MAXIMUM HEAT LOAD TEMPERATURE TESTING

(“Differential Temperature Testing”)

The Concept

“Maximum Heat Load Temperature Testing” is a powerful air-conditioning diagnostic and evaluation technique. It is also sometimes called “Differential Temperature Testing.” During the test, the A/C system is placed under maximum stress (heat load) and a series of temperature measurements are taken at specific points in the system. By testing the system under stress, any underlying weakness in the system is much more likely to be revealed. The results of the temperature measurements are compared to expected values. If any of the results are out of range, three easy-to-follow diagnostic flow charts provide clear diagnostic direction as to the most likely cause of the problem.

Temperature testing allows us to evaluate the performance of each individual component in the system and check if it is operating at peak efficiency - to see, for example, if the condenser and evaporator are maximizing heat exchange.

The Maximum Heat Load Temperature Test Is Performed Outside, In Direct Sunlight with Doors & Windows Open

Temperature testing has several advantages over traditional OE system performance testing:

- The system is tested under maximum stress – at idle with the doors open. This setup creates the greatest demand on the entire system. An underlying weakness is much more likely to be exposed.
- Unlike performance testing, temperature testing uses the same basic vehicle setup and test parameters for all vehicles.
- Three simple diagnostic flow charts provide specific direction on the most likely cause of the problem.
- You can return the vehicle to the customer with confidence that the entire system is operating efficiently and will be unlikely to suffer a premature compressor failure or comeback.
- You can use the test both as a diagnostic tool to determine the root cause of a system problem, or to confirm that the system is truly fixed and operating at peak efficiency.

To get the most use out of temperature testing, it is helpful to understand the basic physics of refrigeration - particularly the concepts of “latent heat of evaporation” and superheating and “latent heat of condensation” and sub-cooling. However, it is not necessary to understand all these concepts to use the technique effectively. To use temperature testing, all you need to do is take the temperature measurements and refer to the appropriate diagnostic flow chart A, B or C on pages 10-12. The flow charts will provide good diagnostic direction on the most likely cause of the problem.

On a CCOT system with a fixed displacement compressor, a maximum heat load temperature test can help you determine the following conditions:

1. That the A/C system is operating at maximum efficiency and if it is not, then what is the most likely cause of the underlying problem.
2. That the system is charged with the right amount of refrigerant.

On a TXV system or a system that uses a variable displacement compressor, the heat load test can provide the following information:

1. That the A/C system is operating at maximum efficiency and if it is not what is the most likely cause of the lack of performance.
2. It can provide some indication of a possible system undercharge or overcharge but not with the same accuracy as on a CCOT system. TXV and variable displacement compressor systems have a feedback component. These systems will try to compensate for an under or overcharge by adjusting the refrigerant flow rate in the system and mask the under or overcharge condition. However, if the system is known to be correctly charged, the temperature test results will expose an underlying weakness in the system and the diagnostic flow charts will point to the most likely underlying cause of the problem.

We have developed a set of temperature testing parameters that are the same for just about any automotive A/C system that you would work on. There are only a few minor variations to take account of basic system design differences (i.e. whether it is a Cycling Clutch Orifice Tube (CCOT), Thermal Expansion Valve (TXV) or a single or a dual evaporator system".

Following is the temperature testing procedure for a single evaporator CCOT system. Later we will explain the methods for testing TXV and dual evaporator systems.

Maximum Heat Load Temperature Test – CCOT Single Evaporator System

This test is designed to place the AC system under a maximum heat load condition. By monitoring the system temperatures and pressures under the parameters listed below, you will be able to identify marginal or failed system components, and the efficiency of the heat exchange process.

- Bring the engine up to full working temperature with the A/C on.
- The test requires a heat load on the system. Place the vehicle outside in direct sunlight. Ideally the ambient temperature should be 79°F or higher. (Later, we will describe methods of generating heat load during low temperature conditions).
- Set the AC controls to max cold and recirculating air.
- Open all doors and windows.
- Set blower speed to high position.
- Allow System to stabilize (operate at idle for at least five minutes).

Now take the temperature readings in each of the three tests below. When you have recorded all your temperature readings find the temperature difference between the two readings taken in each of the tests. You will end up with a single temperature number for each test. We call them the three "D"s or "differences."

1. **Condenser Sub-cooling Test.** Measure and record the temperatures of the condenser inlet and outlet lines as close to the condenser as possible.
2. **Ambient to Duct Air Test.** Measure and record the air temperatures at the center AC duct and the ambient air about one foot in front of the condenser.
3. **Evaporator Superheat Test.** Measure and record the temperature of the evaporator inlet and outlet lines on CCOT / FFOT systems.

Note: Refer to the temperature testing worksheets on pages 18 and 19. Make copies of these worksheets and use them to record the temperature readings for the system you are working on.

Following Are Testing Specifications for an efficiently operating CCOT A/C system:

1. **Condenser Sub-cooling Test.** The difference between the condenser inlet and outlet line should be between 20°F and 50°F.
2. **Ambient to Duct Air Test.** Duct air temperature should be at least 30°F lower than ambient air temperature measured about a foot in front of the condenser.
3. **Evaporator Superheat Test**. Ideally there should be no temperature difference between the evaporator inlet and outlet. 0°F difference is ideal, however, a temperature increase or decrease of up to 5°F across the evaporator is acceptable. On a CCOT system, an evaporator superheat reading within this specification is confirmation that the system is correctly charged.

Now take the numbers recorded in each of the three tests and refer to the appropriate temperature diagnostic chart “A” “B” or “C” on pages 10-12. Use these diagnostic flow charts to confirm that the system is operating efficiently or to help you determine the likely cause of any problems in the system.

Note: The duct temperature reading that you get during the maximum heat load temperature test is likely to be quite a bit higher than you would get during a system performance test or during normal A/C operation. Remember you are performing the test with the doors open, outside on a warm day! The important number is the ***difference*** between ambient temperature and duct temperature. For example, if the ambient temperature is 95°F and the center duct temperature is 60°F, then the ambient to duct air difference is 35°F. This is acceptable. The difference is 5°F greater that the minimum specification of 30°F. Because the system can create at least a 30°F difference between ambient and duct temperature, we know that it has more than enough capacity to reduce the cabin temperature to an acceptable level when the doors are closed.

Important Notes about Taking the Temperature Readings

- **Temperature Testing Tools:**
  For your diagnostic results to be reliable, it is extremely important that the temperature readings are accurate. You will need a good contact type pyrometer or dedicated temperature-testing tool, similar to the ones shown here.

DMM with Fluke Temperature Probe Adapter

CPS Temp Seeker – Dedicated Temperature and Humidity Testing Tool

Taking the Temperature Readings:

- When taking the evaporator and condenser inlet and outlet line readings, be sure to make firm, direct metal contact with the line being measured. If you use a Fluke style adapter like the one shown above, hold the probe as perpendicular to the line as possible and keep firm pressure on it. Paint, dirt, or corrosion on the line can throw the temperature reading off by as much as 30° F.

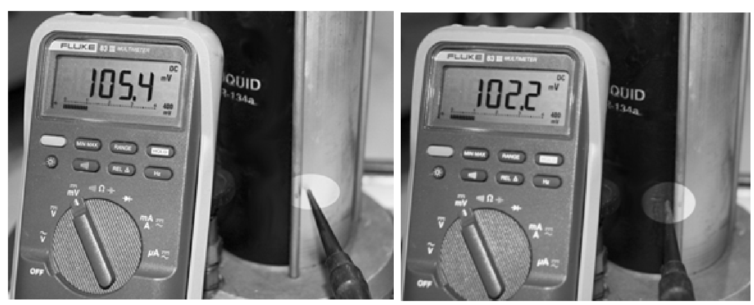
Therefore, you should scrape the line down to the bare metal at the point where you are talking the temperature reading.

- Use a probe with a narrow tip. You may not make good contact with the line if the temperature probe tip is too big. Some vehicles use a very short evaporator outlet pipe between the evaporator case and the accumulator nut. In some cases, only 3/16 of an inch is available for the probe to make contact. Taking readings on flange nuts will skew the actual temperature by more than 20ºF.
- If you are using an alligator type clip-on probe, rotate it back and forth on the line to be sure it is making firm contact.
- Take the readings as close in as possible to the condenser and the evaporator.
- Accessing the outlet side of the orifice tube can be difficult on some applications. It is just inside the evaporator case on some GM light trucks. Access the pipe by cutting a small section of the case away with a hot knife or use the tip of an old soldering iron to create a small access hole.
- When you are finished, seal the area with permagum or insulation tape.

About Infrared Thermometers: We are often asked if infrared thermometers can be used to perform heat load temperature testing. They CANNOT. The infrared beam spreads much too wide to take the pinpoint readings necessary. The laser is just a pointer – it does not represent the infrared beam. For example, in the images shown here, an infrared thermometer and a contact type temperature probe are being used to measure the temperature of a heated refrigerant charging cylinder at the exact same temperature. Half of the cylinder is bare aluminum while the other half is painted black. You can clearly see that the contact probe readings are within a few degrees of each other regardless of whether they are taken on the bare metal or painted surfaces. (Note: that the paint does make a slight difference). However, when the same readings are taken with an infrared thermometer there is a discrepancy of 30°F between two readings! Even though the contact probe confirms that in fact, the two surfaces are about the same temperature. This is why infrared thermometers cannot be used for heat load temperature testing.

There "Appears" to be a 30 ° F Difference between the Bare Metal and Painted Surfaces – In Fact They are Both at the Same Temperature

Heated Refrigerant Charging Cylinder



Temperature of Bare Metal and Painted Surface of Heated Charging Cylinder Measured with Contact Probe– Only Few Degrees of Temperature Difference

Nevertheless, an infrared thermometer can still be a useful tool. It can be used to check ***relative*** temperature differences – for example scanning back and forth across the front of the condenser checking for restrictions.

Infrared Thermometer

Temperature Testing TXV Systems

The vehicle set up for temperature testing a TXV system is identical to a CCOT system.

The "**Condenser Sub-cooling"** and **"Ambient to Duct Air"** tests are also the same.

The only difference is in performing the "**Evaporator Superheat"** test.

Note: TXV systems use a receiver in the liquid line instead of an accumulator in the suction line. On a CCOT system, the accumulator acts as a liquid/vapor separator to prevent any liquid refrigerant from returning to the compressor and slugging it. A TXV system does not have this protection. It is critical that no liquid refrigerant exits the evaporator on a TXV system. The liquid would go straight to the compressor and likely cause catastrophic damage. Therefore, a small amount of evaporator superheating is essential on a TXV system to ensure all the refrigerant is evaporated before it reaches the compressor.

The temperature sensing element of a TXV is constantly measuring evaporator outlet temperature and adjusting the metering of refrigerant into the evaporator to control evaporator superheat.

Evaporator Superheat Test on a TXV System

There are two methods of checking evaporator superheat on a TXV system – the "Direct" and "Indirect":

- **Direct Measurement.** Just as you would on an orifice tube system, simply check the evaporator inlet and outlet temperature. On a typical TXV system, evaporator outlet temperature will be between +2°F and +10°F warmer than the inlet during a heat load temperature test. A few may be slightly higher than this. The actual value depends on the specific superheat rating of the TXV itself. Each TXV is matched to the evaporator and system it is installed in. The specific superheat rating can usually be obtained from the manufacturer's website or catalog.
  Be sure to check the TXV inlet temperature on the evaporator side of the TXV. This is where a problem can arise. The TXV is usually located inside the evaporator case and it may not be possible to take a direct inlet temperature reading on the evaporator side of the valve. In this case, you will need to perform an indirect measurement of evaporator superheat.

- **Indirect Measurement.** If you cannot take a direct measurement of evaporator inlet temperature then it is still possible to infer evaporator superheat indirectly. Compare center duct air temperature with evaporator outlet (suction line) temperature. As a general rule, evaporator outlet temperature should not be more than 10°F warmer than duct air temperature. Think of it this way: if the evaporator outlet temperature was 65°F and duct air temperature was 50°F during a heat load test, you would know that there is at least 15°F of superheating taking place in the evaporator. Some part of the evaporator (close to the inlet) is cold enough to cool the duct air to 50°F, yet by the time the refrigerant leaves the evaporator the temperature has increased by at least 15°F. A disadvantage of this test is that there may be a greater amount of superheating taking place than the 15°F indicated by the test. We are assuming that evaporator inlet temperature is close to the duct air temperature of 50°F. Of course, an air door problem in the dash, or a leaking evaporator case seal could allow warmer air to leak into the airflow before the duct; the evaporator inlet could in fact be quite a bit colder than the duct air. This would mean that the evaporator superheating is actually more that the 15°F we have estimated. If duct air and evaporator outlet temperature were within 10°F of each other, we could be misled into thinking that evaporator superheating was within the normal range. However, if this were the case, the **"Ambient to Duct Air"** test reading would almost certainly be less than 30°F, which would at least let us know that there is still a problem in the system.

Temperature Testing Dual Evaporator Systems

Temperature testing dual evaporator systems is very similar to testing single evaporator systems with just a few minor additional steps.

A few points to note about testing dual evaporator systems:

- Most dual evaporator systems use the same compressor and condenser as the single evaporator model of the same vehicle. This means that the system has to work harder to handle the added heat load of the second evaporator. Both high and low side pressures will be slightly higher on the dual evaporator version of the same system.
- Dual evaporator systems may use all TXVs, all orifices tubes or a combination of both as follows:
    - Front Orifice Tube/Rear TXV (OT/TXV)
    - Front TXV/Rear TXV (TXV/TXV)
    - Front and Rear Orifice Tube (OT/OT) (not very many)

You need to identify the type of system, as it will affect you testing procedure slightly.

Maximum Heat Load Temperature Test – OT/TXV Dual Evaporator System

Vehicle Setup

The vehicle set up is virtually identical to a single evaporator setup except as noted.

- Bring the engine up to full working temperature with the A/C on.
- Place the vehicle outside in direct sunlight.
- Set both front and rear the AC controls to max cold and recirculating air.
- Open all doors and windows
    - Note: Also open the rear door or hatch.
- Set front blower speed to high position
    - Note: set the rear blower to low speed only. This is because the total heat load on the system with both blowers on high can exceed the design capacity of the system and cause temperature and pressure readings to be erratic.
- Allow System to stabilize (operate at idle for at least five minutes).

Now take the temperature readings in each of the three tests below. The condenser sub-cooling test is the same as for a single evaporator system. When you have recorded all your temperature readings, find the temperature difference between the two readings taken in each of the tests. You will end up with a single temperature number for each test. We call them the three "D"s or "differences."

Testing Procedure:

1. **Condenser Sub-cooling Test:** Measure and record the temperatures of the condenser inlet and outlet lines as close to the condenser as possible.
2. **Ambient to Duct Air Test – Front and Rear:** Measure and record the air temperatures at the center front and rear AC ducts and the ambient air temperature about one foot in front of the condenser.
3. **Evaporator Superheat Test:**
    - **Front Evaporator - OT:** Measure and record the front evaporator inlet and outlet temperature.
    - **Rear Evaporator – TXV:**
        - **Direct Measurement**: Measure and record the rear evaporator inlet and outlet temperature as described previously for a single evaporator system under the heading “Direct Measurement” on page 5.
        - **Indirect Measurement:** If it is not possible to access the rear evaporator inlet line to take the temperature reading, use the indirect method described for a single evaporator system under the heading “Indirect Measurement” on page 5.

Temperature Testing Specifications for an efficiently operating OT/TXV dual evaporator System:

1. **Condenser Sub-cooling Test.** The difference between the condenser inlet and outlet line should be between 20°F and 50°F – t he same as for single evaporator systems.
2. **Ambient to Duct Air Test.** Both front and rear duct air temperature should be at least 30°F lower than ambient air temperature measured about a foot in front of the condenser - same as for single evaporator systems.
3. **Evaporator Superheat Test:**
    - **Front Evaporator - OT:** -2°F ideal, ± 5°F acceptable. The acceptable range (± 5°F) is the same as for a single evaporator system but the ideal is -2°F instead of 0°F. A slightly negative temperature drop across the front evaporator on an OT/TXV dual evaporator system is preferred as it indicates a slight reserve of liquid refrigerant to handle the heat load of a dual system under extreme conditions.
    - **Rear Evaporator – TXV:**
        - **Direct Measurement**: Same as for a single TXV system - evaporator outlet temperature will be between +2°F and+ 10°F warmer than the inlet during a heat load temperature test. It depends on the superheat setting of the specific TXV valve. Refer to the specifications under the same heading for a single evaporator TXV system on page 5 for additional information.
        - **Indirect Measurement:** Same as for a single evaporator TXV system. Evaporator outlet temperature should not be more than 10°F warmer than the rear duct air temperature. Refer to the specifications under the same heading for a single evaporator TXV system on page 5 for additional information.

Now take the temperature readings recorded in each of the tests above and refer to the appropriate temperature diagnostic chart “A,” “B” or “C” on pages 10-12. Use these diagnostic flow charts to confirm that the system is operating efficiently or to help you determine the likely cause of any problems in the system.

Temperature Testing a Dual Evaporator TXV/TXV Systems

The vehicle set up is the same as for a dual OT/TXV system

Condenser sub-cooling and ambient to duct specifications are also the same.

Both the front and rear evaporator superheating specifications are also the same as for a single evaporator TXV system. Refer to page 5 for specifications and testing details.

Temperature Testing a Dual Evaporator OT/OT Systems

Vehicle set up is the same as for other dual evaporator systems.

Condenser sub-cooling and ambient to duct specifications are also the same.

Evaporator superheat specifications are: -2°F ideal, ± 5°F acceptable, on both evaporators. The same as the front evaporator on an OT/TXV system.

Note: Typically, the front and rear duct temperatures should be within 4°F of each other on a dual evaporator system.

Compressor Case Temperature:

Get in the habit of checking compressor case temperature on every vehicle you work on. It can be a valuable diagnostic aid. There is no absolute specification for compressor case temperature. It will vary widely by compressor type and vehicle and the ambient temperature and humidity on the day. However, with experience gained from regular checking, you will develop a feel for what is normal on the common systems that you work on.

Checking Compressor Case Temperature

For example, if a system is under undue stress for any of the following reasons, compressor case temperature will be elevated - a low charge, a cooling system problem, a restriction in the system or lubrication is not reaching the compressor.

Before checking case temperature, operate the system for at least 15 minutes under a heat load. Check the temperature in the middle of the case away from the suction and discharge connections.

Methods of Generating Heat Load During Cooler Weather Conditions

For a Maximum Heat Load Test to be effective, the A/C system must be subjected to a substantial heat load. The vast majority of A/C related customer complaints occur during warm weather when generating a heat load is usually not a problem. However when ambient temperature is low (less that 78°F) you can use one of the following methods to artificially generate a heat load on the evaporator.

Heater Method

- Close all the doors and windows
- Turn the heater on to full heat and run the engine at idle.
- Monitor the cabin air temperature until it reaches at least 90ºF
- Set the AC controls to MAX AC, recirculating air (this will allow the warmed air to pass over the evaporator)
- Keep the doors and windows closed during the test
- Set blower speed on high
- Continue to run the engine at idle
- First: Measure and record the temperature of the evaporator inlet and outlet lines (CCOT / FFOT Systems)
- Second: Measure and record the temperature of the condenser inlet and outlet lines
- Third: Measure and record the center duct outlet and interior air temperatures

Note: Artificially heating the interior air in this way will create a heat load on the evaporator. The temperature data that you record will provide enough information to determine if excessive superheating is occurring at the evaporator or if proper sub-cooling is taking place at the condenser. Since the ambient air temperature is cool, a condenser airflow issue may not be obvious. Therefore condenser airflow should be checked mechanically, with an anemometer or the old “rag test” (positive airflow should hold a rag flat against the front of the condenser).

Fresh Air Method

- Run the engine at idle until normal operating temperatures are reached
- Set the AC controls on maximum cold and normal or outside air flow
- Open all the doors and windows
- Set blower speed on high
- First: Measure and record the condenser inlet and outlet line temperatures
- Second: Measure and record the evaporator inlet and outlet line temperatures
- Third: Measure and record the center duct outlet air and the air entering the fresh air cowl (place the probe inside the air grill).

Note: This method allows air that is heated as it flows through the engine compartment to enter the fresh air cowl before it is drawn across the evaporator core. This artificially heated air may climb above 110ºF. This method will allow you to determine if excessive superheating or minimum sub-cooling is occurring. Due to the cool ambient air temperatures, the test may not reveal low condenser air flow. As explained above, test for proper airflow across the condenser mechanically.