

HVAC applications for the Fluke T+ and T+PRO Electrical Testers

Application Note

Popular, solenoid-type voltage detectors have been in use for nearly 100 years and probably still are, at any construction site you visit today. These testers apply a mechanical load across a circuit, causing a solenoid to position a spring-loaded plunger at the matching voltage level on the tool's preset voltage indication scale. Simple and low cost, most of these testers are not even CAT rated and can fail catastrophically under certain adverse conditions. (See Fluke application note "Differences in voltage detectors can be shocking".) Given today's technology, there is no reason to expose yourself to this kind of risk. If you're still using one of these solenoid testers, it's time to trade up to a solid-state electrical tester. If you're not using an electrical tester, there are good reasons to add one to your arsenal of test equipment favorites.

Tool features

The T+ and T+PRO testers have nine stacked LEDs labeled for nominal voltage from 12 to 600 volts, plus a continuity LED. The testers automatically turn on when its probes are placed across a complete circuit, and turns off when the probes are removed from the test circuit, unless the HOLD function has been activated on the T+PRO.

If no voltage exists but there is circuit continuity less than 20 Kohms, the top continuity LED illuminates along with a steady beep tone. If voltage is present, the meter automatically switches to voltage mode and illuminates the sequential LED voltage indicators according to

the voltage detected. In addition to the LEDs, the meters emit a continuous tone for dc voltages and a chirping tone for ac voltages. An ac or dc LED will also illuminate appropriately, plus the dc indicator displays polarity. At voltages greater than 30 volts, the hazard LED will illuminate. At voltages of 40 volts and greater, the meters will vibrate as well as sound a tone.

The pliable silicon test leads are internally connected to the tester by heavy-duty lugs, guarding against accidental disconnection while allowing for future replacement. The probe tips snap in place on the back of the meter for sheathed tip storage, and one probe slips into place at the top of the meter, aligned with a bright LED flashlight for easy two handed operation. The tester,



Testing control voltage on a 480 V panel controlling two small chiller pumps.

leads, and probe tips are 600 volt CAT IV and 1000 volt CAT III rated and the circuit impedance has been carefully selected to prevent ghost voltages and loading that may interfere with the circuit under test. The five inch probe tips are removable so they can be replaced if damaged, or alternate tips may be used if needed.

If the two AAA batteries fail, the T+ and T+PRO *remain nominally operational* since the voltage indicator LEDs are powered by the circuit under test. However, without batteries, the tone, vibration, and flashlight functions will not operate.

The T+PRO has a large LCD display that shows the actual voltage detected to tenths whenever the voltage is greater than 10 volts. A hold button will freeze the LCD display (and the LED bank) for one minute upon removal from the circuit. The tester has an ohmmeter function to measure resistance up to 9.99 KΩ, and a GFCI receptacle trip test function. An additional function called rotary field direction determines whether the equipment power supply is phased correctly, so you can avoid running scroll compressors, or any motor, backwards on start-up.

T+PRO applications and advantages

GFCI receptacle trip function

Most RTU's come with either a field-wired or self-powered GFCI receptacle. The T+PRO will check the trip function at the UL standard of 6–9 mA hot to neutral imbalance. Insert the red probe into the smaller hot receptacle jack and insert the black probe into the ground jack. Then, press the "GFCI" test button and after six or seven seconds, a properly operating GFCI receptacle will trip. Also, with its large LCD display, the T+PRO can check actual voltage at the receptacle from hot to neutral and hot to ground.

Rotary field direction

Three-phase HVAC equipment comes from the factory with properly phased internal wiring and the installing contractor relies on electricians to properly phase the service to the unit disconnect. Upon start-up, the HVAC installer checks for proper rotation of the motors.

If the equipment is supplied with scroll compressors and the phasing is incorrect, the disturbing racket of the compressors running backwards is readily apparent. If, for some reason, an unintended and unattended start-up should occur with the scroll compressors running backwards, compressor damage could occur.

With the Fluke T+PRO, the rotary field direction function can be used to check for proper phasing before the disconnect is closed, and before the equipment is started. While three-phase color-coding may be used, it is not required by the current NEC except for neutral (white), ground (green), or the high leg of a high leg delta system (orange). One should expect that L1 leads L2 by 120°, which would also result in L2 leading L3 by 120°. With the red probe on L1 and the black probe on L2, an "R" and a clockwise arrow will appear in the LCD display if the feed is properly phased with L1 leading L2 by 120°. If an "L" and a counter-clockwise arrow appear, then L1 lags L2 by 120° and any two of the three line wires can be reversed to correct the phasing.

Note: This test is only good on phase-to-phase, and not phase-to-neutral measurements.

Line voltage checks

In addition to checking if the circuit is live, the T+PRO can be used for most of your line voltage checks.

Is the voltage correct? Voltage should be ± 10 % for 230 volt and 460 volt equipment, and -5/+10 % for 208/230 equipment (197 to 253 volts).

Is the voltage balanced between phases? Ideally, voltage imbalance should not exceed 1 %, but 2 % is usually acceptable with most HVAC equipment.

% voltage imbalance =
 $((100 \times \text{maximum voltage deviation}) / \text{average voltage})$

If L1 - L2 is 474 volts, L2 - L3 is 481 volts, L1 - L3 is 476 volts, maximum deviation is
 $481 - 474 = 7$

average voltage is
 $(474 + 481 + 476) / 3 = 477$

$100 \times 7 / 477 = 1.47$ % voltage deviation

Is there voltage drop across the motor contactors or relays?

Voltage drop should be negligible.

L1 - L2 should equal T1 - T2,
 L2 - L3 should equal T2 - T3,
 L1 - L3 should equal T1 - T3.

If there is slight voltage drop across a contactor, it should be proportional and have acceptable voltage deviation.

Control voltage checks

Traditional HVAC electro-mechanical control circuits are 24 V ac nominal. While specifications for low voltage controls may be from 18 to 30 V ac, control voltage must never be supplied at less than 21 V ac, or failures during peak demand times are likely to occur.

A chattering contactor due to low control circuit voltage can cause an expensive motor or compressor failure. Dual rated 208/230 volt equipment is likely to have control transformers with multiple tap primaries that are factory wired for 230 volts, and must be re-wired in the field for 208 volt supplies. 24 volt circuits typically operate at 26 to 28 volts.

If control circuit voltage is low (less than 24 volts) check primary voltage and switch the transformer primary from the 230 volt tap to the 208 volt tap. This will provide the correct low voltage. Be careful not to install field-supplied controls that may

exceed the VA rating of factory installed transformers. The VA (Volt-Amp) rating of a 24 volt, 70 VA transformer is $70/24=2.9$ Amps. An excessive voltage drop on field-installed low voltage circuits would likely indicate insufficient wire gauge size. Minimum wire size for 24 volt control circuits is 18 gauge up to 100 feet. Longer runs will require heavier gauge wire. Use the T+PRO to check control voltage starting with no loads applied, then increase the control loads and watch for voltage drop.

While traditional control circuits are 24 volts, 115 volt and higher control circuits may be in use, depending on circuit design. The T+ and T+PRO may be used on any circuits exceeding 10 V ac/v dc.

Energy management systems are very common in today's control schemes, and incorporate DDC (Direct-Digital-Controls) to control HVAC systems as well as other building functions. The HVAC DDC controls are similar to a wall thermostat that controls heating, cooling, fan, and occupied functions based on temperature, time of day, and switch settings. The difference is

that the EMS (Energy-Management-System) is programmed with the operational parameters and uses space sensors to relay information such as temperature, humidity, and CO₂. Be careful when checking 24 V ac outputs from DDC controls. Many DDC controls are configured for "low side switching". Traditionally, the "hot" side of the transformer is switched ("high side switching") through a thermostat or control and the grounded leg is "common" to all controls. In low side switching, the grounded side of the transformer is switched through the DDC control. This prevents arcing that may occur when loads are switched on or off. The practice of checking circuits by placing the black probe on a ground and using the red probe on the "hot" outputs will not work. *Both the red and black probes must be placed across the contactor coil, or any control, to properly check for applied voltage.*

Most space thermostats use relay outputs, but DDC controls usually incorporate Triac outputs. Some HVAC controls use Triac inputs. A Triac output cannot be used to control more than one

control, nor can a Triac output control another Triac. When more than one relay must be controlled by a single Triac, the Triac must control a relay which in turn will control multiple relays. When the output and input are both Triacs, the input must be loaded with an auxillary relay or a resistor. This loading resistor is typically a 1,000 ohm, 5 watt resistor and can be checked with the T+PRO. Disconnect the resistor, set the T+PRO for "Ω", and place the probes across the resistor. The reading should be 1 KΩ , ± 5 % (50 ohms).

Modern HVAC DDC controls can also monitor and react to analog signals used to monitor temperature, enthalpy, humidity, CO₂, CO, light, etc. These signals can be 0 to 10 V dc, 2 to 20 mA, "floating" (pulsing), or even others. The T+PRO can't be used to check these low analog signals, but can be used to check some of these circuit resistors. A 499 ohm resistor can be used to convert 0 to 10 V dc outputs to 2 to 20 mA, or convert 2 to 20 mA to 0 to 10 V dc. If the analog function in question is not working properly, use the T+PRO "Ω" function to check these resistors.



Checking fuses and switch positions with the T+ and T+PRO

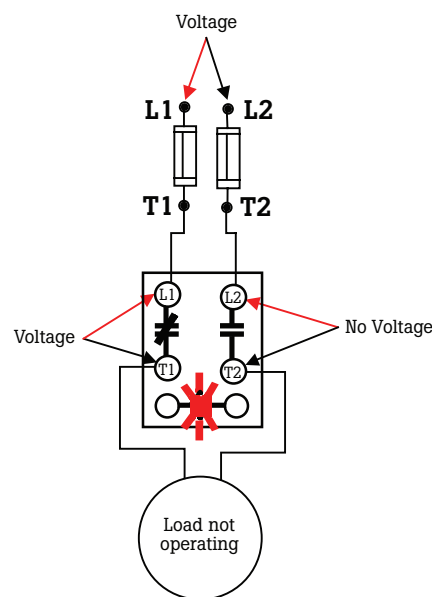
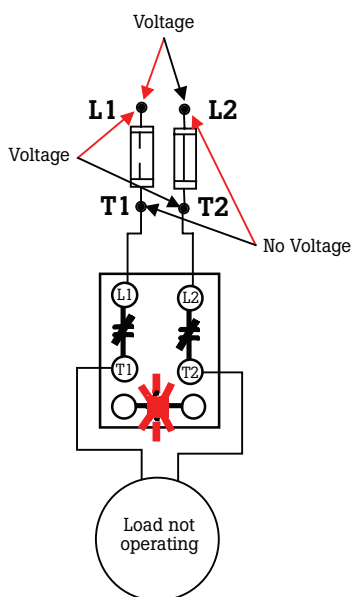
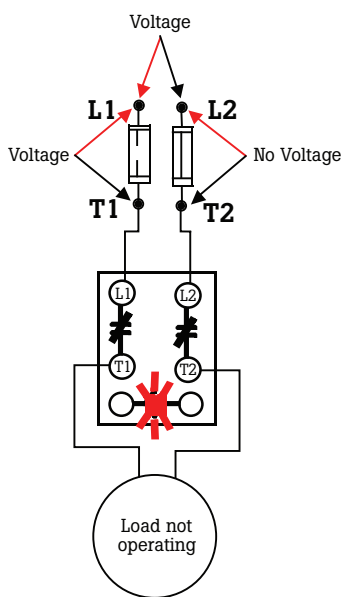
Fuses and switches removed from the circuit can be checked with the T+PRO "Ω" function, but sometimes it's desirable to check for fuse or switch conditions in a live circuit using the voltage function. One advantage of the T+ and T+PRO is that if voltage is present, the meter will switch automatically to the voltage function and avoid meter damage. If the contactors, switches, or relays are closed, but the load is not operating, maybe a fuse or relay contact is open. There are two ways to check for an open energized circuit: Parallel or series voltage tests.

Parallel voltage checks for an open fuse, for instance, can be made on the fused disconnect by connecting the leads alternately from L1 - L2, then L1 - T2, then T1 - L2. If L1 - L2 is hot, voltage will be detected. If L1 - T2 has voltage, but T1 - L2 does not, then the L1 fuse is open.

Series voltage checks for an open fuse or switch can be made by placing probes across the fuse or switch in question. For this to work, the circuit must be complete except for the single open fuse or switch. If voltage is present across the fuse or switch, the fuse or switch is open. This works by changing the inoperable load into part of the supply

circuit and putting the potential across the open point. If the load were working, of course, no voltage potential would be measured across the good fuse or closed switch.

Whether you are looking for just a low cost electrical tester like the T+, or a tester like the T+PRO that bridges the gap between mere voltage detectors and basic DMM functions, Fluke has a solution to fit your needs.



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Printed in U.S.A. 2/2007 2825348 A-EN-N Rev A