Causes of Misdiagnoses - Refrigerant Pipe Clamp Temperature Sensor Errors

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ABSTRACT

Accurately measuring the refrigerant temperatures in an air conditioning system is of great importance in system diagnostics. Having inconsistent or incorrect temperature readings in the liquid and suction lines of an air conditioning system can lead to misdiagnosis and lower operating efficiencies. Building energy codes like California Title 24 specify that refrigerant line temperature measuring devices meet certain instrumentation specifications. These specifications apply to the accuracy of the measurement and may also specify a maximum response time for the device to produce readings within the specified accuracy. This paper summarizes both accuracy and response time of various commercially available pipe clamp thermocouples, Type K thermocouples and thermistors. Tests on various refrigerant lines of a package air conditioner and on a refrigerant line test apparatus at the laboratory were conducted to measure the accuracies and response times of these devices. Accuracy tests conducted on a package unit air conditioner show that temperature differentials of around 100°F between the refrigerant line and ambient produce errors in line temperature measurements in excess of 3.5°F compared to the actual temperature of the refrigerant line. Response time tests illustrate that a temperature differential of 40 °F produced thermistor response times of 1.5 to 12 minutes to reach within 1.3°F of the actual refrigerant line temperature. Pipe clamp thermocouple response times were between 1-4 minutes depending on the model.

This paper recommends that changes be made in the most common refrigerant line temperature sensing devices to alleviate these problems.

INTRODUCTION

Refrigerant charge diagnosis in air conditioning units is often accomplished by measuring the system superheat or subcooling once the system has achieved steady state. The system superheat is the difference between the evaporator saturation temperature and the temperature of the refrigerant vapor returned to near the compressor. The evaporator saturation temperature is generally established by the suction line pressure and the returning vapor temperature is determined by measuring the surface temperature of the suction line. The subcooling similarly is the difference between the condenser saturation temperature (established by the liquid line pressure) and the liquid refrigerant temperature exiting the condenser as measured on the surface of the liquid line (Carrier, 1994). Having inconsistent or incorrect temperature readings in the liquid and suction lines leads to misdiagnosis, improper adjustments, and lower operating efficiencies. Misdiagnosis can also lead to premature compressor failure. It has been observed in inspections of technicians' work that systems theoretically operating with proper charge where, in fact, often undercharged or overcharged. This phenomenon is observed even with technicians who are properly schooled in measuring superheat and subcooling and regularly report both the targets and actual for these measurements. Clearly there are multiple reasons for these discrepancies including, but not limited to: erroneous measurement of system pressures, erroneous measurement of system temperatures, improper procedures, and falsified reports. This study addresses one of these – erroneous measurement of system temperatures. Digital refrigerant manifolds are becoming more readily available and are used to reduce errors in pressure readings.

When operating, the system produces temperatures above and below the ambient temperature. Depending on the location of the measurement sites with respect to fans, one can also have large volumes of air moving across the line temperature sensors which can influence line temperature measurements. Limiting the influence of ambient temperature on the line temperature sensor is very important in measuring the correct refrigerant line temperature.

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When measuring the temperature of the refrigerant lines, the air conditioning unit must be in steady state. During the transients line temperatures fluctuate. Only when this fluctuation is minimal should line temperature measurements be taken. The same can be said when attaching a line temperature sensor to a refrigerant line. One must wait until the sensor signal has reached steady state in order to correctly measure the refrigerant line temperature. Line temperature sensor manufacturers commonly state response times of the various sensors they produce, however, these specifications are generally ideal and don't necessarily reflect the real conditions of air conditioner refrigerant lines operating in the field.

California building energy code, Title 24, specifies accuracies and response times of temperature measuring devices on air conditioners. The accuracy and response time of these temperature measuring devices needed to be tested in real world conditions to understand what is really being measured in the field and not just the laboratory.

RESPONSE TIME TESTING

Various response time tests were conducted on 9 different commercially available pipe clamp temperature sensors. All of the thermocouple sensors were new and were calibrated to manufacturer's specifications. Thermistors were used with their integrated measurement display and were not calibratible. The pipe clamp temperature sensors among the most available on the market. During these tests, response time was recorded as the time it took for the measurement to reach within 1.3°F of the actual refrigerant line temperature. 1.3°F is the required accuracy of calibrated temperature measuring devices to meet California's Title 24. The response time specification for the energy code is within 1.3°F within 15 seconds from being applied to the refrigerant line at least 40°F different from the ambient temperature surrounding the refrigerant line and the sensor prior to application.

A laboratory test apparatus was built consisting of two test chambers with a refrigerant line running through both. The lower chamber consisted of an ice bath where the refrigerant line was cooled. The upper chamber was heated to 100°F and various pipe clamp temperature sensors were installed after the apparatus had reached steady state. The refrigerant line had a pressure gauge indicating actual refrigerant temperature in the line. Temperature readings were manually recorded every 2 minutes after sensor installation. A total of 5 different commercially available pipe clamp temperature sensors were tested at once. A summary of the testing can be seen in Figure 1.

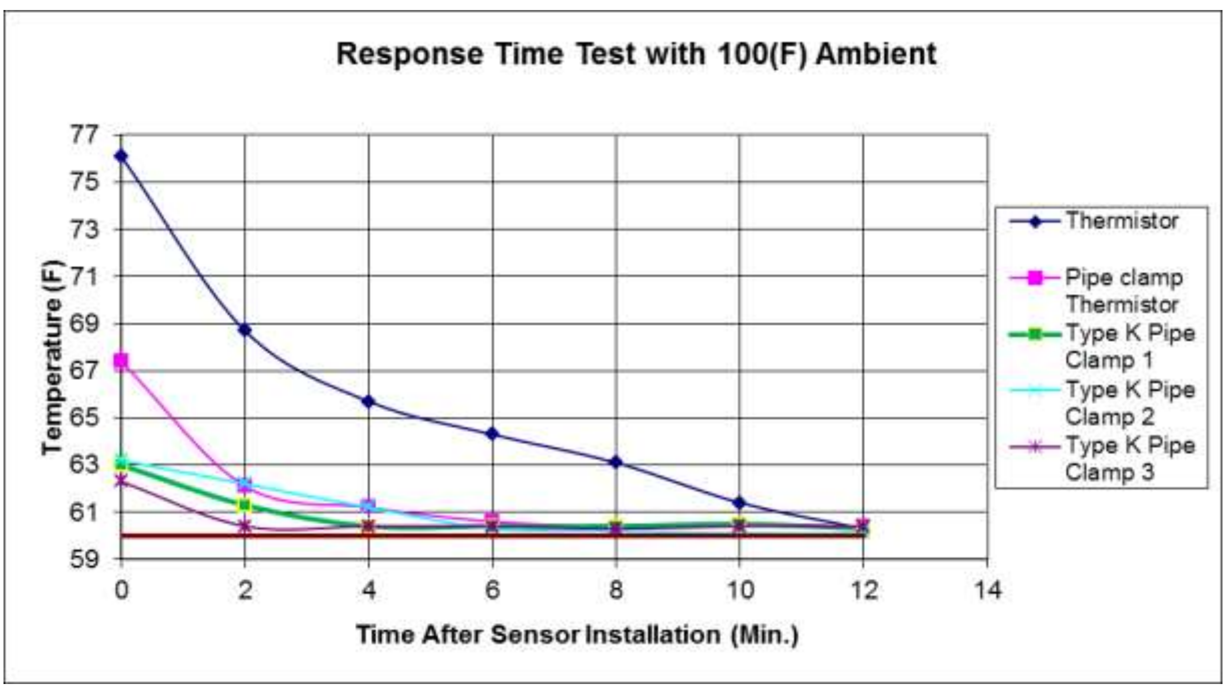

Figure 1 The response time of the tested refrigerant line temperature sensors in still air was as long as 12 minutes.

Figure 1 illustrates the response time of each sensor to reach the refrigerant line temperature in an ambient temperature of 100°F. The cylindrical thermistor wrapped in closed cell pipe insulation took 12 minutes to achieve within 1.3°F of the refrigerant temperature. The pipe clamp thermistor (using a smaller cylinder) and type K pipe clamp thermocouple #2 were within 1.3°F of the refrigerant temperature in 4 minutes. The type K thermocouple pipe clamps #1 and #3 were within 1.3°F of the refrigerant temperature in 2 minutes.

Response time tests were repeated using automated data collection. The same apparatus was used as in the manual data collection. The upper chamber was heated to 100°F and pipe clamp temperature sensors were attached to the refrigerant line after the apparatus had reached steady state. The actual refrigerant temperature was 60°F. The results are displayed in Table 1.

Table 1. Response Time of Refrigerant Temperature Sensors

Temperature Sensor	Time to Reach 1.3°F (Sec)
Pipe Clamp Thermistor A	90
Pipe Clamp Thermistor B	120
Type K Pipe Clamp Thermocouple 1	87
Type K Pipe Clamp Thermocouple 2	48

In the testing conducted, thermistors produced longer response times greater than the tested thermocouples. Response times of refrigerant line temperature sensors varied by model and manufacturer.

Accuracy Testing

Accuracy tests were conducted on the refrigerant lines of a split AC and a package AC serving a large single family house. Multiple types of temperature sensors were attached and data simultaneously recorded with data loggers. To produce large temperature differences between the refrigerant line and ambient temperature, as well as to test the effect of ambient air movement, the hot gas discharge line was selected for many of the tests.

Figure 2 illustrates one of the tests on the package AC. Temperature measurements were logged over 30 minutes with an ambient temperature of 60°F. Figure 2 also illustrates that it takes the air conditioner about 15 minutes to reach steady state. In all of the accuracy testing, an insulated type k thermocouple was attached to the line with aluminum foil tape and then covered in closed cell pipe insulation. The temperature measurement this sensor produced was the reference refrigerant line temperature. Figure 2 shows that both pipe clamp thermocouples tested produced readings 8 to12°F lower than the reference refrigerant line temperature.

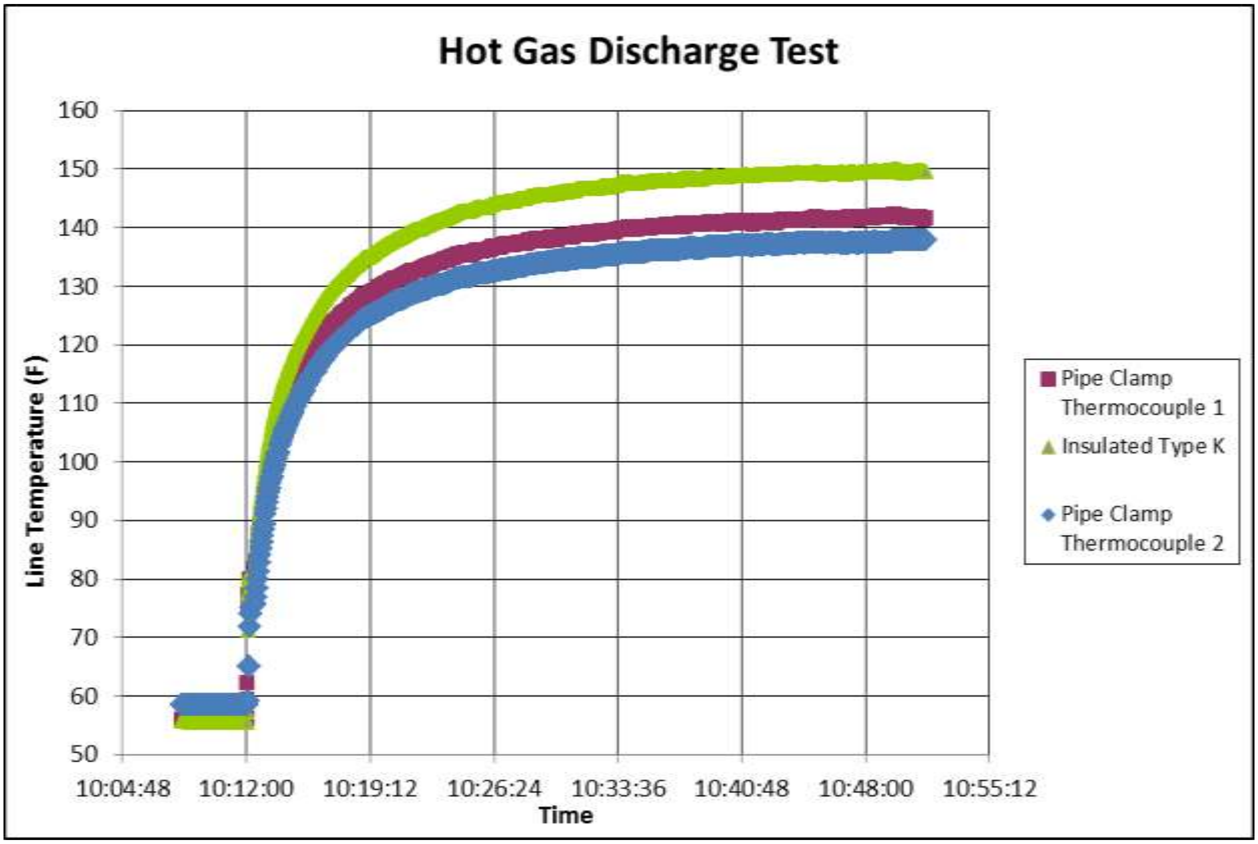

Figure 2 Pipe clamp thermocouples #1 and #2 produced errors of 8 and 12ºF when tested in moving air.

Accuracy tests were performed using moving air and an 80ºF temperature differential between the hot gas and ambient air. All data was collected through data loggers and is displayed in Table 2.

Table 2. Accuracy of Refrigerant Temperature Sensors

Temperature Sensor	Temperature Below Reference (ºF)
Pipe Clamp Thermistor A	3.5
Pipe Clamp Thermistor B	11
Bare Type K with Cork Tape Insulation	4
Uninsulated Type K Thermocouple	40
Type K Thermocouple Pipe Clamp 3	24
Type K Thermocouple Pipe Clamp 4	60

Cork insulation wrapped around a bare Type K thermocouple is one common method of testing refrigerant lines. The test in Table 2 shows that this is not an effective way of measuring the correct refrigerant line temperature. Compared to a bare Type K thermocouple affixed to the refrigerant line with aluminum tape and insulated with closed cell insulation, all the tested methods were inaccurate. One pipe clamp thermocouple showed an error of 60°F. The manufacturer of this pipe clamp thermocouple has discontinued this model.

The results from the tests in Figure 1 show that all the tested sensors would achieve readings within 1.3ºF of the reference if they remained in place for a long time in still air. Tests by Robert Davis (2007) found that even insulated thermocouples (three tested) would not reach within 1.3ºF of the reference temperature when the temperature differential was 56ºF with respect to ambient. It is not known how still the air was for Davis's tests. Tests by Mowris, Eshom and Jones (2013) showed a variety of temperature measurement errors between 1.1ºF for certain Type K clamp sensors to 9.7ºF for a certain insulated cylindrical thermistor. The temperature differential for these tests was approximately 40ºF and there was air movement within the test chamber.

CONCLUSION

Commercially available refrigerant line temperature sensors show significant errors in accuracy and longer than desired response times. From response time testing, it is recommended that pipe clamp thermistors and thermocouples be left in place on the refrigerant line for at least 4 minutes before temperature measurements are taken.

Accuracy testing has shown that all the pipe clamp temperature sensors tested are influenced by ambient temperature and the movement of ambient air in the vicinity of the sensor. The measured inaccuracies ranged from about 4°F to 60°F. Testing has shown that cork insulation is not effective in measuring refrigerant line temperature with type K thermocouples. Individual pipe clamp temperature sensor accuracy varies by manufacturer and model. The best tested results were achieved by a bare wire thermocouple wrapped in aluminum foil with closed cell pipe insulation wrapped around it and the pipe.

The authors recommend that refrigerant line temperature sensors be redesigned to reduce errors associated with ambient air temperature and air movement to a level of insignificance. Having refrigerant line temperature sensors reading the correct temperature is extremely important in air conditioner diagnostics.

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