

HVAC/R Systems Service Tips with Fluke Multimeters and Accessories

Application Note

Getting the job done right

Servicing and maintaining refrigeration, air conditioning, and heat pump systems can be a tricky business—unless you have the right tools.

Measurements must be accurate, even when taken in changing or harsh environments. Speed and ease-of-use are important, too. Often a single-point-in-time measurement doesn't provide all the information. What you really need are measurements over time—minimum/maximum values recorded overnight, for example.

In addition, some troubleshooting techniques require knowledge of temperature, pressure, voltage, and current values in a system, which means that a single-function meter won't do.

And finally, there's often a customer waiting in the wings, so you want to make sure your job gets done right the first time, every time.

This application note provides information about refrigeration, air conditioning, heat pump, and heating applications and how to tackle some typical troubleshooting tasks using Fluke thermometers, digital multimeters, pressure/vacuum modules, and Fluke HVAC/R accessories. Basic refrigeration and heat pump theory is also provided solely to illustrate how digital thermometers, multimeters, and accessories can make servicing and maintaining HVAC/R systems straightforward, fast, and accurate.

Fluke advantages

Fluke meters are handheld, professional test tools that provide many advantages over other measurement tools.

Among these advantages:

- Rugged construction protects Fluke meters from damage due to falls and electrical overloads.
- Compact designs make Fluke meters easy to carry and easy to use.
- Accuracy and resolution for measurements you can trust.
- Versatility to perform many types of tests required of the HVAC/R technician.
- Safety standards and ratings to ensure operator protection.
- Service means that if anything goes wrong, you're backed up by Fluke's warranties and rapid turnaround from Fluke's own Service Centers.



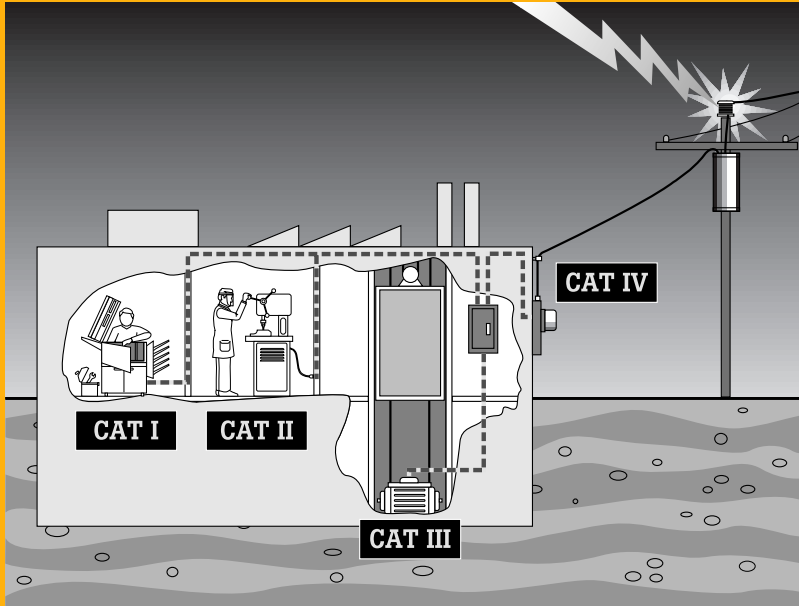


Figure 1. Four IEC 1010 Categories

Testing, repair, and maintenance of electrical and HVAC/R equipment should be performed by trained and experienced service personnel who are thoroughly knowledgeable about the equipment and electrical systems. Dangerous voltages and currents are present that may cause serious injury or extensive equipment damage.

Fluke cannot anticipate all possible precautions that you must take testing all the different equipment for which this brochure is applicable. Be certain that all power has been turned off, locked out, and tagged in any situation where you must actually come in contact with the circuit or equipment. Make sure that the circuit cannot be turned on by anyone but you. Always practice Log Out/Tag Out procedures as required by OSHA or local regulating agencies.

Use only well designed and well maintained equipment to test, repair, and maintain electrical systems and equipment. Use appropriate safety equipment such as safety glasses, insulating gloves, flash suits, hard hats, insulating mats, etc. when working on electrical circuits. Make sure that multimeters used for working on power circuits contain adequate protection on all inputs, including fuse protection on ALL current measurement input jacks.

Use meters designed and rated for your job application. Modern electrical test meters are now rated

by Overvoltage Category based on the risk of high-energy transients traveling through the power system.

Each Overvoltage Category (CAT) corresponds to an electrical environment within the electrical distribution system. CAT III meters are intended for 3 phase distribution circuits. This includes polyphase motors on compressors, three phase fans, feeders, and single phase lighting. CAT II meters are intended for single phase receptacle connected loads. CAT I meters are intended for electronic equipment connected to (source) circuits in which measures are taken to limit transient overvoltages to an appropriately low level.

Newer Fluke test meters are CAT III and independently certified to the highest standards currently available, meeting or exceeding the requirements for most HVAC/R applications. Refer to the Fluke Bulletin titled, "ABCs of Multimeter Safety," for an extended description of these Overvoltage Installation ratings and requirements.

This brochure is not intended to be a substitute for the instruction manuals shipped with your multimeter, thermometer, probes, or electrical equipment. Make sure you read and understand all of the applicable manuals before using the application information in this brochure. Take special notice of all safety precautions and warnings in the instruction manuals.

All refrigeration applications are based on the Second Law of Thermodynamics which states that heat flows naturally from a warmer object to a cooler object. What this means is that a refrigeration unit does not destroy heat, nor does it impart coolness, rather it extracts heat from an object or area and moves it to another place (outside a room to be cooled, for example).

At the simplest level, the heat is extracted by routing cold refrigerant through the area to be cooled. The heat is transferred to the refrigerant which is then quickly taken outside of the cooled area to dissipate heat.

Two types of heat are commonly discussed in HVAC/R applications: sensible heat and latent heat. Sensible heat can be measured with a thermometer and sensed by touch.

Latent heat on the other hand is often called hidden heat because it can't be directly measured with a thermometer. For example, water can exist both in liquid and solid form at 32°F (0°C) because of latent heat. In order to change one pound of water at 32°F (0°C) into ice at 32°F (0°C), 144 BTUs of latent heat must be removed.

Latent heat is also a factor in changing liquids to gas. In this case, latent heat must be added to the liquid before it will change to gas. In order to change one pound of water at 212°F (100°C) into steam at 212°F (100°C), 970 BTUs of latent heat must be added.

Evaporation (changing a liquid to a gas) and condensing (changing a gas to a liquid) are used in refrigeration systems. Because it takes latent heat to change a liquid to a gas, refrigerant evaporating into gas absorbs more heat than it would in liquid form. In refrigeration systems, the refrigerant is allowed to evaporate (boil) within the evaporator, thereby absorbing heat from the area to be cooled. During condensing, heat is released at the condenser to the surrounding area. Thus, this process is used to get rid of the heat that has been carried by the gas from the evaporator.

Although any liquid that can easily be changed from liquid to gas and back to liquid can be used as a refrigerant, special refrigerants have been developed that exhibit qualities that are particularly well suited to refrigeration. A typical refrigerant evaporates (boils) at a temperature below the freezing point of water, so it readily absorbs heat during evaporation even at low temperatures. It is also desirable for refrigerants to be nontoxic, non-explosive, non-corrosive, nonflammable, environmentally friendly with low or minimum ozone depletion potential, and stable in gas form.

The refrigeration cycle

A basic vapor compression refrigeration system consists of four primary components; a metering device (e.g. a capillary

tube or a thermostatic expansion valve), evaporator, compressor, and condenser. (See Figure 2.) The basic cooling process is as follows:

First, liquid refrigerant under high pressure is forced through a metering device into a lower pressure region within the evaporator where it begins to change to vapor.

The refrigerant is circulated through the cooling coils of the evaporator absorbing heat from the area surrounding the coils. As it moves through the evaporator, it steadily changes from almost all liquid to all vapor. The vapor (and the heat it carries) continues to move through the coils to the compressor.

The compressor compresses the gas to a high pressure. The compression process simulta-

neously raises the temperature of the gas. The hot gas is then delivered to the condenser where it is cooled and dissipates the heat and steadily converts the gas to a liquid.

A liquid receiver (on thermostatic expansion valve systems) captures the refrigerant between the condenser and the metering device. When the liquid under high pressure reaches the metering device, the cycle starts over. (See Figure 3.)

In most refrigeration systems, temperature and pressure provide quick and accurate checks on system performance. Close monitoring of temperature and pressure to verify proper control and operation can ensure longer system life and reduce energy consumption.

Figure 2. The refrigeration cycle. Based on the principle that heat flows naturally from warmer areas to cooler areas, the refrigeration cycle consists of seven stages: the compression of the hot gas, then its cooling, condensing, subcooling, expansion, evaporation, and superheating.

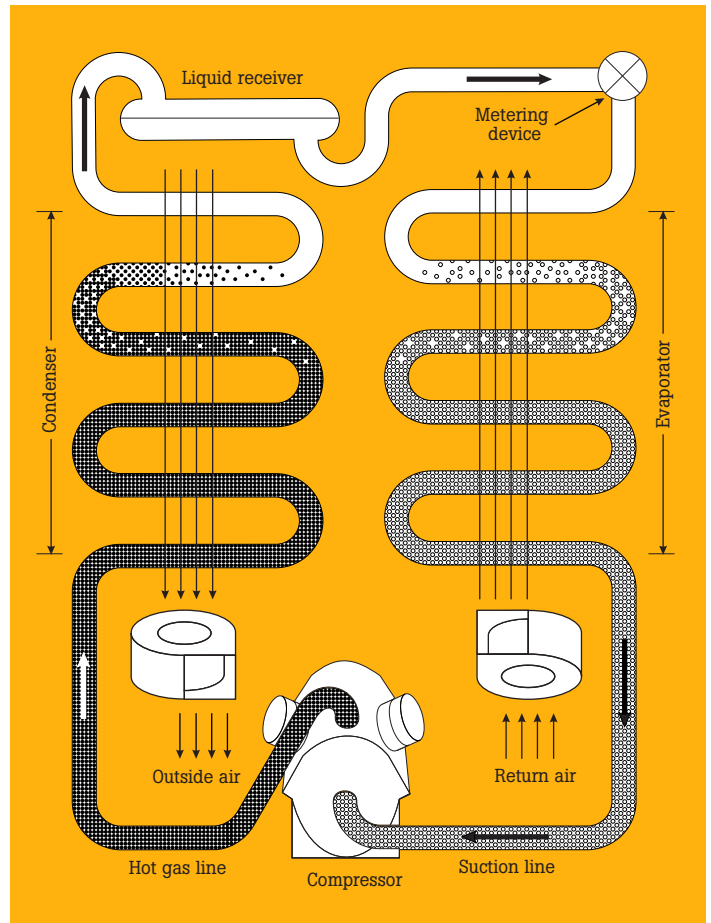
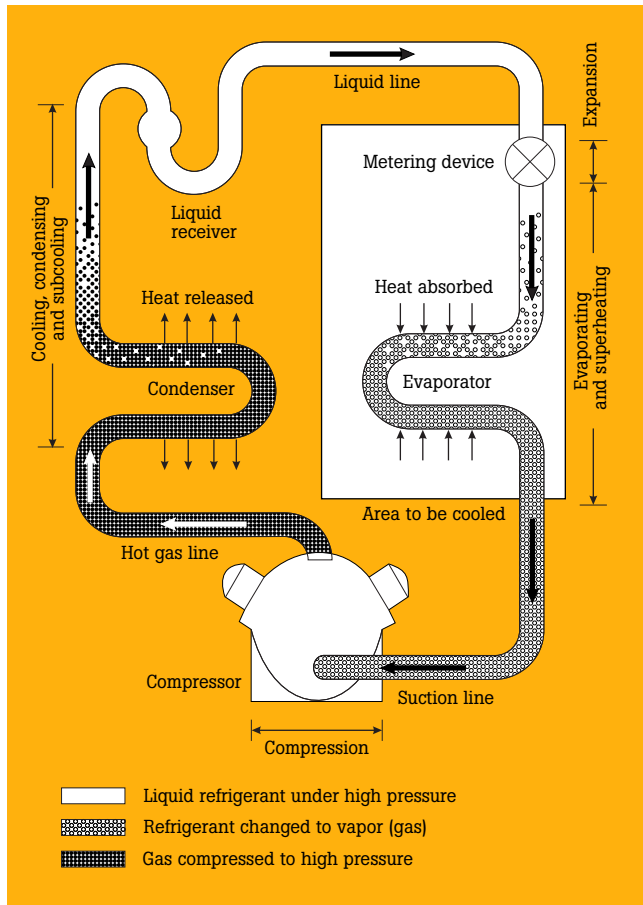


Figure 3. The refrigeration system. In a typical refrigeration system, the compressor sends hot gas to the condenser. Then the condensed liquid passes through an expansion valve into the evaporator where it evaporates and collects heat from the area to be cooled. The gaseous refrigerant then enters the compressor where the compression process raises the pressure and temperature. From the compressor, the refrigerant is routed back to the condenser and the cycle repeats.

Refrigeration Applications

Often, measuring temperatures or pressures at key points in a system can pinpoint trouble spots. In addition, basic electrical measurements are required to verify the proper operation of the various electrical components such as the compressor motor. Examples of such measurements follow.

Refrigerant leak detection

A common failure of refrigeration systems is the loss of refrigerant over long periods of time due to a small leak in the system. Whenever a system has been opened and reassembled it must be checked for leaks.

Additionally, federal law established by the U.S. EPA is requiring systems with predetermined leaks to be repaired by certified technicians upon detecting a loss of refrigerant charge. A pressure test using refrigerant or an inert gas allows you to determine if a leak exists, without examining every inch of the system.

With proper care, dry nitrogen and a minimum amount of R-22 as a trace gas may be used safely when pressure testing for leaks. The pressure in the nitrogen cylinder can reach 2000 psig when full, so a pressure-reducing device that has a pressure regulator and a pressure relief valve must be used.

Connect the PV350 Pressure/Vacuum Module and a manifold gauge set to the system to be pressurized. After pressurizing the system, observe the reading on the digital meter to see if the pressure holds or if it leaks off. If a leak is detected, then standard leak detection methods such as soap suds or electronic detectors may be employed. The advantage of using a solid state pressure gauge and digital meter is that a leak which may take hours to detect using only manifold gauges can be detected almost immediately, saving precious time on the job.

Superheat and its measurement

In the system's evaporator, conversion of liquid to vapor involves adding heat to the liquid at its boiling temperature,

commonly referred to as the saturation temperature. Any additional temperature increase is called superheat.

Finding suction line superheat requires two temperatures—the evaporator boiling temperature at a given pressure and the temperature of the refrigerant at the outlet of the evaporator on the suction line, commonly referred to as the superheat temperature/pressure method.

Note: Boiling temperature is derived from using a pressure-temperature (PT) chart. On new refrigerant blends with high temperature glide, this is called the dew point temperature.

The best method to determine superheat using Fluke products is to use the 80PK-8 Pipe Clamp Temperature Probe in conjunction with the PV350 Pressure/Vacuum Module. The 80PK-8 Pipe Clamp allows pipe temperature measurements to be made more quickly and accurately than other methods because it clamps directly to the pipe without the need to add insulation and tape or velcro as in the case of a bead thermocouple. The PV350 allows accurate and quick pressure measurements.

When measuring for superheat, allow the system to run long enough for temperatures and pressures to stabilize while verifying normal airflow across the evaporator. Using the 80PK-8 Pipe Clamp, find the suction line temperature by clamping the probe around a bare section of the pipe at the outlet of the evaporator. Pipe temperature can be read at the inlet of the compressor on the suction line if the pipe is less than 15' from the evaporator and there is a minimum pressure drop between the two points. (See Figure 4.) Best results are obtained when the pipe is free of oxides or other foreign material. Next, attach the PV350 to the suction line service valve (or refrigerant service port on your manifold gauge set). Make a note of the pipe temperature and pressure.

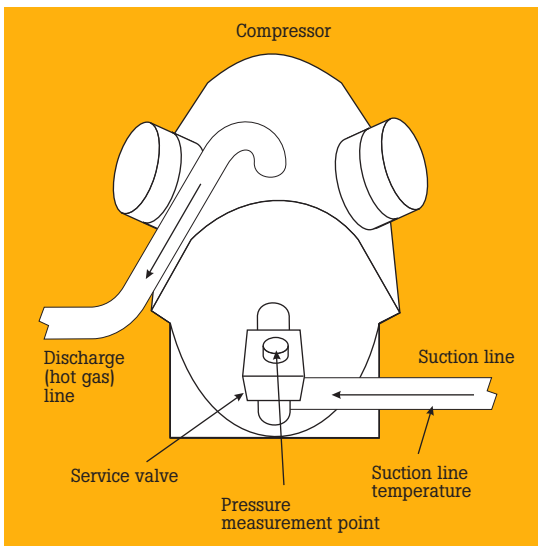


Figure 4. Suction line superheat using the temperature-pressure method. Measure the pressure at the suction line service valve. Find the evaporator boiling temperature from a temperature-pressure chart using suction line pressure. Subtract this temperature from the suction line temperature measured by the Fluke digital thermometer. The difference is superheat.

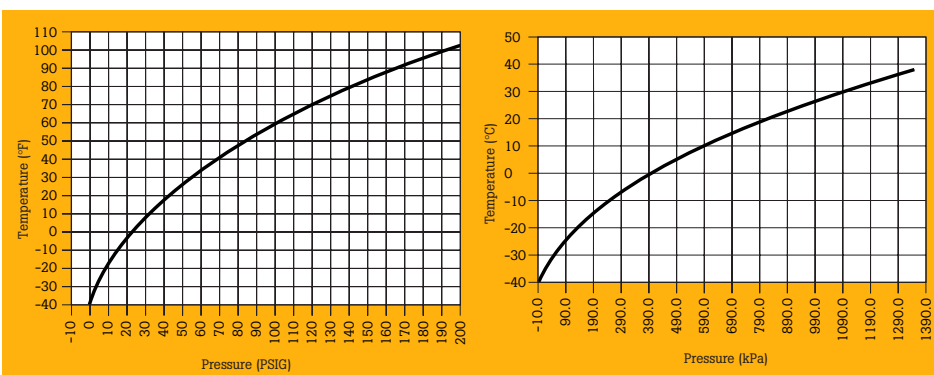


Figure 5. Pressure-temperature chart.

This pressure reading will be that of the boiling refrigerant inside the evaporator assuming no abnormal restrictions in the suction line. Using this pressure value, find the evaporator boiling temperature from a PT chart for the refrigerant type being used. (See Figure 5.) Subtract the boiling temperature from the suction line temperature to find the superheat.

The suction line temperature may also be taken by attaching a bead thermocouple to the suction line. Be careful to insulate the thermocouple and use heat conducting compound to minimize errors due to heat loss to ambient air.

Subcooling and its measurement

In the system's condenser, conversion of vapor to liquid involves removing heat from the refrigerant at its saturation condensing temperature. Any additional temperature decrease is called subcooling. Finding liquid line subcooling requires two temperatures—the condensing temperature at a given pressure and the temperature of the refrigerant at the outlet of the condenser on the liquid line. The liquid line temperature involves measuring the surface temperature of the pipe at the outlet of the condenser. (See Figure 6.)

Note: Condensing temperature is derived from using the PT chart. On new refrigerant blends with high temperature glide, this is called the bubble point temperature.

To measure subcooling with an 80PK-8 Pipe Clamp, allow the system to run long enough for temperatures and pressures to stabilize. Verify normal airflow and then find the liquid line temperature by clamping the 80PK-8 around the liquid line. Attach the PV350 to a service port on the liquid line (or discharge line at the compressor if a liquid line valve is not available). Make a note of the liquid line temperature and pressure.

Convert the liquid line pressure to temperature using a PT chart for the refrigerant type being used. The difference of the two temperatures is the subcooling value.

Trouble diagnosis using superheat and subcooling

Data from superheat and subcooling measurements can be useful for determining various conditions within the system including amount of charge, expansion valve superheat, efficiency of the condenser, evaporator, and compressor.

Before making conclusions from the measured data, it is important to check external conditions that influence system performance. In particular, verify proper air flow in cubic feet per minute (CFM) across coil surfaces and line voltage to the compressor motor and associated electrical loads.

Using superheat to troubleshoot

The superheat value can indicate various system problems, including a clogged filter drier, undercharge, overcharge, faulty metering device, or improper airflow. Suction line superheat is a good place to start diagnosis because a low reading suggests that liquid refrigerant may be reaching the compressor. In normal operation, the refrigerant entering the compressor is sufficiently superheated above the evaporator boiling temperature to ensure the compressor draws only vapor and no liquid refrigerant.

A low or zero superheat reading indicates that the refrigerant did not pick up enough heat in the evaporator to completely boil into a vapor. Liquid refrigerant drawn into the compressor typically causes slugging, which can damage

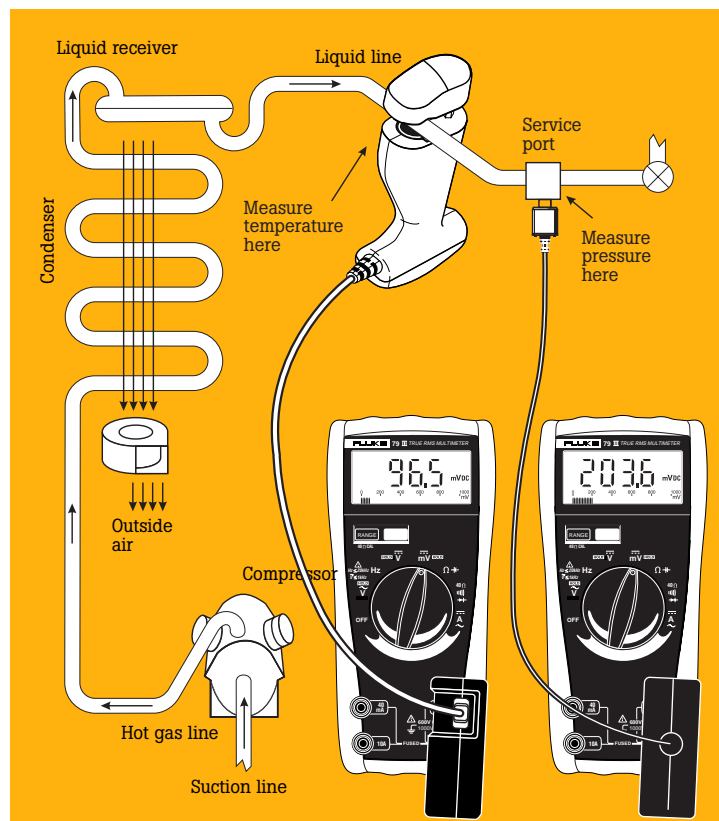


Figure 6. Subcooling. After verifying normal airflow, place the 80PK-8 Pipe Clamp on the liquid line. Note the temperature. Then attach the PV350 Pressure/Vacuum Module to a port on the discharge line and measure the liquid line pressure. Determine the condensing temperature by using the temperature-pressure chart for the refrigerant type used. The difference in temperature is the subcooling value.

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the compressor valves and/or mechanical components. Additionally, liquid refrigerant in the compressor, when mixed with oil, reduces lubrication and increases wear, causing premature failure.

On the other hand, if the superheat reading is excessive, it indicates that the refrigerant has picked up more heat than normal, or that the evaporator is short of refrigerant. Possibilities include a metering device that is underfeeding, improperly adjusted, or simply broken. Additional problems with high superheat could indicate a system undercharge, refrigerant restriction, or excessive heat loads upon the evaporator.

Using subcooling to troubleshoot

An improper subcooling value can indicate various system problems, including overcharge, undercharge, liquid line restriction, or insufficient condenser airflow (or water flow when using water cooled condensers).

For example, insufficient or zero subcooling indicates that the refrigerant did not lose the normal amount of heat in its travel through the condenser. Possible troubles include insufficient airflow over the condenser, the metering device stuck too far open, overfeeding, or misadjusted, or the system is undercharged.

Excessive subcooling means the refrigerant was cooled more than normal. Possible explanations include an overcharged system, the metering device is restricted, misadjusted (underfeeding), or faulty head pressure control during low ambient conditions.

Testing for non-condensibles gases within refrigerant recovery cylinders

Since the discovery of the ozone hole over Antarctica, the Federal Clean Air Act has established legislation that mandates the recovery of refrigerants on all air conditioning equipment, either stationary or motor vehicles. During the recovery process, the service technician must properly handle and process the refrigerant prior to any reuse in the refrigeration system. This process may be either a simple recovery of the refrigerant, extended recycle procedures, or shipping the refrigerant to a reclaim site. Regardless of which process the technician chooses, they must determine if the refrigerant cylinder has been contaminated with non-condensibles by-products (such as atmospheric air) prior to recharging the system with the used refrigerant.

Testing for non-condensibles within the refrigerant cylinder is a simple process. The instruments you will need are the Fluke PV350 Pressure/Vacuum Module, the 80PK-3A Surface Probe Thermocouple, and a digital multimeter with a temperature input.

Here's how the test process works. Allow the refrigerant cylinder to cool down to ambient temperature, preferably in a cool shaded area. Connect the PV350 directly to the refrigerant cylinder using a short refrigerant hose with a 1/4" female flare fitting. Attach the electrical connections of the module to your digital multimeter and record the pressure.

Use the 80PK-3A Surface Probe to measure the temperature of the refrigerant cylinder. Using your standard PT chart for the refrigerant, convert the temperature of the tank into its associated pressure.

Note: On refrigerant blends with a high glide, refer to the bubble point (liquid) section of the PT chart.

Next, determine if the refrigerant is within the proper range as indicated on the PT chart. If the measured refrigerant pressure is lower than indicated on the PT chart, it does not have non-condensibles. If the measured refrigerant pressure is greater than the limit shown on the PT chart, then there are noncondensibles residing within the cylinder. At this point, the cylinder contents must be transferred into a U.L. approved recovery/recycling machine and properly treated as per manufacturer's instructions to separate the non-condensibles from the refrigerant.

Repeat this process until the refrigerant cylinder pressure is within the acceptable pressure as noted on the PT chart.

Troubleshooting compressor discharge line temperatures

Use the 80PK-8 Pipe Clamp to measure the discharge line temperature at the discharge of the compressor. High temperatures above 275–300°F (135–148°C) will slowly destroy lubricant qualities and performance of the compressor. These high temperature conditions can be caused by high condensing temperatures/pressures, insufficient refrigerant charge, non-condensibles within the system, high superheat from the evaporator, restricted suction line filters, or low suction pressure. These conditions cause the compressor to have a higher compression ratio, work harder, generate hotter internal hermetic motor windings, and prematurely creates compressor wear, fatigue and failure.

Temperature survey

A temperature survey is a critical part of the service technician's job. A quick check of a system's components not only helps to diagnose troubles but also allows you to anticipate failures by regular monitoring of critical temperatures. (See Figure 7.)

Use the 80T-IR Infrared Temperature Probe to do a quick survey of:

1. Compressor head temperatures
2. Compressor oil sump temperatures
3. Evaporator coil and suction line temperatures
4. Discharge line temperatures
5. Condenser coil and liquid line temperatures
6. Fan motor temperatures

With the 80T-IR you can quickly survey a refrigeration system by scanning the temperatures of various components. While this is often done by touching each of the components, a non-contact infrared probe is often faster.

By keeping careful records it is possible to detect trends that indicate impending failure. This allows you to keep the system in top condition and avoid costly failures.

Note: IR instruments read best when measuring an object with a dull (not shiny) surface. If the surface is shiny, dull it with either black markers, non-gloss paint, masking tape, electrical tape, etc.

Recording a temperature overnight

To check refrigeration system performance, it is often useful to record temperatures in the refrigerated space. This allows you to detect problems that may go unnoticed with a single system check.

For instance, in a refrigerated space it is important to ensure that temperature variations are minimized. Temperature variations may result from changes in load or ambient conditions that occur over periods of time, so constant monitoring is called for. By recording minimum and maximum temperatures in key locations over a period of time you can be sure that air circulation and refrigeration capacity meets the application requirements.

The Fluke Model 52 Digital Thermometer allows you to record minimum and maximum temperatures over extended periods of time. To record overnight values, just select T1, T2 or T1-T2 as the input and push the RECORD button. The thermometer immediately starts recording the minimum and maximum values. Temperature values can be viewed at any time by pressing the view button (recording still continues). If the HOLD button is pushed, the recorded MIN/MAX values are saved and recording stops. The data is saved until the user selects a different input or turns off the 52. The Fluke 16 can also measure MIN/MAX of a single temperature plus the benefit of a 100-hour relative time stamp to know when the MIN/MAX occurred.

Motor compressor performance test

To test small hermetic and semi-hermetic compressors used for medium and low temperature applications, the following method can be used to test for internal valve leakage: Attach the PV350 to a DMM and put the PV350 function switch to cm/in Hg. Connect the PV350 at the suction line service port. Close the compressor off from the low side of system by front seating the suction service valve. Run the compressor for two minutes. Turn off the compressor and observe the reading. The compressor should have pulled down to at least 16" (410 mm) of Hg. If the vacuum reading starts weakening toward 10" (254 mm) of Hg vacuum, the discharge valves of the compressor may be leaking and will probably need to be replaced. If the compressor doesn't pull a vacuum below 16" Hg, the suction valves are weakening and may need to be

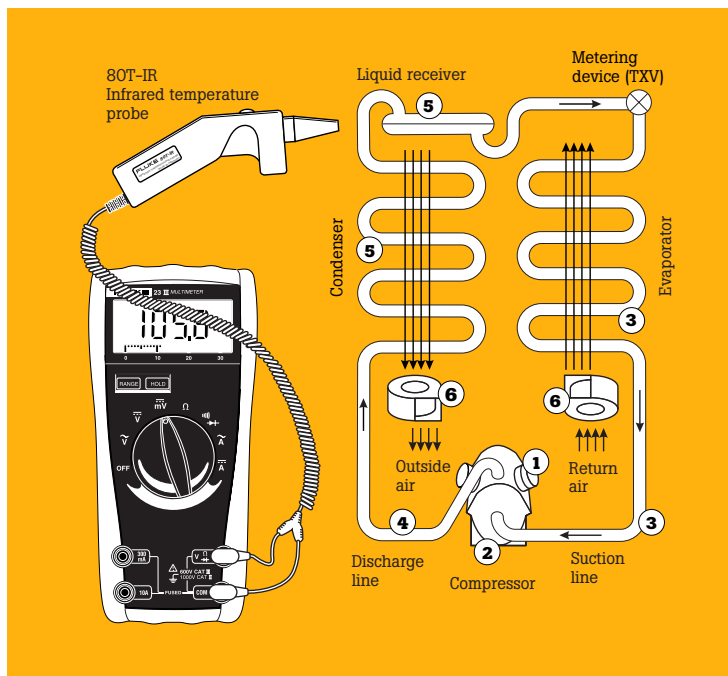


Figure 7. Temperature survey. Regularly monitor temperatures at key locations to anticipate component failure.

replaced. If the compressor is welded or hermetically sealed and these conditions exist, a new compressor is the only possible remedy.

Caution: Whenever replacing a compressor with faulty valves, be sure to diagnose the complete refrigeration system before and after a new compressor is installed to avoid repeated compressor failures.

Troubleshooting compressor motor faults

The Fluke Model 30 Clamp Meter is designed to accurately measure both ac voltage and ac current. A big advantage of this meter is its built-in current clamp. This allows current to be measured without breaking into the electrical circuit.

A compressor failure is often caused by an electrical fault. To check the compressor for electrical problems, remove the electrical terminal cover and check the following external connections.

1. Check line voltage at the load center with the compressor off. Low line voltage causes the motor to draw more current than normal and may result in overheating and premature failure. Line voltage that is too high will cause excessive inrush current at motor start, again leading to premature failure.
2. Check line voltage at the motor terminals with compressor running. The voltage should be within 10% of the motor rating.

3. Check running current. The readings should not exceed manufacturers full load rated amps during heavy load periods. Low amps are normal during low load conditions. Excessive current may be due to a shorted or grounded windings, a bad capacitor, a faulty start relay, or an indication of excessive bearing fatigue.

Caution: When doing electrical measurements on compressors with internal thermal motor protection devices that have been running extremely hot, be sure to give the compressor time to cool down prior to the electrical test. This will allow the device to reset to its normal position.

Troubleshooting compressor motor failures caused by refrigeration system problems

Occasionally, defective compressors with electrical winding failures are condemned prematurely by the service technician as having been caused by an electrical system problem. However, compressor electrical problems are often caused by mechanical system failure or inferior installation and service practices. These problems include poor piping practices resulting in oil not returning to the compressor, high discharge temperatures creating acids in the oil, insufficient air flows across the evaporator and condenser coils, extremely low suction pressures, and liquid refrigerant flooding back into the compressor.

Diagnosing these refrigeration system problems and avoiding compressor failure can be done effectively using the Fluke 16 DMM, Model 30 Clamp Meter, Model 52 Digital Thermometer, 80PK-8 Pipe Clamp, 80T-IR Infrared Temperature Probe, and PV350 Pressure/Vacuum Module.

Here's some simple procedures:

1. Compressor bearings can fail or lock up due to poor piping practices, which causes oil logging in the system and results in insufficient oil return to the compressor. If the bearings don't lock up and continue to wear during these conditions, the rotor will lower into the stator housing, shorting out the windings. To diagnose this problem, measure the compressor amps. They should not exceed manufacturers full load ratings. Worn bearings will cause higher than normal amps. Inspect the oil level via the compressor sightglass. If there is no sightglass, use your Fluke 16 and 80T-IR Temperature Probe to measure the sump of the compressor housing. The oil level can be detected with the temperature probe. The sump temperature will be different on the compressor housing at the oil level.

Caution: Whenever an oil problem exists due to poor piping practices, the correct remedy is to fix the piping, not to continue to add more oil to the system.

2. High discharge temperatures are caused by high head pressures or high superheat. The compressor discharge line can be measured quickly using the 80T-IR on a dull section of pipe. Measure the discharge pressure using the PV350. Convert the refrigerant pressure to temperature and compare it to the ambient air temperature. If there is a temperature difference greater than 20-30°F (11-17°C) temperature difference, there is either noncondensable gases in the system or restricted air flow across the condenser.

Note: Temperature differences will vary due to original manufacturer's design and efficiencies.

3. Insufficient air flows across the evaporator are easily checked by using the Fluke 52 Digital Thermometer. Place a bead thermocouple on the discharge side of the coil and on the return side of the coil. On air conditioning units, expect about 18–22°F ΔT (10–12°C) and on refrigeration units about 10–15°F (5–8.5°C) temperature difference.

Note: Temperature differences may vary depending upon initial design and humidity requirements.

4. Extremely low suction pressures can be checked using the PV350. Install it at the compressor and record your suction pressure. Convert the refrigerant pressure to temperature using the corresponding PT chart. Measure the return air temperature before the evaporator. Compare the refrigerant temperature to the desired evaporator return air temperature. On air conditioning units, expect about 35–40°F (19–22°C) temperature difference and refrigeration units expect about 10–20°F (5–11°C) temperature difference.

5. Liquid refrigerant flooding back to the compressor can be checked by determining the superheat using the PV350 and the 80PK-8 Pipe Clamp. Check suction pressure and convert the refrigerant pressure to temperature, using your pressure temperature chart. Measure the suction line pipe temperature. Compare the two temperatures. If there is no temperature difference, then you are bringing back liquid to the compressor. If there is a temperature difference between 10–20°F (5–11°C), then you have normal superheat and you are not slugging the compressor with unwanted liquid.

Checking for voltage imbalance in a three-phase compressor motor

(See Figure 8.) Voltage imbalance in three-phase motors is a problem because it causes high currents in the motor windings. These higher currents generate additional heat that degrades winding insulation. A 10°F (5°C) rise in motor temperature can reduce motor life by half. Voltage imbalance is usually caused by adding single phase loads on the same circuit used by the compressor, although sometimes component failure is the culprit.

Voltage imbalance for three phase motors should not exceed 1%. To calculate voltage imbalance, use this formula:

$$\% \text{ Voltage Imbalance} = \frac{100 * (\text{Maximum Deviation From Average})}{\text{Average Voltage}}$$

For example, given voltages of 449, 470, and 462, the average voltage is 460. The maximum deviation from the average in this example would be 11 volts. The percent imbalance is:

$$100 \times 11 / 460 = 2.39\%$$

Note that in this example, you would have a voltage imbalance problem.

Today's motors are often closely matched to the load requirements and have little reserve power. Therefore, you should periodically check motor supply voltages to ensure long motor life and reliable service.

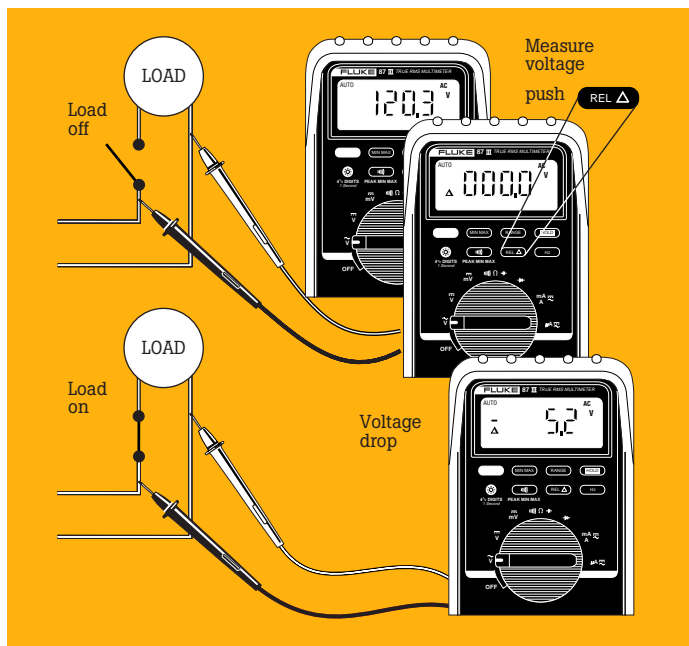


Figure 8. Measuring voltage drop in branch circuits. Use the Fluke 80 Series DMMs and the Relative mode to measure voltage drop. First turn off all loads on the branch circuit. Then measure the voltage at the most distant outlet on the circuit. Press the REL Δ mode button on the DMM while measuring the no-load voltage. The displayed reading will be stored, and the display will read zero. Next, turn on all the loads and measure the voltage again at the same outlet. The voltage drop (difference between the no-load and the full-load voltages) will be displayed.

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Checking for current imbalance in a three-phase compressor motor

(See Figure 9.) Current should be measured to ensure that the continuous load rating on the motor's nameplate is not exceeded and that all three phases are balanced. If the measured load current exceeds the nameplate rating or the current is unbalanced, the life of the compressor motor will be reduced due to higher operating temperatures. Unbalanced current may be caused by voltage imbalance between phases, a shorted motor winding, or a high resistance connection.

To calculate current imbalance, use the same formula as for voltage imbalance but substitute current in amps. Maximum current imbalance for three-phase motors is typically 10%.

Motor capacitor measurements (on single-phase motors)

(See Figure 10.) Some motors use capacitors in the starting circuit to provide additional torque to start the compressor. This capacitor is removed from the circuit after the motor has been started. In addition, some motors have a capacitor attached to the "run" winding. It is used to improve the efficiency (power factor) of the motor. This capacitor has a lower value than the start capacitor; thus the run and the start capacitors are not interchangeable.

If a capacitor shorts out, the motor windings may burn out. Open capacitors or capacitors that have changed value may result in poor starting or other improper operation. The capacitance function of the Fluke 16

measures up to 10,000 microfarads. This easily allows measurement of large electrolytic capacitors found on ac motors. As an added precaution, the Model 16 automatically discharges the capacitor if residual voltage is present before making the measurement.

To measure capacitance, first disconnect the capacitor (and bleed resistor, if installed). Then discharge the capacitor using a 20 kΩ 2W resistor. Do not short the terminals as this may damage the capacitor. Put the meter in capacitance mode and perform the measurement. Read the microfarads directly from the meter and compare the results to the "mfd" rating stamped on the side of the capacitor. Your results should be within the "mfd" range of the manufacturer's specifications.

If upon completion of these procedures, you determine you have a faulty capacitor, begin to troubleshoot the electrical system using your Fluke 16 for possible shorts or faulty circuits which may have caused premature capacitor failure. Capacitors don't usually

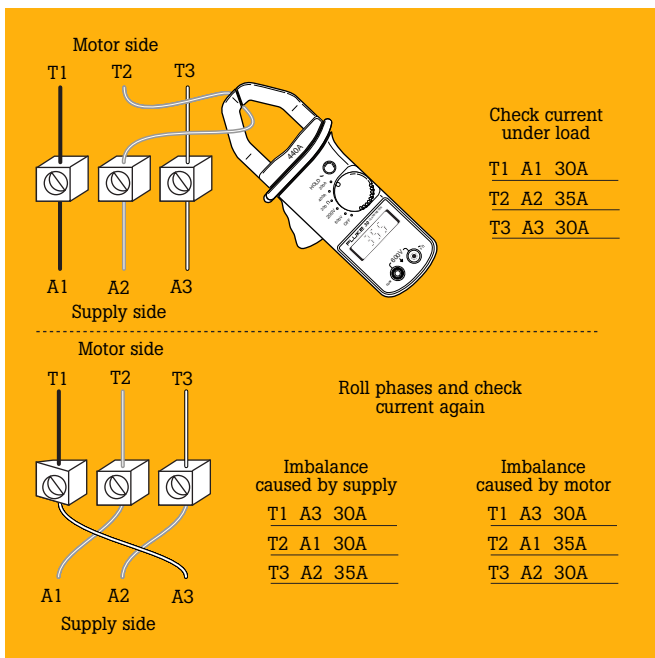


Figure 9. Locating the source of current imbalance—motor or supply. Use the Fluke Model 30 to check for current imbalance on each of the phases while the motor is running under load. If the current in the phases is unbalanced you can determine if the imbalance is caused by the motor or supply by interchanging or rotating the phases. First, measure the current in the phase conductors while the motor is under load, and note which phase has the highest current. Next, connect supply phase A to motor terminal T2, phase B to terminal T3, and phase C to terminal T1, and measure the phase current again. Note: All three phases must be rotated, or the motor will run in reverse. If the same supply phase still has the highest current as before the reconnect, the imbalance is caused by the supply. If the highest current is now carried by another supply phase, the imbalance could be the result of a shorted winding in the motor.

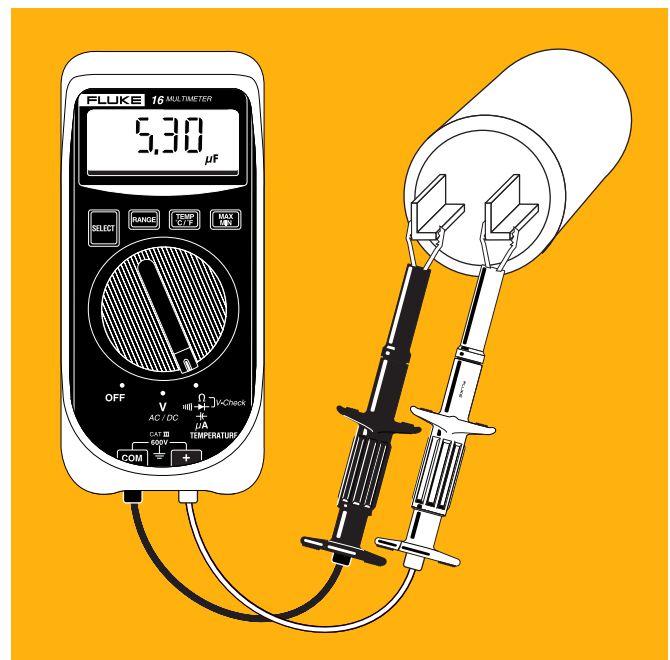


Figure 10. Troubleshooting capacitors. The capacitance function of the Fluke 16 measures to 9999 μF. This allows measurements of large electrolytic capacitors found on ac motors. To prevent measurement errors, the meter's discharge mode discharges the capacitor if residual voltage is present. The meter displays "dISC" while discharging the capacitor.

fail in the field under normal working conditions, unless they have been subjected to excess heat conditions or other electrical device failure.

Finally, replace the faulty capacitor with an exact match.

Note: Always remember to analyze each electrical system cautiously, working safely, to cure the problem prior to installing a new capacitor in your system to avoid repeat failures.

Determine the condition of motor windings

(See Figure 11.) Some compressor failures are due to shorts, grounds or opens in the windings. While a motor circuit tester may be necessary for a complete checkout, these failures are easily detected with a handheld meter such as the Fluke 79.

The Fluke 79 works well for checking motor windings and relays for shorts, grounds, and opens. First disconnect the system wiring from the compressor; this includes the relay, capacitors, and overload protection. Then check the resistance of the motor windings to deter-

mine if a fault has occurred. Maintenance records or measurement of other known good components can be used for comparison during troubleshooting.

On single phase motors, check Start winding, Run winding, Start to Run winding. The ohms reading between the three windings will provide three different readings as follows: the highest resistance is found between the Start and Run windings, the least resistance between the Common and Run windings, and the middle amount of resistance is between the Common and Run windings.

On 3 ϕ motors, check phase to phase, and phase to ground. The phase to phase ohm readings should be equal between phases, with no continuity from any phase to ground.

Analog gauge calibration

(See Figure 12.) Analog manifold gauges often become inaccurate and out of calibration through rough handling and

normal wear. The PV350 and a Fluke DMM combination when used with a known pressure reference source is significantly more accurate than, and can be used to verify, an analog gauge. The best reference pressure source is to use a new, uncontaminated standard refrigeration cylinder at a known temperature and pressure. First connect the PV350 to the digital meter and put the function switch in the proper function for verification. If a manifold gauge is being verified, attach the PV350 to the center port of manifold gauge set. Apply pressure to the analog gauge from the refrigerant cylinder. Measure the cylinder temperature using the Fluke 80PK-3A and then reference the temperature to a PT chart for the expected pressure. View the display on the digital meter. Compare the reading from the PV350 to the pressure/temperature of the refrigerant. Adjust the analog gauge calibration screw as necessary to match the two pressures.

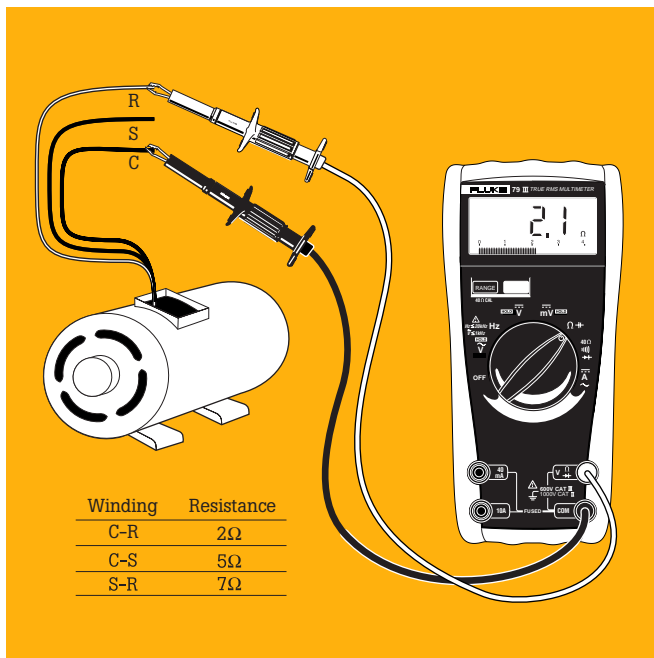


Figure 11. Checking motor windings. Disconnect supply wiring from the compressor. Then check the motor windings to determine if a fault has occurred. Maintenance records or known good components can be used for comparison.

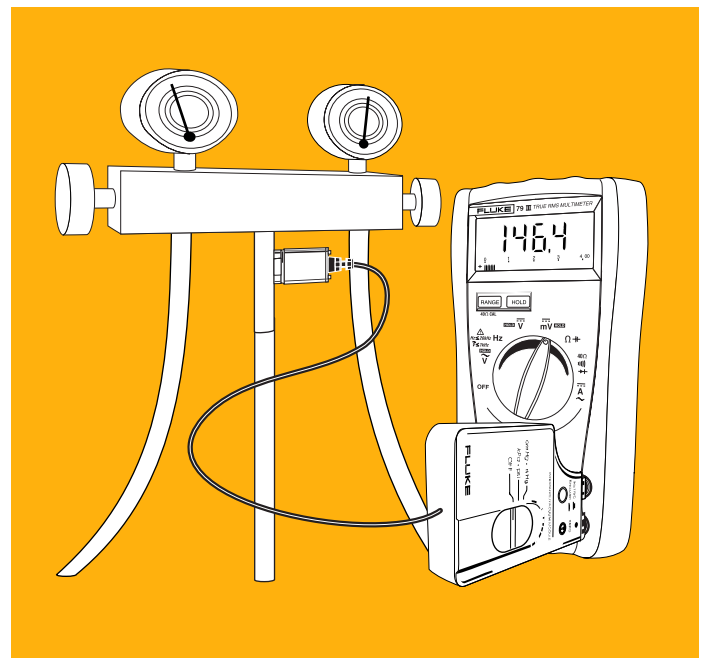


Figure 12. Analog gauge calibration. If a manifold gauge set is being verified, attach the PV350 to the center port of the manifold gauge set. Apply pressure or vacuum to the analog gauge. Adjust the analog gauge calibration screw or bezel as necessary.

Heat Pump Theory

Heat pumps

(See Figure 13.) Heat pumps are a variation of a refrigeration system. They are unique in that they have the capability of operating as both a heating and cooling system. A typical air-to-air system includes two coils labeled "indoor coil" and "outdoor coil." Each coil has its own expansion device. A reversing valve steers the direction of the refrigerant flow, making one coil the condenser and the other the evaporator. When the thermostat calls for heat, the controls position the reversing valve to select the indoor coil as the condenser and the outdoor coil as the evaporator. As the refrigerant evaporates in the outdoor coil it picks up heat from the outside air.

The compressor raises the temperature and pressure of the refrigerant and delivers it to the indoor coil where it gives up heat to the indoor air. In the cooling mode, the coils reverse roles and heat is removed from the indoor air and transferred to the outside air.

Heat pumps are most efficient as heating systems when they are installed in moderate climates that have average outside air temperatures during winter months above 32°F (0°C). When the temperature falls below freezing or the balance point of the heat pump system, the system will require an auxiliary heat source. This auxiliary heat or supplemental heat is normally provided as electric resistance heat in the air handling unit on most installations.

Calculating heat pump air flow

(See Figures 14 and 15.) In heating mode, the temperature of the air leaving the indoor coil will typically be 95°F (35°C). This discharge air temperature is lower than most types of combustion heating systems. It means that the heat pump requires a greater volume of indoor airflow to deliver the same amount of heat. Each heat pump system has a design rating for air volume typically given in cubic feet per minute (CFM) or m³/sec (cubic meters per second). If the airflow is too low, the condensing temperature and pressure will increase, causing an increased load on the compressor. The airflow is governed in part by blower speed and duct-work sizing. Most systems provide electrical connection taps on the blower motor to change speed. In order to verify that the correct speed is selected, the CFM (m³/sec) should be measured. Mechanical methods are available but a simpler electrical-temperature method can be used on systems that are equipped with electrical supplemental heat.

Start by setting the system into the emergency heat mode so that the compressor is off. Next, use a Model 30 to measure the input voltage and current. These readings allow the calculation of BTU/hour using the following formula:

$$\text{BTU/hour} = \text{Volts} \times \text{Amps} \times 3.412$$

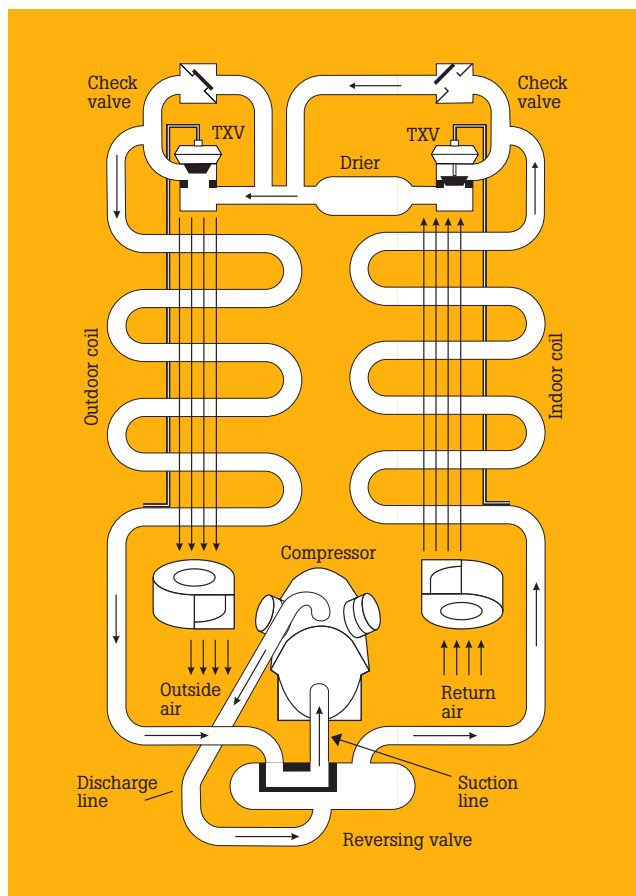


Figure 13. Heat pump. Shown here is a heat pump in heating mode. Heat is collected from outside and transferred to the area to be heated through condensation. The 4-way reversing valve allows the flow to be reversed, turning the heat pump into a conventional cooling system.

Heat Pump Applications

Using a Fluke 52, measure the temperature rise across the heating element. To do so, measure the inlet temperature T2 and the outlet temperature T1 simultaneously and use the T1-T2 function to display the difference. If possible, measure the outlet temperature downstream from a bend in the ductwork where the air has been adequately mixed, thus giving a more accurate reading, or take an average of several readings across the duct.

Using this temperature reading, plus the BTU/hour calculation above, calculate the airflow as follows (see example in Figure 15):

$$CFM = \frac{(BTU/hour)}{(1.08 * (T1-T2))}$$

Checking the defrost control on the heat pump

On modern heat pumps, defrost is accomplished automatically with electronic defrost controller boards. Initiation of defrost is done by time and temperature of the outside coil conditions. The temperature at which a heat pump system goes into defrost mode is usually preset at the factory. However, the time function for sampling if defrost is required can be adjusted on the defrost logic board by moving jumper pins. Termination of defrost is done by either temperature or time, preferably by coil temperature.

Here's how a Fluke 16 with the 80PK-8 Pipe Clamp Thermocouple can be used to verify the defrost start and end

points: Clamp the pipe clamp thermocouple to the outlet of the outside air coil, as close as possible to the termination temperature sensor coming from the defrost controller board. Either wait for a defrost to occur or force a defrost by jumping out the controller board per manufacturer's instructions. Check the temperature when the defrost cycle is initiated and terminated. Check these readings against the manufacturer's recommended values. If the temperatures are outside the specified range, adjust to proper operation temperatures (if possible) or replace the defrost control.

Caution: Don't condemn the defrost control until the heat pump has been checked for proper refrigerant charge. Heat pumps with low charge will not have enough refrigerant to adequately complete the defrost cycle.

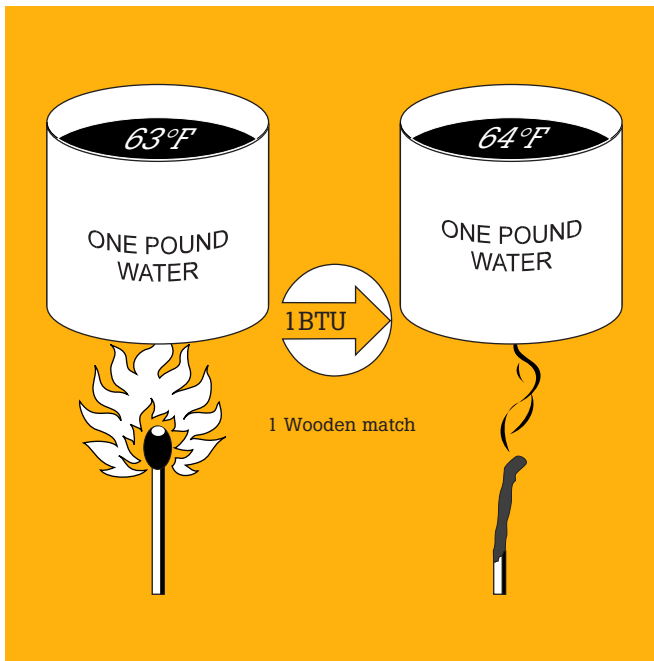


Figure 14. BTUs. BTUs (British Thermal Units) are a measurement of heat. A BTU is the amount of heat required to raise a pound of water one degree Fahrenheit at sea level. This is approximately the heat given off by burning a wooden match.

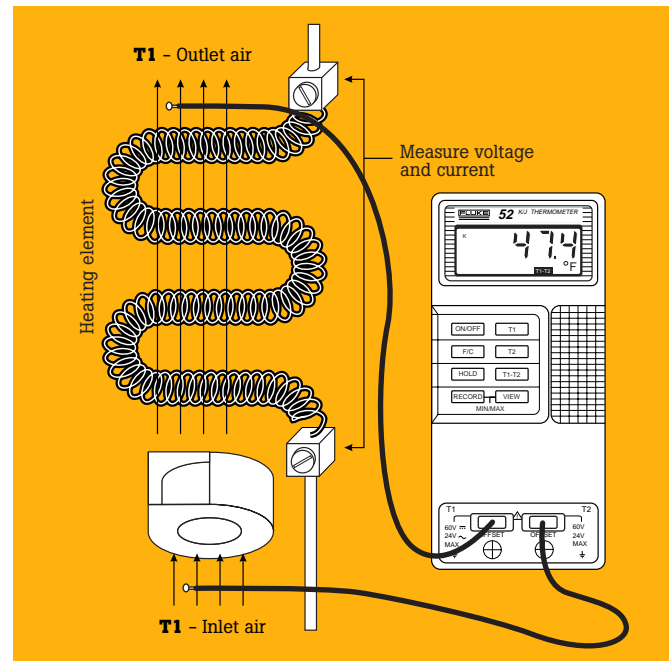


Figure 15. Calculate the BTUs and CFM of a system. Measure the input voltage and current. Then measure the temperature rise across the heating element. In the example shown, a 240V system drawing 62.5A produces a temperature rise of 47.4°F (8.5°C). Plugging these values into the simple formulas (see text) yields 51,180 BTU/hr and 100 CFM.

Measuring Relative Humidity

Measuring relative humidity

(See Figures 16 and 17.) Comfort in a home or office depends on relative humidity as well as on air temperature. Even given the proper temperature, residents or workers may experience dry throats, dry skin, or excessive static electricity if the relative humidity is too low. If the humidity is too high, condensation may form on windows and the air will feel damp. Humidity should usually be between 35% and 65% for reasonable comfort.

The relative humidity in an environment can be determined by measuring wet-bulb and dry-bulb temperatures. The Fluke 51, 52, or Fluke 16 can be used to make these measurements.

Take the dry bulb measurement by recording the temperature as you fan air past the thermocouple with a newspaper or other object. Don't blow on the thermocouple because your breath is warmer than the air you are trying to measure.

Take the wet-bulb measurement by placing a clean 3" (7 cm) piece of wet cotton shoelace over the thermocouple (the lace serves as a simple and inexpensive sock). The sock should be saturated but not dripping with clean water, preferably distilled. If the sock is not saturated, an inaccurate reading may result. The thermocouple should be inserted about half way into the sock.

Fan air around the sock. The temperature reading displayed on the thermometer will slowly decrease until the wet-bulb temperature is reached. This typically takes a minute or two. Record the temperature.

Now use the psychrometric chart to find the relative humidity. Start on the bottom axis at the dry bulb temperature. Move vertically along the dry bulb temperature line corresponding to your reading. Locate the intersection of the diagonal line that represents the wet bulb temperature. The relative humidity is indicated by the curved line that runs through the intersection of the two temperature lines.

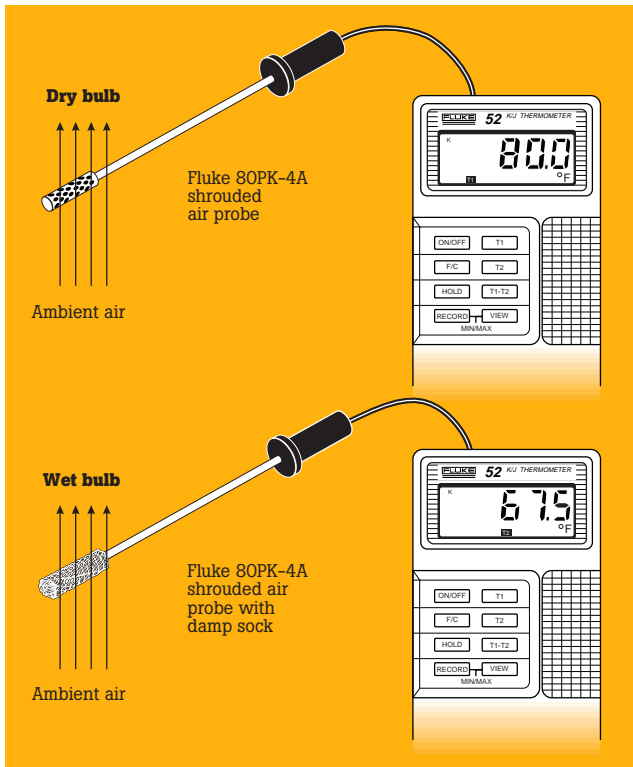


Figure 16. Relative humidity. Fluke 50 Series Thermometers can be used to calculate relative humidity. Dry bulb measurements can be taken directly (top drawing). A small piece of cotton shoelace quickly converts a temperature probe so it can measure wet bulb temperature. Saturate the shoelace and slip it about halfway over the probe. Then take the wet bulb measurement. It may take a couple of minutes before the reading stabilizes.

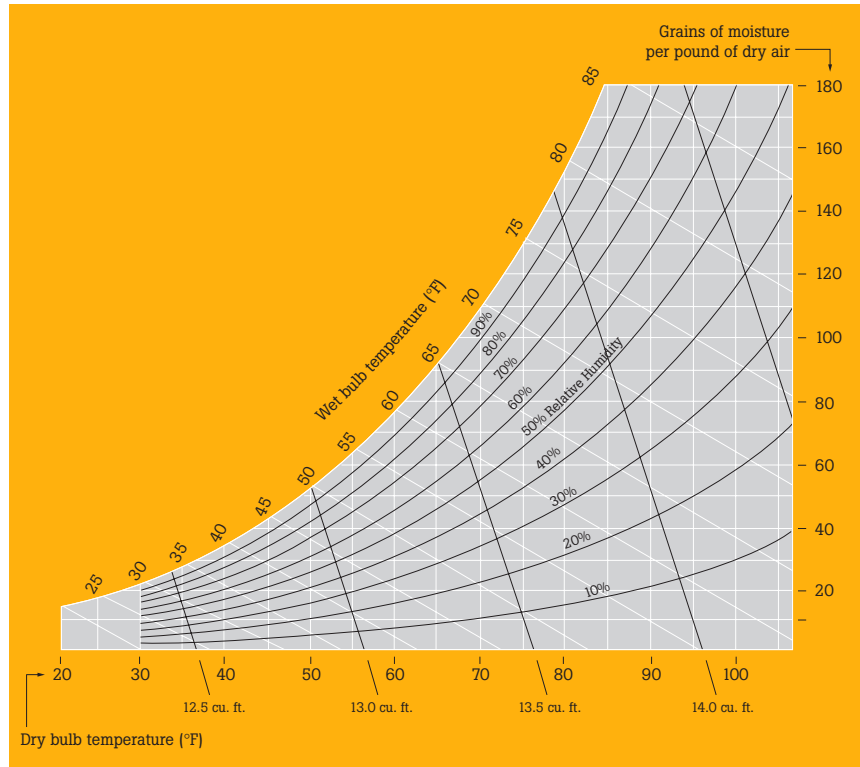


Figure 17. Psychrometrics. Psychrometrics is the science dealing with thermodynamic properties of moist air and the effect of moisture on materials and human comfort. The psychrometric chart is convenient for solving numerous process problems involving moist air. Processes performed with air can be plotted on the chart for quick visualization as well as for determining changes in significant properties such as temperature, humidity ratio, and enthalpy for the process. The psychrometric chart provided here is a simplified version that can be used for determining relative humidity at sea level. A slightly modified chart can be used for other altitudes, depending on atmospheric pressure.

Psychrometric chart reprinted with permission from the Carrier Corporation.

Testing Combustion Heating Systems

Carbon monoxide testing around combustion systems

(See Figure 18.) Carbon monoxide is called the “silent killer.” It is a colorless, odorless, toxic gas whose primary source is the incomplete combustion of fossil fuels. Carbon monoxide can be a potential problem in any building that uses combustion devices for space heating, hot water heating, cooking, vehicles such as propane forklifts, and emergency power generation equipment.

Gas heating equipment using combustible gases such as natural gas or liquefied petroleum (LP) require that the service technician inspect the equipment annually for possible carbon monoxide gas leaks into the building. Using the Fluke CO-210 Carbon Monoxide Probe makes it easy to take accurate measurements of CO levels to determine if there is a carbon monoxide gas leak into the ambient environment.

Troubleshooting using CO gas detection devices

High CO levels in the ambient environment within the building can indicate problems such as a cracked heat exchanger, blocked/defective flue, or an improperly ventilated/pressurized building. CO levels as low as 200 parts per million (PPM) can cause headaches, fatigue, nausea, and dizziness over an extended period of time. At 800 PPM of carbon monoxide, death can occur in as little as 2 to 3 hours. Typically, there should be less than 5 PPM in the ambient air within a building. ASHRAE references a maximum level of 9 PPM, while OSHA mandates a maximum exposure of 50 PPM for an eight-hour work day.

For initial first pass analysis, the Fluke CO-210 can act as a stand-alone indicator. Simply detach the CO-210 cord and rely upon the device’s bright LED and beeper that trigger with increasing frequency (like a Geiger counter) as CO levels rise. The beeper can be turned off when silent operation is preferred. Use this method at a supply register close to the furnace to check for a cracked heat exchanger which is leaking into the supply air system. If the CO-210 “tick” rate increases, then plug it into a digital multimeter with dc mV inputs to get an accurate numerical readout. The Fluke CO-210 measures CO levels from 0 to 1000 PPM, with an accuracy of 3%.

Next, use the Fluke CO-210 with a digital multimeter to check for small shifts in ambient carbon monoxide levels around the exterior of the furnace and along the flue vent. Keep in mind that CO is lighter than air and will rise from a leaky heat exchanger or flue.



Figure 18. CO-210 w/79 Series III meter testing ambient carbon monoxide levels around hot water heaters.

Testing Combustion Heating Systems



Figure 19. Fluke 16 in the microamps mode testing the flame rectification circuit.

Testing flame rods with the microamp function

(See Figure 19 and 20.) Measuring microamps is required regularly as part of the troubleshooting process when a flame will not stay lit on a gas or oil furnace. Most of today's light commercial and residential gas burner controls utilize a flame rod to confirm the presence of the flame. Here's how it works: The control center sends out a voltage to the flame rod. The flame itself serves as a partial diode rectifier between the flame rod and the ground. Without a flame, the circuit is open and there is no current. However, the presence of a flame will allow a few microamps of dc current to flow. The acceptable microamp reading varies from one manufacturer to another. Some controllers such as the Honeywell Smart Valve yield only 0.6 microamps under full flame. However, it is more typical to find readings around 3 to 4 microamps such as with the White-Rodgers controller.

The test procedure itself is simple. Shut off the furnace and locate the single wire between the controller and the flame rod. Typically, the wire is terminated at the control panel or the flame rod with standard spade connectors. Break the spade connection and place the test leads from the Fluke 16 in series into the circuit. Having alligator clips for the test leads (such as the Fluke AC70) will make the connection much easier. Turn on the Fluke 16 Multimeter and set the meter in the dc microamp (μA) mode. Restore power to the furnace (follow furnace manufacturer's instructions for safe operation) and set the furnace to call for heat. Once the burner or pilot ignites, check your reading on the Fluke 16. Refer to the furnace troubleshooting instructions to determine how to proceed with this result. Typically, a low or zero microamp reading may indicate that the flame sensor is not close enough to the flame, carbon build-up on the rod is limiting current flow (clean flame rod with steel wool), the flame rod is shorted to ground, continuity is not present between the control module and the flame rod (use the Fluke 16's continuity function to check), or the control module is bad and needs to be replaced.

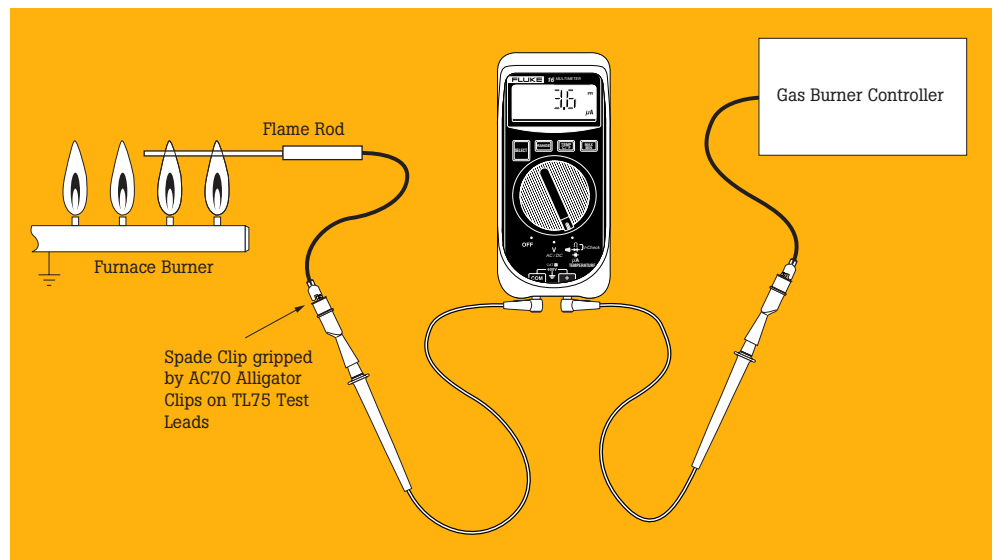


Figure 20. Depicting schematic of flame rod circuit with Fluke 16 in circuit.

Definitions

BTU

British Thermal Unit. The quantity of heat needed to raise the temperature of one pound of water one degree Fahrenheit at sea level; approximately the amount of heat given off by burning one wooden match.

Bubble point

A term used with new refrigerant blends to indicate the refrigerant pressure/temperature relationship at the outlet of the condenser (i.e., liquid pressure). Used when measuring for subcooling on refrigerant blends with temperature glide.

CFM

Cubic Feet Per Minute. A standard air flow quantification used to describe air flow across coils and through ducted fan systems.

Change of state

The change of a substance from one form to another, resulting from the addition or removal of heat. Changes of state due to the addition of heat: liquid to gas (evaporation), solid to gas (sublimation). Changes of state due to the removal of heat: liquid to solid (freezing), gas to liquid (condensation).

Condensing

The change of state from a gas to a liquid. Heat is rejected during this process.

Dew point

A term used with new refrigerant blends to indicate the refrigerant pressure/temperature relationship at the outlet of the evaporator (i.e., vapor pressure). Used when measuring for superheat on refrigerant blends with temperature glide.

Evaporation

The change of state from a liquid into a gas. Heat is absorbed during this process.

Heat pump

A compression cycle system used to supply heat or cooling to a temperature-controlled space.

Heat pump balance point

The outdoor temperature at which the heating capacity of a heat pump in a particular installation is equal to the heat loss of the conditioned area.

High side

Parts of a refrigeration system which are under condensing or high pressure. Typically from the compressor piston discharge valves to the thermostatic expansion valve (TXV).

Latent heat

Heat energy absorbed in the change of state of a substance (melting, vaporization, fusion) without a change in temperature.

Liquid line

The tube or pipe that carries liquid refrigerant from the condenser (king valve) to the refrigerant control mechanism (TXV).

Low side

The portion of a refrigeration system which is at evaporating pressure. Typically, from the thermostatic expansion valve (TXV) to compressor piston suction valves.

Refrigerant

Substance used in a refrigerating system. It absorbs heat in the evaporator by a change of state from a liquid to a gas. It releases its heat in the condenser as the substance returns from the gaseous state to a liquid state.

RH

Relative Humidity. The percentage of moisture in the air as compared to the amount of moisture in fully-saturated air (i.e., 100% humidity) at the same pressure and temperature conditions.

Sensible heat

Heat energy which causes a change in the temperature of an object. Sensible heat can be felt.

Subcooling

The difference between the measured liquid line temperature of a refrigerant and its condensing temperature at the same pressure.

Superheat

The difference between the measured suction line temperature of a refrigerant vapor and its normal boiling temperature at the same pressure.

Temperature glide

A term used with new refrigerant blends to give the range of condensing or evaporating temperatures when the pressure remains constant.

TXV

Thermostatic Expansion Valve. A control valve that measures and maintains a constant superheat in the evaporator. It responds to a combination of three forces: evaporator pressure, spring tension, and bulb pressure.

Ton of refrigeration

The number of BTUs required to melt a ton of ice in 24 hours: One ton of refrigeration equals 12,000 BTUs per hour.



Fluke VoltAlert 1AC and 1LAC

- Two versions: 1AC for 90-600V ac 1LAC for 24-90V ac
- Detects voltage without metallic contact
- Easy to use—tip glows red if voltage is in the line
- Fits in a shirt pocket for convenience
- 1 year warranty
- UL, CSA, CE, TÜV listed



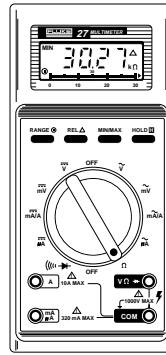
Fluke 12B

- Volts, ohms, capacitance and diode test modes
- MIN/MAX recording with relative time stamp
- Fast continuity testing
- Millivolt range for compatibility with temperature and other accessories
- Autoranging
- 2 year warranty
- Cat III 600V rating
- UL, CSA, CE, TÜV listed



Fluke 16

- Accurate temperature measurement with any K type thermocouple
- Microamps for flame sensor testing
- Volts, ohms, capacitance and diode test modes
- MIN/MAX recording with relative time stamp
- Fast continuity testing
- Millivolt range for compatibility with accessories
- Autoranging
- 3 year warranty
- Cat III 600V rating
- UL, CSA, CE, TÜV listed



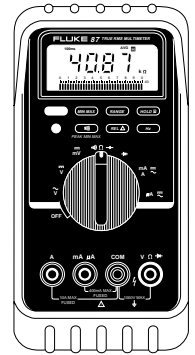
Fluke 27

- Ruggedized, waterproof case
- Microamps for flame sensor testing
- Volts, ohms, diode, continuity, mA, and 10A modes
- MIN/MAX recording
- Millivolt range for compatibility with temperature and other accessories
- Automatic Touch Hold*
- Analog/digital display
- Autoranging
- 3 year warranty
- UL, CSA, CE, VDE, MSHA listed



Fluke 79/26 Series III

- High accuracy true-rms to assure reliable readings
- New tapered slimline design fits great in your hand
- Permanent overmolded case for great durability
- Volts, ohms, diode, capacitance, frequency, mA, and 10A modes
- Millivolt range for compatibility with temperature and other accessories
- Automatic Touch Hold*
- Analog/digital display
- Autoranging
- Lifetime warranty
- CAT III 1000V rating
- UL, CSA, CE listed; TÜV pending
- * Fluke 26 also includes premium electrician test leads with detachable probes



Fluke 87 Series III

- The premier meter of the industry!
- New brighter backlit display with 20% larger digits
- High accuracy true-rms to assure reliable readings
- Microamps for flame sensor testing
- Volts, ohms, diode, continuity, frequency, mA, and 10A modes
- 250 μ S peak MIN/MAX mode to capture spikes
- MIN/MAX/Average recording
- Millivolt range for compatibility with temperature and other accessories
- Automatic Touch Hold*
- Analog/digital display
- Autoranging
- Lifetime warranty
- Cat III 1000V rating
- UL, CSA, CE, TÜV listed



Fluke T5-600 Electrical Tester

- Quickly measures volts ac and dc with precise resolution
- Displays continuity and resistance up to 1000 Ω
- Easy and accurate OpenJaw™ current measurement up to 100A ac (0.5" jaw opening)
- Compact design with neat probe storage
- Test leads feature detachable probe tips and accept other Fluke test clips
- Hold button to freeze display
- 2 year warranty
- Cat III 600V rating
- UL, CSA, CE listed; VDE pending



Fluke CO-220 Carbon Monoxide Meter/CO-210 Carbon Monoxide Probe

- Quickly and accurately measures carbon monoxide levels up to 1000 ppm
- CO-220 meter features a large backlit LCD display
- CO-210 accessory works with a multimeter with mV inputs (output: 1 mV per ppm)
- Both feature a beeper that ticks like a Geiger counter
- Automatic sensor zeroing and self-test sequence upon start-up
- Replaceable sensor (typical sensor life = 3 years)
- 1 year warranty
- CE listed



Fluke 30

- Rugged enough to take a fall from a tall ladder
- AC volts, current, ohms, and continuity beeper
- Jaws accept cables up to 1.5" in diameter
- Data hold button
- 1 year warranty
- Cat III 600V rating
- UL, CSA, CE, TÜV listed

Fluke 32

- Similar features to the Fluke 30 plus:
- True-rms to assure proper readings in environments with non-linear loads



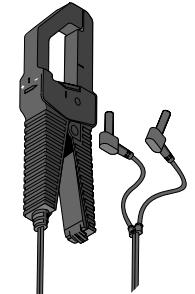
Fluke 36

- AC/DC true-rms clamp meter for reliable readings
- Rugged enough to take a fall from a tall ladder
- AC and dc volts, current, ohms, and continuity beeper
- Tapered jaws (1.2" diameter) allow access into tight spaces
- Max hold function captures peak in-rush current
- 1 year warranty
- Cat III 600V rating
- UL, CSA, CE, TÜV listed



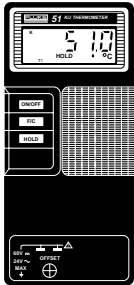
Fluke 80T-IR

- Fast, non-contact infrared temperature probe
- Works with most multimeters with mV inputs (1 mV per °F or °C output)
- 0°F to 500°F (-18°C to 260°C)
- Internal selection switch for °F or °C
- 1 year warranty



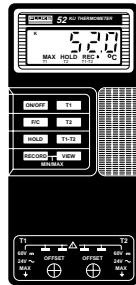
Fluke 80i-400

- Measures ac current from 1A to 400A
- Plugs into multimeter with a mA input (output: 1mA per amp)
- Accuracy: $\pm(3\% + 0.4A)$ from 48 Hz to 1000 Hz
- 1 year warranty
- CE listed



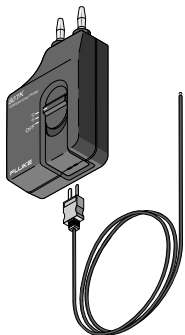
Fluke 51

- High accuracy handheld thermometer with single input
- Works with any K- or J-type thermocouple
- Calibration pots on the front allow for simple field calibration
- HOLD mode freezes reading on display
- Selectable readout in °F or °C
- Includes one 80PK-1 Bead Thermocouple
- 3 year warranty
- CE listed



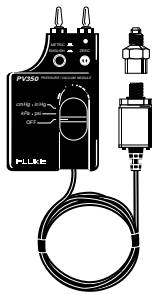
Fluke 52

- High accuracy handheld thermometer with dual inputs
- Works with any K- or J-type thermocouples
- Differential display mode [T1-T2].
- Min/Max recording of T1, T2, or [T1-T2]
- Calibration pots on the front allow for simple field calibration
- HOLD mode freezes reading on display
- Selectable readout in °F or °C
- Includes two 80PK-1 Bead Thermocouples
- 3 year warranty
- CE listed



Fluke 80TK

- Converts most multimeters into thermometers
- Selectable readout in °F or °C
- Accepts a wide variety of K-type thermocouple accessories
- Includes one 80PK-1 Bead Probe Thermocouple
- 1 year warranty



Fluke PV350

- Converts most multimeters into a high resolution digital gauge
- Measures pressure up to 500 psig (3477 kPa)
- Measures vacuum down to 29.9" Hg (76 cm Hg) (not intended for micron measurement)
- Displays readings in English (psig or "Hg) or metric (kPa or cm Hg)
- 1 year warranty

Temperature Probes (Type-K Thermocouples) all cables 4 feet (120 cm) long with stranded wire unless otherwise noted.

Model/Range	Style	Description
80PK-1 Air and General Purpose Probe -40°F to 500°F (-40°C to 260°C)		Low cost bead probe for general purpose temperature measurement (solid thermocouple wire). Teflon insulation. Not suitable for liquid immersion.
80PK-2A Immersion Probe -320°F to 1994°F (-196°C to 1090°C)		General purpose immersion probe for liquids or gels. Not for food use. Inconel sheath. Overall length 12.5 in (32.75 cm).
80PK-3A Surface Probe 32°F to 500°F (0°C to 260°C)		Surface probe designed for flat or slightly convex surfaces. Teflon support piece.
80PK-4A Air Probe -320°F to 1500°F (-196°C to 816°C)		Shrouded air probe for air or gases. 316 stainless steel baffle. Designed for insertion into ductwork through a typical balancing port.
80PK-5A Piercing Probe -320°F to 1500°F (-196°C to 816°C)		Piercing probe for use in soft or semi-hard materials. Suitable for food use. FDA approved 316 stainless steel for food handling. Overall length: 8.62 in (21.89 cm).
80PK-6A Exposed Junction Probe -320°F to 1500°F (-196°C to 816°C)		Exposed junction probe—a bead probe with a handle for safe high temperature measurement. Inconel sheath. Overall length: 12.55 in (31.87 cm).
80PK-7 High Temperature Surface Probe -197°F to 1112°F (127°C to 600°C)		Ruggedized, high-temperature surface probe made of 303 stainless steel with ribbon sensor. Shaft can be permanently bent to reach difficult contact points.
80PK-8 Pipe Clamp Thermocouple Probe -20°F to 300°F (-29°C to 149°C)		Pipe clamp temperature probe measures temperature on pipe surfaces from 1/4" to 1-3/8" diameter (6.4 mm to 34.9 mm). Rugged ribbon sensor.

Electrical Tester, Digital Multimeter and Clamp Meter Selection Guide

Models	Electrical Testers		Digital Multimeters						Clamp Meters		
	7-300 7-600	T5-600 T5-1000	12B	16	27	77	26/79	87	30	32	36
Display Counts	4000	1000	4000	4000	3200	3200	4000	4000/20,000	2000	2000	2000
Autoranging	•	•	•	•	•	•	•	•	Manual	Manual	Manual
Continuity Beeper	•	•	• Note 2	• Note 2	•	•	•	•	•	•	•
Automatic Touch-Hold®		Data Hold Note 3			•	•	•	•	Data Hold Note 3	Data Hold Note 3	Data Hold Note 3
Analog Bargraph					•	•	•	•			
Special Features											
Lifetime Warranty					•	•	•	•			
True-rms							•	•		•	•
Backlit Display								•			
Temperature			Note 1	•	Note 1	Note 1	Note 1	Note 1			
Min/Max			• Note 4	• Note 4	•			• Note 5			Max Hold
Min/Max Peak								•			Max Hold
Frequency							• Note 6	•			
Offset/Relative Ref.					•		• Note 7	•			
Sealed Case Water/Chemical Resistant		Note 8			•			Note 8			
DC Volts											
Max DC Voltage	300/600	600/1000	600	600	1000	1000	1000	1000			600
Best Resolution	1 mV	1V	1 mV	1 mV	0.1 mV	0.1 mV	0.01 mV	0.01 mV			0.1V
AC Volts											
Max AC Voltage	300/600	600/1000	600	600	1000	1000	1000	1000	600	600	600
Best Resolution	1 mV	1V	1 mV	1 mV	0.1 mV	1 mV	0.1 mV	0.01 mV	0.1V	0.1V	0.1V
AC Frequency Response	400 Hz	400 Hz	400 Hz	400 Hz	30 kHz	1 kHz	1 kHz	20 kHz	50/60 Hz	50/60 Hz	400 Hz
AC and DC Amps											
Fused 10A Range					•	•	•	•			
Max Amps w/o Probe Accessory		100A (AC only)		200 µA	10A	10A	10A	10A	400A (AC only)	600A (AC only)	600A AC 1000A DC
Best Resolution		0.1A		0.1 µA	0.1 µA	0.01 mA	0.001 mA	0.01 µA	0.1A	0.1A	0.1A
Other Electrical											
Max Resistance	400Ω	1000Ω	40 MΩ	40 MΩ	32 MΩ	32 MΩ	40 MΩ	40 MΩ	200Ω	200Ω	200Ω
Best Resolution	0.1Ω	1Ω	0.1Ω	0.1Ω	0.1Ω	0.1Ω	0.01Ω	0.01Ω	0.1Ω	0.1Ω	0.1Ω
Max Capacitance			10k µF	10k µF			10k µF	5 µF			
Diode Test			•	•	•	•	•	•			
Conductance					•			•			

Notes:

- Standard feature
- 1 Temperature capable with 80TK accessory
- 2 Also includes Continuity Capture Mode
- 3 Data Hold does not automatically update
- 4 Min/Max plus relative time stamp
- 5 Min/Max plus Average
- 6 Frequency of voltage only
- 7 Lo-Ohms zero calibration subtracts test lead resistance
- 8 Partially sealed, splash and dust proof



The ABCs of Digital Multimeter Safety Video Tape

Learn how proper work procedures and equipment can protect you from hazards. Part Number 609104 For sale at Fluke distributors, or call the appropriate phone number listed to the right on this page to order.

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