

# Fluke 561 HVACPro IR Thermometer Applications

## Application Note



Measuring chiller pump motor bearing and case temperature.

The 561 HVACPro is the first Fluke Infrared thermometer specifically designed with the HVACR technician in mind. It features higher optical performance, measurement accuracy, and professional quality for a market that is overloaded with entry level IR thermometers. It combines the best of contact and non-contact thermometry.

IR non-contact thermometry provides speed, convenience, accessibility and, sometimes, safety. Type-K thermocouple thermometry provides the accuracy needed for critical measurements of metallic objects, internal temperatures, and ambient temperature with the flexibility and precision provided by a choice of many probe styles available for the particular task at hand. It is the best of both worlds, but they are indeed different worlds and it is important to understand those differences.

In contact thermometry, the measuring device transfers heat to or from a contacted object until it is at the same level of molecular activity, or temperature. It is simple, sensible and intuitive.

All matter seeks temperature equilibrium. Heat is transferred by conduction, convection and radiation. Conduction is the transfer of heat by molecular contact. Convection is the transfer of heat by the mixing of a fluid (gas or liquid). Radiation is the transfer of heat by transmission through a medium or space, which is independent of conduction or convection. It is this invisible IR radiation that an IR thermometer is detecting and reporting as the surface temperature of the source of the radiation.

While all matter above absolute zero radiates/infrared energy three major factors determine how accurately we can measure this radiated heat: emissivity, reflectivity and transmissivity.

### Infrared (IR) radiation

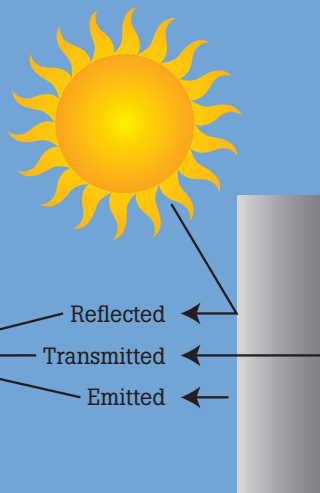
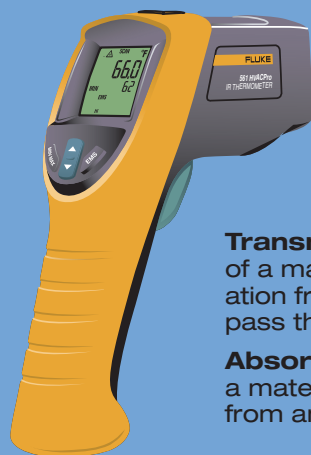
IR radiation is everywhere and continuous. The greater the difference in material temperatures, the more obvious IR radiation is. The vacuum of space transmits IR radiation emitted from the sun 93,000,000 miles to earth where we absorb and are warmed by that IR radiation as we stand in view of the sun. We are cooled

by the IR radiation we emit to the frozen foods as we walk down the freezer aisle at the grocery store. These are two obvious examples of the quality of IR radiation effects. We feel the change so we know it is occurring.

When we want to quantify the effects by measuring the IR radiation temperature, we break out our IR thermometer. Different materials exhibit different IR radiation qualities. Before we interpret the readings from an IR thermometer, we need to understand the basic principles of measuring IR radiation and the IR radiation characteristics of the particular material being measured.

**Emissivity** is the quality of a material that allows it to radiate its heat from its surface.

**Reflectivity** is the quality of a material that allows it to reflect radiated heat from another source.



**Transmissivity** is the quality of a material that allows radiation from another source to pass through it.

**Absorption** is the quality of a material to receive radiation from another source.

### IR radiation = absorption + reflection + transmission

Whatever IR radiation is emitted, will be absorbed. So absorption = emissivity. It is the IR radiation emitted from a surface that the IR thermometer reads. An IR thermometer cannot read IR radiation transmitted in the air (gas), so we can ignore transmissivity by most field work. This leaves us with a basic IR radiation measurement formula.

### IR radiation = emissivity - reflectivity

Reflectivity is inversely proportional to emissivity. The more an object reflects IR radiation, the less it emits. Reflectivity often can be relatively judged according to our visual determinations of reflectivity. New copper has a very high reflectivity and low emissivity (0.07-0.2). Copper that is oxidized has less reflectivity and more emissivity (0.6-0.7).

Copper blackened by very heavy oxidation has even less reflectivity with proportionately more emissivity (0.88). Most painted surfaces have very high emissivity (0.9-0.95) and negligible reflectivity.

The only setting on most IR thermometers is for the emissivity rating of a material, and in many cases, that will be preset at 0.95, which works quite well for organic and painted surfaces. An emissivity adjustment feature allows the thermometer to compensate for less IR radiation emitted by some material surfaces, particularly metals. Reflectivity is only an issue if there is a source of high temperature emission in the vicinity of a surface being measured that can reflect that nearby high temperature IR radiation.

The 561 HVACPro has three emissivity settings: High (0.95), medium (0.7), and low (0.4). There are three methods of determining the emissivity. One, use a chart that lists the emissivity of various materials, or two, apply a piece of black electrical tape to the surface being measured. Apply the tape to the surface, compare the measured IR temperature of the taped to the bare surface, adjust emissivity until the temperatures match or closely match. The third method is to plug a K-type contact probe into the 561 HVACPro to measure surface temperature while reading IR temperature, then adjust emissivity until the IR temperature display most closely matches the KTC temperature display.

### Examples:

- Polished Brass: 0.03
- Oxidized Brass: 0.61
- Roughly Polished Copper: 0.07
- Black Oxidized Copper: 0.78
- Black Lacquer Paint: 0.96
- Commercial Sheet Aluminum: 0.09
- Oxidized Lead: 0.43
- Rusted Iron: 0.78
- Organic/painted materials 0.95

### IR or contact thermometry: the choices

Use the IR temperature function when speed, convenience, accessibility, safety, trending, surface temperature or temperature comparisons are the key consideration.

Use the contact thermocouple function when internal temperature, ambient temperature or the accuracy of critical temperatures of metallic objects are prime. Use both together when a temperature differential between a surface (IR) and the air (KTC) is key, or when adjusting the IR emissivity setting.

## The IR advantage

Speed, convenience and accessibility top the list for IR vs. contact thermometry. The 561 HVACPro takes less than 500 milliseconds to display an IR temperature. With contact thermometry, the probe must be in good thermal contact with a cleaned surface, and time allowed for the probe to sink heat and reach equilibrium with the surface. This can take minutes, and the surface must be accessible and safe to measure. Many IR temperature readings can be made in less time than it takes to prepare a surface, attach a probe, and wait for temperature equilibrium.

Many of the temperatures sought in the HVAC/R trades are more qualitative than quantitative ("qualitative" meaning

relative/comparative temperatures and "quantitative" meaning specific, accurate temperatures). And, on most surfaces, the IR temperature is highly accurate and will be your primary choice except on critical temperatures such as superheat and subcooling, or for air temperatures which a IR thermometer cannot read directly.

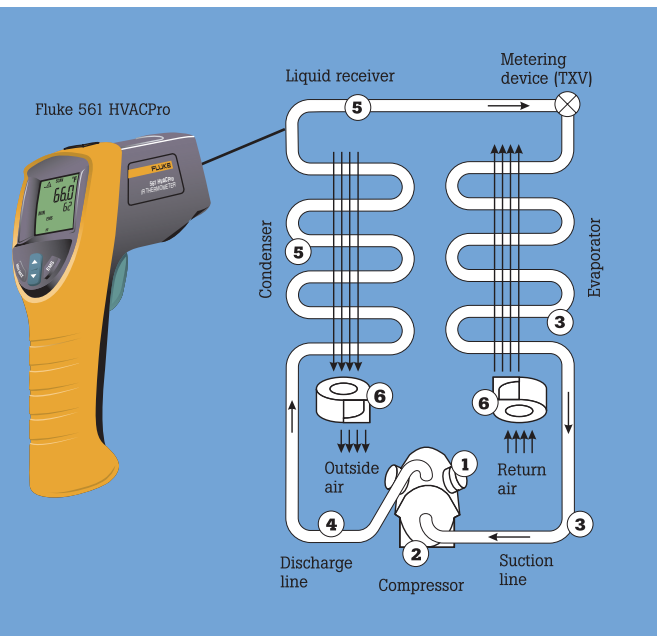
While scanning without the thermocouple connected, the 561 HVACPro can record maximum, minimum, and differential temperatures. One at a time, these temperatures can be read in the secondary display. During or after the scan, the rocker button can be used to scroll between these values. Releasing and pulling the trigger will begin recording new values to store.

- IR thermometers are invaluable for walk-through assessments of building surfaces from indoors or outdoors. Providing accessibility through heights and distances, an IR thermometer can scan building envelope surfaces for temperatures that could indicate points of infiltration or insulation deficiencies. Scan along baseboards and around windows and doors for building envelope integrity.
- Discharge temperatures of grills, diffusers and registers can be quickly determined from a comfortable stance in a convenient location. The IR thermometer does not directly measure the temperature of the air but of a nearby surface that has equilibrated to the air stream. Effects of register throw and evidence of stagnant zones can be determined by scanning ceiling and wall surfaces.
- Scanning ductwork for air leaks or quality of insulation is quick work. Duct insulation surface temperature should never be less than 5 °F (-15 °C) above the highest ambient dew point temperature to prevent sweating. Relative humidity at the duct insulation surface should remain below 60 % RH to prevent mold growth. These same rules apply for scanning basement or crawlspace surfaces. The Fluke 971 Humidity meter is a perfect companion for the 561 HVACPro when checking for conditions that can support mold growth. The 971 displays air temperature, wet bulb temperature, dew point temperature, and relative humidity.



Measuring temperature of fuses and electrical connections.





To troubleshoot compressor discharge line temperature use an IR thermometer to survey temperatures at the compressor head, compressor oil sump, evaporator coil and suction line, discharge line, condensor coil and liquid line, and fan motor.

- IR thermometers are perfect for routine trending of equipment operating temperatures. Scan compressor discharge and suction line temperatures, compressor head and sump temperatures, capacity control operation.
- Compare motor or blower bearings for equivalent operating temperatures. Scan sheaves from the hub to the circumference for even temperature. Elevated sheave temperature at the circumference points to slipping belts. (Don't try this with a contact thermometer probe.)
- Scan evaporator or condenser hairpins and U-bends, distributor tubes, or driers for restrictions.
- Scan reversing valve pilot tubes for proper discharge or suction gas flow.
- Scan steam pipes and traps for proper operation, or indicators that will lead to the source of problems.
- Scan for temperature differential between hydronic supply and return loops and temperature rise across boiler supply and return lines.
- Scan to locate radiant heat loops.
- Scan energy recovery wheels for effectiveness.
- Scan for discharge temperatures of unit heaters mounted high above a warehouse floor.
- Scan a room thermostat case to compare to temperature displayed by the thermostat.

IR thermometers allow you to safely check temperatures in locations such as live electrical circuits that would be difficult or dangerous to access with a contact thermometer. Loose or poor quality electrical connections are sure to fail, sometimes catastrophically. Poor electrical connections have increased resistance, which results in increased temperature. Elevated temperatures will direct the mechanic to

a closer mechanical inspection of the device. Relays and contactors have full load operating temperature rise specifications that can assist in the determination whether or not they are operating within parameters.

- Scan contactors or starters for elevated temperatures between fixed and movable contacts, and at the lug connections. Look for temperature differentials between poles. Each pole should have equivalent temperatures under equivalent load. If one pole has elevated temperatures compared to the other poles, that indicates a problem.
- Scan relay connections and relay case for elevated temperatures.
- Scan disconnects, buss connections and fuses for elevated temperatures. Look for equivalent temperatures between poles. Remember that the emissivity for the paper covering of a fuse is higher than the emissivity of a clean bare conductor.
- Scan wire nut or bug connections for elevated temperature.
- Scan along the length of conductor insulation for consistent temperature.

Remember to always follow electrical safety procedures. The higher the voltage, the quicker it can find an alternate path to ground. Don't let that path be you.



Taking a contact temperature measurement at the compressor outlet on the liquid line.

## Contact thermometry

There are times when there is no substitute for contact thermometry. Critical temperatures such as superheat and subcooling require good contact thermometry to obtain the required accuracy and precision. Suction line superheat of systems using a fixed restrictor metering device is a critical temperature.

Forty years ago, expected liquid line subcooling may have been 20 °F (-6 °C) or even more for some equipment. Today, especially with the new 13 SEER minimum efficiency requirement of all single phase comfort cooling air conditioners and heat pumps 5 tons or less, liquid line subcooling of thermal expansion valve equipment is a critical temperature. 10 °F (-12 °C) of subcooling for modern TXV equipped systems is no longer necessarily a valid target. High efficient equipment frequently

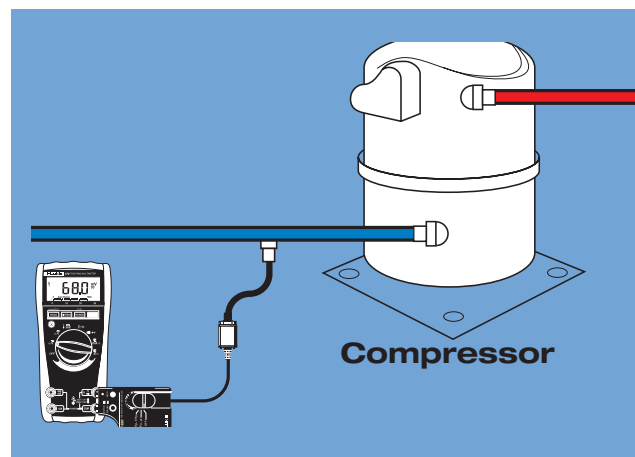
requires subcooling values less than 10 °F. Subcooling values are sometimes listed with tenths of a degree target value. Some smaller capacity equipment is even listed with subcooling values as low as 3 °F (-16 °C). So now, even subcooling is a critical value.

An IR thermometer cannot measure air temperature directly, so contact thermometry is required for this purpose. Air temperature rise across a furnace still requires a probe to be inserted into the ductwork. Accurate conditioned space or outdoor air temperatures need to be taken by the thermocouple probe. Low mass boilers should have the temperature rise taken by contact thermocouples for accuracy.

When IR temperatures are not what is expected, use a thermocouple probe to verify accuracy. HVAC/R technicians rarely rely on a single test, or reading, to

condemn a process. They use all of the techniques in their bag of tricks to validate their diagnosis. With two temperature technologies in one tool, with simultaneous display, the technological bag of tricks just expanded. The 561 HVACPro comes equipped with a type-K thermocouple, complete with a Velcro strap for fastening to pipe surfaces. Any of the other type-K thermocouples with a standard mini-connector you may already have can also be used. While bead thermocouples are versatile and very portable, they are not necessarily the best choice for all purposes.

The Fluke 80PK-8 pipe clamp thermocouple is a perfect and fast solution for any temperature measurement from tubing and pipes; Subcooling, superheat, hydronics, service water supply. The 80PK-26 general purpose probe with its 8 inch insertion length and low mass casing tip is well suited for speedy air temperatures and surface contact measurements. For both air, surface and liquid immersion, the 8 inch probe length with pointed tip of the 80PK-25 is likely to become one of your essentials.



Use a multimeter and a pressure module to quickly and accurately determine suction pressure.

There is one contradictory requirement of the two temperature measurement requirements of the 561 HVACPro. Oxidized copper will result in more accurate IR temperature readings, but contact thermometry requires that the copper be clean since oxidation acts as an insulator and will retard the transfer of heat by conduction.

- Superheat is a critical measurement that must be taken on equipment utilizing a fixed restrictor metering device. Without specific instructions from the equipment manufacturer, measure superheat 6 inches from the compressor suction stub. Superheat equals suction line temperature minus evaporator temperature. While a TXV continuously adjusts refrigerant flow to maintain a predetermined amount of superheat at the evaporator outlet, a fixed restrictor system's superheat is dependent on several variables that can be broken down into two: heat applied to the evaporator and condensing temperature. Most superheat tables specify 400 cfm of air per ton of capacity as a baseline for continuing. Given the proper airflow across a clean evaporator and condenser, the superheat is determined by the wet bulb temperature of the return air and the outdoor ambient temperature at the condensing unit (air temperature in the shade to avoid the effects of radiant heat from the sun).



A quick infrared survey can check for leaks and uneven temperatures in both the heater and pipes.

Since this superheat is a critical temperature, no “rules of thumb” should be used in its place. If the equipment manufacturer’s superheat chart or slide rule is not available, use one supplied by another manufacturer. Remember that a good technician will not bless or condemn a process based on a single test.

Checking superheat is the last step. First check cleanliness of coils, filters, blowers, air flow, electrical, etc. and know that the system is ready for the final fine tuning that superheat assures. Superheat is the amount of sensible heat added to the refrigerant after all of the refrigerant

in the evaporator is “boiled” to a vapor. Adding refrigerant will reduce the amount of superheat. Recovering refrigerant will increase the amount of superheat. Low suction pressures do not necessarily mean low charge. Check for evaporator and filter cleanliness, proper air flow, and suction line temperature before adding refrigerant.

- Subcooling should be measured with a contact thermometer probe. The new NAECA 13 SEER minimum requirement that became effective in January 2006 for single phase equipment 5 tons or less may introduce you to subcooling values lower than you are





A quick scan can pick up substantial differences in temperature values that could indicate an insulation leak. Don't rely on the exact temperature readings, however, without first adjusting for the emissivity and reflectivity of the insulation material.

accustomed to seeing. Expect to see more match-ups that require thermal expansion valve metering, high efficiency condenser and evaporator motors, and even larger heat transfer coils. Since thermal expansion valves control superheat, liquid line subcooling is the method for fine-tuning the refrigerant charge. Proper air flows, cleanliness of coils and filters, mechanical integrity and electrical should be confirmed correct before adjusting charge to subcooling values.

Subcooling measures how much the refrigerant has been cooled below its condensing temperature. In order to cool the refrigerant below its condensing temperature, the refrigerant must be exposed to the condensing medium long enough for its temperature to be reduced sufficiently. In an air-cooled condenser, the refrigerant backs up into the condenser for the air to cool it below its condensing temperature. Too much refrigerant backed up into the condenser results in an overcharge indicated by too much

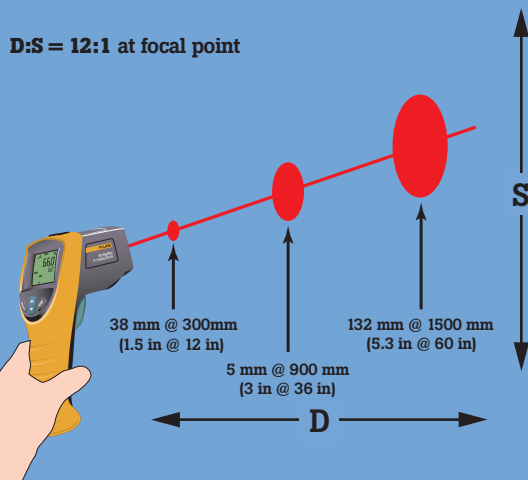
subcooling. Too little refrigerant results in an undercharge and insufficient subcooling. Subcooling equals condensing temperature minus liquid line temperature. Some manufacturers may substitute "approach" temperature values for subcooling temperature values. While subcooling compares liquid line temperature to condensing temperature, the approach temperature compares liquid line temperature to outdoor ambient air temperature. The manufacturer has calculated what the approach temperature should be to achieve the desired subcooling. This allows a technician to check the charge without attaching gauges. If the approach temperature is OK and all of the other checks confirm proper operation, then there is no need to attach gauges.

## Conclusion

Higher optical performance, measurement accuracy, and professional quality are reason enough to choose the 561 HVACPro. Add to this single hand operation, laser sighting, MIN/MAX/DIF temperature, high-medium-low emissivity adjustment, bead thermocouple with Velcro fastener included and you have a highly accurate and versatile tool. Equipped with the standard miniconnector jack for type-K thermocouples, there are many general purpose and specialty probes that can be used in place of the provided Velcro pipe probe thermocouple. Additionally, the companion user guide that comes with the thermometer has extensive step-by-step procedures for most of the applications outlined in this article.

## IR thermometer specifications

IR thermometer models are designed with variable characteristics depending on the application design. Variables in model design include distance to spot ratio, field of view, focus and focal distance, wavelength of emitted IR radiation, and environmental operating conditions.



When measuring smaller objects, use the Fluke 561 within 6 ft (1.75 m) of the intended target. The measured area increases with distance (the distance divided by 12, approximately).

### Distance to Spot Ratio

**(D:S)** is a handy way to approximate the size of the measurement spot on the target relative to the distance the thermometer is from the target. A D:S of 12:1 would result in a three inch spot at a target distance of 36 inches or a slightly larger than one foot spot at a target distance of 12 feet. At a given distance, the larger the D:S ratio, the smaller the spot. An IR thermometer with a 90:1 ratio would have about a 1-1/16 inch measuring spot at an eight ft distance to target,

while a thermometer with a 12:1 ratio would have about an 8 inch measuring spot at an 8 ft distance to target. The laser spot is for targeting purposes only and is unrelated to the IR measuring spot size.

**Field of View** refers to the spot size in relationship to the surface being measured. The spot size should be contained within the perimeter of the target surface, centered on the area of interest. Ideally, the surface being measured should be at least twice the diameter of the spot size for greatest accuracy.

**Focus** is preset in most IR thermometers at infinity.

**Minimum Focal Distance** is the distance from target that results in the smallest spot size. With the 561 HVACPro, the minimum focal distance is 36 inches. As thermometer distance to the target is either increased or decreased, the measuring spot size will increase.

### Environmental Conditions

are factors that affect the operation of the IR thermometer. The ambient operating range (temperature of the 561) should be between 32 °F to 120 °F within a relative humidity between 0 % to 90 % RH as long as moisture from the air does not condense onto or into the thermometer. Accuracy is compromised outside of these conditions. A thermometer stored overnight in a 30 °F van and then brought into a 70 °F, 25 % RH (32 °F DPT) environment will cause moisture from the air to condense on the cold surfaces of the thermometer. The thermometer storage temperature range is from -4 °F to 150 °F. An adjustment period

is required for sudden changes of 10 °F or more degrees for the thermometer to be accurate under the new conditions.

Particulates in the air (e.g., steam, dust, smoke) between the thermometer and the target will distort the readings.

Some of the other basic specifications report ranges, accuracy and response time. The Fluke 561 IR thermometer temperature measuring range is from -40 °F to 1022 °F at an IR wavelength of 8 to 14 microns with a response time of less than 500 milli-seconds. The K-type thermocouple included with the Fluke 561 has a range is from -32 °F to 212 °F. Also within are other specifications and features that make this an especially attractive thermometer such as the ability to record in real time maximum, minimum and relative IR temperatures. Or a single handed operation for point and shoot measurements with the index finger, guided by a laser beam site, while simultaneously scrolling through temperature variables with the thumb on a rocker button.

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