 μF off: no).

The run capacitor is the single most-replaced part in residential HVAC. Master it completely and you'll fix a meaningful chunk of all summer no-cool calls in your first month.

2. Tools & materials

- Capacitor graveyard: bulged, popped, rusted, healthy-but-weak, healthy
- New stock: common sizes (35/5, 40/5, 45/5 duals; 5/7.5/10 singles), a Turbo-200 universal for show
- 20 k Ω bleed resistor tools (we make one per student: resistor + insulated leads), meters with μF , clamp
- Shop condenser (instructor-energized for the under-load test)

3. Watch first

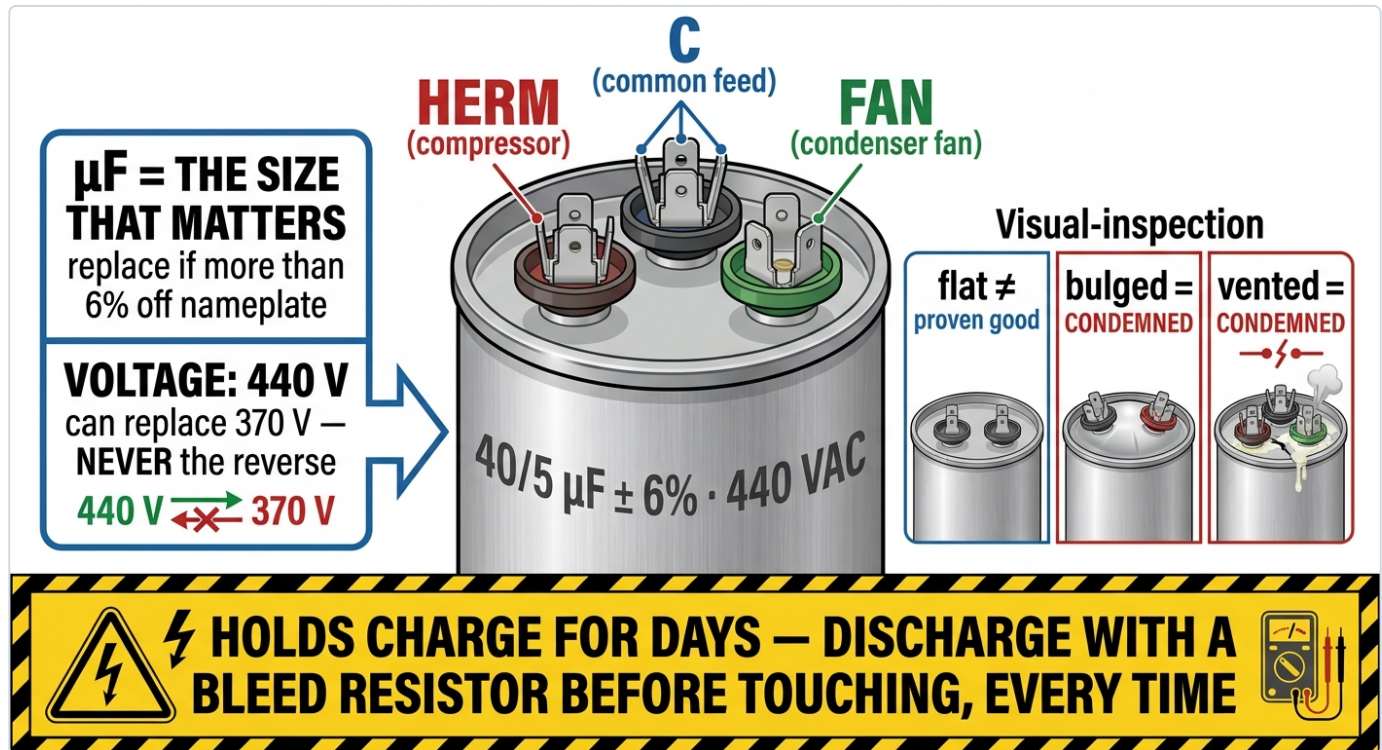
Order	Video	Channel	Length	Why
1	How Do You Discharge a Capacitor?	HVAC School	1:42	First, always
2	Run Capacitor Fundamentals Class	HVAC School	13:57	What it does and why motors need it
3	Capacitor Testing — 3 Methods	AC Service Tech	22:02	The full testing doctrine
4	Capacitor Test Under Load 3D	HVAC School	4:07	The best method, animated
5	Dual Capacitors — Identify, Test, Wire	AC Service Tech	4:41	HERM/FAN/C decoded
6	Why Capacitors Fail (not why you think)	HVAC School	36:33	Heat, voltage, time — the real story
7	Watch It Break!	AC Service Tech	9:45	The failure, on camera

4. The idea

What it does (one paragraph, no ghosts)

A single-phase motor can't start or run efficiently with one winding alone — it needs a second winding fed out of phase to make the magnetic field rotate. The **run capacitor** shifts the phase of current to the start/auxiliary winding continuously. Weak cap = weak phase shift = motor runs hot, draws high amps, starts hard, dies young. Dead cap = hum, no start, thermal trip. (Start capacitors + relays give a bigger kick for hard-starting compressors — they're in the circuit only for the first half-second; 6.7 covers them.)

Identity card



- **μF (microfarads)** = the size that matters. Tolerance: **within 6% of nameplate or it's done.**
- **Voltage (370/440 VAC)** = what it can withstand. **440 replaces 370, never the reverse.** (Today's better practice: stock 440s.)
- **Dual run cap** = two caps in one can: **C** (common feed), **HERM** (compressor), **FAN** (condenser fan). Three terminals, two ratings ("40/5 μF").
- Shape is irrelevant; round vs oval changes the strap, not the physics.

The discharge ritual (before ANY touching)

1. Kill power at the disconnect (3.2 ritual — live-dead-live).
2. **Discharge across the terminals with a bleed resistor tool** (20 kΩ / 5 W across HERM-C, then FAN-C, then HERM-FAN). NOT a screwdriver blade — the bang is hard on the cap, the screwdriver, and your heart; and never your meter alone (the voltmeter-discharge video: it works but takes minutes).
3. Verify near-0 VDC across terminals before fingers.

A 45 μF cap charged to 340 V stores enough to stop a heart in the wrong circumstances and WILL stop your enthusiasm. It holds that charge for days on a dead unit. **This ritual is graded every time it appears for the rest of the program.**

Testing, ranked

1. **Under load (the truth):** unit running — measure volts across the cap and amps on the start-winding wire (HERM-to-start lead): $\mu F \approx (2,652 \times A) \div V$. Compare to nameplate. This catches the cap that "bench-tests fine" but sags when hot — the Friday-afternoon ghost.
2. **Bench μF mode:** discharged, wires off, meter across each section. Within 6% = pass today (says nothing about under-load behavior at 140°F in July).
3. **Visual:** bulged dome, popped vent, oil leak, rust ring = condemned on sight. But **a flat-topped cap is not proven good** — visual only convicts, never acquits.

Replacement discipline

Photo first → discharge → one wire at a time to the same terminal name (C/HERM/FAN) → strap snug → ratings double-checked (μF exact; V equal-or-up) → restore → **verify with an under-load reading and clamp the motor amps** (did the fix actually fix?). Log the μF you removed and installed.

5. Bench procedure

1. **Discharge ritual reps:** every student, on a charged demo cap (instructor charges from a cord rig), full ritual with verification. Then once more. Graded gate, like 3.2's.
2. **Graveyard sort:** the bin — condemn/pass each on visual, then bench-test your "passes": find the flat-topped liar that reads 28 μF on a 40 μF label (planted).
3. **Decode drill:** five caps — read $\mu F/V$ /dual sections aloud; match three loose motors' nameplates to the right cap from new stock.
4. **Under-load math:** on the running shop condenser (instructor supervising): volts across HERM-C, amps on the start lead, compute μF , compare to bench reading of the same cap. Numbers should agree within a few percent — see the method's power.
5. **Full replacement:** photo → discharge → swap → verify under load. Timed second pass: a competent swap is a 10-minute job including verification, not including the diagnosis that justified it.
6. **The wrong-size demo (instructor):** the WTcNVvCW0ZY experiment recreated — 30 μF where 40 belongs: clamp the amps, feel the motor temp. "It runs" $\neq$ "it's right."

Checkout: unaided full sequence on the bench unit — discharge ritual, identify, bench + under-load test, replace, verify, log. Comp 19 (capacitor half) signed at mentor-guidance level.

6. Field gotchas

- **The cap is the #1 misdiagnosed scapegoat too:** "replaced the cap, still dead" — because the fan motor was seized (high amps killed the cap as a SYMPTOM). When a cap fails young, ask what killed it: failing motor? cooking sun exposure? voltage spikes? (Surge protector upsell is legitimate here.)

- **6% weak $\neq$ "still kinda works."** It costs amps, heat, and motor life daily. Replace at the threshold, document the reading.
- **HERM and FAN mixed up** = fan on the 40 section, compressor on the 5 = nothing runs right and the smell arrives shortly. The photo-first habit exists for this.
- **Two singles can replace a dual** (and a Turbo-200 replaces almost anything) — fine practice, label clearly, mind the C-terminal commoning.
- **370 V caps in 2026:** stock 440s; the price difference is pennies against a truck roll.
- **Discharge EVERY cap, even ones you "know" are dead** — including the one the last tech left disconnected and charged in the bottom of the cabinet.

7. Competency link

- **Comp 19 (capacitors)** — completed at bench level; the contactor half is 3.6, field reps in Unit 6/8.
- The under-load method returns for motors (6.1–6.2) and compressors (6.7).

8. Check yourself

1. The discharge ritual, step by step, with the tool named.
 2. Why not a screwdriver? Why not "just the meter"?
 3. What does a run capacitor actually do for the motor?
 4. Dual cap terminals — name and destination of each.
 5. The under-load formula and why it beats the bench test.
 6. Nameplate 45 μF ; bench reads 41.8. Verdict? ($45 \times 0.94 = 42.3 \rightarrow 41.8$ is OUT. Replace.)
 7. 370 V vs 440 V substitution rules?
 8. Bulged top — test it anyway? Flat top — proven good?
 9. Cap #3 on this unit in two summers. Three questions you ask before hanging #4.
 10. After the swap, what TWO measurements close the job?
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