



## **Thermal/HVAC/PTC Test Vehicle Instrumentation Procedure**

### **1 Introduction**

**Note:** Nothing in this standard supercedes applicable laws and regulations.

**Note:** In the event of conflict between the English and domestic language, the English language shall take precedence.

**1.1 Purpose.** This standard describes the preferred installation techniques to drive a common installation process for instrumentation in Thermal/HVAC/Powertrain Cooling (PTC) test vehicles. Using these preferred installation techniques as the common installation process will aid in test data correlation.

**1.2 Applicability.** Applies to all Thermal/HVAC/PTC vehicles.

**1.3 Remarks.** Not applicable.

### **2 References**

**Note:** Only the latest approved standards are applicable unless otherwise specified.

#### **2.1 External Standards/Specifications.**

None

#### **2.2 GM Standards/Specifications.**

GMW3059

#### **2.3 Additional References.**

- Best Practice THMINT-17. The supplier shall work with the GM Thermal Development Engineer to comprehend this requirement.
- Frost King. (<http://www.frostking.com/>)
- GM Part Number 12346240.
- Loctite. (<http://www.loctite.com/>)
- Marlin Connectors Mini-Plug (Part Number (No.) 1260-K). (<http://marlinmfg.com/>)
- Nylaflow. Airlite Plastics Company 6110 Abbott Drive, Omaha, NE 68110. (<http://www.nylaflow.com/>)
- OMEGATHERM. (<http://www.omega.com/>)
- QuilTak Basting Tool and Tak No. 6025-P. ([www.quiltak.com](http://www.quiltak.com))
- Swagelok male fitting (Part No. QC4-D-20). (<http://www.swagelok.com>)
- Swagelok vented female Quick-Connect (Part Number QC4 B 2PMBB). (<http://www.swagelok.com>)
- Teflon (a polytetrafluoroethylene) by Chemours. (<https://www.chemours.com/>)
- Vaisala. (<https://www.vaisala.com>)
- Vehicle Technical Specification (VTS).
- Velcro. (<http://www.velcro.com/>)

### **3 Test Preparation and Evaluation**

#### **3.1 Resources.**

##### **3.1.1 Facilities.**

**3.1.1.1 Calibration.** The test facilities and equipment shall be in good working order and shall have a valid calibration label.

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**3.1.1.2 Alternatives.** Alternative test facilities and equipment may also be used. However, all measuring variables as specified in this standard shall be determined correctly with respect to their physical definition.

**3.1.2 Equipment.** Not defined.

**3.1.3 Test Vehicle/Test Piece.** Not applicable.

**3.1.4 Test Time.** Not defined.

**3.1.5 Test Required Information.** Not defined.

**3.1.6 Personnel/Skills.** Knowledgeable in typical thermal instrumentation installation techniques.

**3.2 Preparation.** Not defined.

**3.3 Conditions.**

**3.3.1 Environmental Conditions.** Not applicable.

**3.3.2 Test Conditions.** Deviations from the requirements of this standard shall have been agreed upon. Such requirements shall be specified on component drawings, test certificates, reports, etc.

**3.4 Instructions.** Instructions are included within the requirements in Section 4. Instrumentation to be installed is dependent on the Thermal, Powertrain Cooling, and HVAC procedures required in the vehicle validation and/or development plan. Refer to the vehicle validation plan and applicable Program Development Engineers if unsure of required instrumentation.

**3.5 Data.** Not applicable.

**3.6 Safety.**

This Engineering Standard may involve safety requirements for hazardous materials, the method of operations and equipment. This standard does not propose to address all the safety issues associated with its use. It is the responsibility of the user of this standard to ensure compliance with all appropriate safety and health practices. This would include any specific training that may be required. The safety and health standards include site specific rules and procedures, company rules and procedures, and Government Standards. Contact shall be made with the appropriate site Safety and Health personnel for further direction and guidance in these matters.

**3.7 Documentation.** Samples of components or material released to this standard shall be tested for conformity with the requirements of this standard and approved by the responsible GM Department prior to the start of delivery of production level components or materials.

Any change to the component or material, e.g., design, function, properties, manufacturing process and/or location of manufacture requires a new release of the product. It is the sole responsibility of the supplier to provide the customer, unsolicited, with documentation of any change or modification to the product/process, and to apply for a new release.

If not otherwise agreed to, the entire verification test shall be repeated and documented by the supplier prior to start of delivery of the modified or changed product. In some cases, a shorter test can be agreed to between the responsible GM department and the supplier.

**3.7.1 Test Results.** Not applicable.

## 4 Requirements and Procedure

### 4.1 Temperature Measurement Requirements.

**4.1.1 Engine Oil Sump/Dipstick.** Verify the instrumentation procedure to ensure the fluid temperature measured represents the bulk engine oil sump fluid average temperature. The measurement location of engine oil may require special care due to localized hot or cold regions in the oil sump. Consult with the appropriate Engine Application Development Engineer prior to testing.

**4.1.1.1 Sump.** Instrument engine oil drain plug with a (1.6 to 3.2) mm ((1/16 to 1/8) in) or equivalent diameter thermocouple probe. Extend thermocouple probe tip 15 mm beyond drain plug. See Appendix A, Figure A1.

**4.1.1.2 Dipstick.** Instrument the engine dipstick with thermocouple wire (recommend 30 American Wire Gauge (AWG) K-30-2-506), down the length with the thermocouple junction at the tip of the dipstick. The dipstick may be substituted with a probe type thermocouple that is set up to the same length as the dipstick. A rubber cork should be used to seal the dipstick tube.

### 4.1.2 Transmission or Drive Unit.

**4.1.2.1 Transmission Sump.** Locate a thermocouple probe at the inlet midpoint of the transmission filter screen as follows:

**4.1.2.1.1** Install and tighten compression plug to case.

**4.1.2.1.2** Insert thermocouple until it bottoms out on the oil filter.

**4.1.2.1.3** Retract the thermocouple 3 mm from the filter.

**4.1.2.1.4** Tighten compression nut while holding the plug.

**4.1.2.2 Transmission Dipstick.** Instrument transmission dipstick with thermocouple wire, (recommend 30 AWG K-30-2-506) down the length with the junction at the tip of the dipstick. The dipstick may be substituted with a (1.6 to 3.2) mm or equivalent probe type thermocouple that is set up to the same length as the dipstick. A rubber cork should be used to seal the dipstick tube.

**4.1.2.3 Transmission Stator.** Contact the transmission manufacturer engineering group regarding the location and installation technique for transmission stator temperature measurement. It is common for the manufacturer to install the stator thermocouple.

**4.1.2.4 Transmission Oil Case Inlet and Outlet.** Locate a thermocouple probe in each cooler line within (50 to 100) mm of the transmission case. See technique in 4.1.2.6.

**4.1.2.5 Transmission Oil Auxiliary Cooler Air Inlet and Outlet.** Locate at midpoint and 10 mm off the cooler surface in each fitting.

**4.1.2.6 Transmission Oil Cooler Fluid Inlet and Outlet Pipe.** Locate a thermocouple probe in the cooler pipe within (50 to 100) mm of the radiator connection in both the inlet and outlet pipe.

**4.1.2.6.1 Technique 1.** Weld (silver solder) a (1.6 to 3.2) mm or equivalent thermocouple probe in the cooler pipe. The probe tip must be in the midpoint of the flow stream. Typically these pipes are steel and can be silver soldered. If an aluminum pipe is used, go to Technique 2.

**4.1.2.6.2 Technique 2.** Braze a small (approximately 10 mm x 10 mm x 1 mm) copper square onto the end of the thermocouple probe and apply heat transfer paste similar to OMEGATHERM High Temperature High Thermally Conductive Paste (a heat transfer paste) on the copper square and then cable tie the copper square and thermocouple to the pipe. Wrap the clamped thermocouple junction with Frost King, Mortite No Drip tape (an insulation tape) or equivalent insulation tape. This minimizes the influence of other heat sources or air-cooling of the thermocouple.

**4.1.2.6.3 Technique 3.** Clamp the welded thermocouple junction to pipe with a small worm gear clamp. Be sure to clamp only the welded tip, trying not to create a new junction with the exposed wire. Wrap the clamped thermocouple junction and clamp with No Drip tape or equivalent insulation tape. This minimizes the influence of other heat sources or air-cooling of the thermocouple. This technique should only be used for non-invasive testing (e.g., competitive, saleable, or show vehicles).

**4.1.2.6.4 Technique 4.** Attach the thermocouple with an applicable reliable tape on the pipe surface. Wrap the clamped thermocouple junction and clamp with No Drip tape or equivalent insulation tape. This minimizes the influence of other heat sources or air-cooling of the thermocouple. This technique should only be used for non-invasive testing (e.g., competitive, saleable, or show vehicles).

**4.1.2.7 Transmission Oil Auxiliary Cooler Fluid; Inlet and Outlet Pipe.** See 4.1.2.6.

**4.1.2.8 Drive Unit.** Contact the drive unit manufacturer engineering group regarding the location and installation technique for drive unit temperature measurement. It is common for the manufacturer to install drive unit thermal instrumentation.

**4.1.3 Rear Axle.** Instrument (1<sup>st</sup>) the drain plug or (2<sup>nd</sup>) the fill plug with (1.6 to 3.2) mm or equivalent diameter thermocouple probe.

**Note:** Alternate method is to instrument the cover plate, locating the thermocouple in approximately the 5 o'clock position to avoid the ring gear. See Figure A1.

**4.1.4 Engine Air Intake Manifold.** The position and method of instrumentation of this thermocouple is to be determined by the requestor.

**4.1.5 Power Steering Sump Oil.** Instrument with a (1.6 to 3.2) mm or equivalent diameter thermocouple probe. Locate the thermocouple junction at the tip of the dipstick of a remote fluid reservoir.

**4.1.6 Turbocharger Air Inlet and Outlet.** Locate thermocouple probe in the turbocharger pipe within (50 to 100) mm of the air cooler inlet and outlet. Drill and tap the turbocharger pipe to accept the fitting (often National Pipe Thread (NPT)) being installed. Use a bored through fitting for temperature measurements.

**4.1.7 Engine Oil Cooler Oil Inlet and Outlet.** Locate thermocouple probe in the cooler pipe within (50 to 100) mm of the radiator connections. See 4.1.2.6. The primary engine oil cooler may be in the radiator end tank or may be pan caked to the oil filter.

**4.1.8 Engine Oil Cooler Air Inlet and Outlet.** Locate a thermocouple at midpoint, 10 mm off the cooler surface.

**4.1.9 Engine Oil Cooler Coolant Inlet and Outlet.** Locate a thermocouple probe in the cooler pipe within (50 to 100) mm of the cooler. See 4.1.2.6.

**4.1.10 Grille.** Locate a thermocouple (50 to 125) mm behind and near midpoint of vehicle grille or fascia opening, but not behind any emblems or supports. The thermocouple needs to be in the airflow stream.

**4.1.10.1 Technique 1.** After welding the junction, attach a thermocouple to the grille with tie wraps.

**4.1.10.2 Technique 2.** Use (32 x 102) mm ((1¼ x 4) in) long polyvinyl chloride (PVC) tubing and locate the thermocouple at the midpoint of the tube and center of the air stream inside the tube. Attach to the vehicle at grille level.

**4.1.11 Roof.** Use (32 x 102) mm ((1¼ x 4) in) long PVC and locate a thermocouple at the midpoint of the tube and center of the air stream inside the tube. Attach to the vehicle roof (with Velcro (a hook and loop system) or magnet) at the midpoint or above the driver's door.

**4.1.12 Dry and Wet Bulb Exterior.** The Instrumentation method and location is to be determined by the requestor. See 4.7 regarding interior humidity measurements.

**4.1.13 Interior Passenger Compartment and Interior Airflow.**

**4.1.13.1 Cowl Air Inlet.** Thermocouple location shall be decided upon by the requestor.

**4.1.13.1.1 Technique 1.** Place thermocouple on the Body Air Inlet (BAI) scoop/awning at the outermost opening in center of opening (see Figure A23).

**4.1.13.1.2 Technique 2.** Place thermocouple at vehicle centerline in middle of plenum cross section 30 mm off the plenum floor (see Figure A23).

**4.1.13.2 Recirculation Air Inlet.** Locate a thermocouple near midpoint of the recirculation opening on the cabin side of the inlet opening.

**4.1.13.3 Front Blower Air Inlet.** Locate a thermocouple near midpoint of the air stream and approximately 12.5 mm before the blower air inlet orifice.

**4.1.13.4 Front Blower Air Outlet.** Locate a thermocouple at midpoint of discharge throat of the blower scroll. Drill a hole in the module case and install the thermocouple (25 to 30) mm into the air stream.

**4.1.13.5 Rear Blower Air Inlet.** Locate a thermocouple near midpoint of the air stream and approximately 12.5 mm before the blower air inlet orifice.

**4.1.13.6 Front Evaporator Air Inlet.** Locate the thermocouple at the center point of the local air stream without making contact with evaporator pipes, tubes, or fins.

**4.1.13.7 Front Evaporator Air Inlet Grid.** Locate a thermocouple in each of the locations in Table 1. Alternately, a four (4) point thermocouple grid may provide sufficient data provided the grid follows a diagonal pattern across the evaporator face and if a matched inlet and Outlet Grid is not required.

Table 1: Front Evaporator Air Inlet Grid Thermocouple Locations

|                                         |                                    |
|-----------------------------------------|------------------------------------|
| Front Evaporator Air Inlet-Grid Average | Front Evaporator Air Inlet Grid 9  |
| Front Evaporator Air Inlet Grid 1       | Front Evaporator Air Inlet Grid 10 |
| Front Evaporator Air Inlet Grid 2       | Front Evaporator Air Inlet Grid 11 |
| Front Evaporator Air Inlet Grid 3       | Front Evaporator Air Inlet Grid 12 |
| Front Evaporator Air Inlet Grid 4       | Front Evaporator Air Inlet Grid 13 |
| Front Evaporator Air Inlet Grid 5       | Front Evaporator Air Inlet Grid 14 |
| Front Evaporator Air Inlet Grid 6       | Front Evaporator Air Inlet Grid 15 |
| Front Evaporator Air Inlet Grid 7       | Front Evaporator Air Inlet Grid 16 |
| Front Evaporator Air Inlet Grid 8       | -                                  |

**4.1.13.7.1** Thermocouples shall be located on the evaporator in a 16 point grid as seen in Appendix A, Figure A16. The locations and numbering of the Inlet Grid is set to the have the Number (No.) 1 thermocouple in the top RH side position of the inlet face of the Evaporator Core which would be called the Evap In Grid. The rest should be numbered Right to Left ending with Evap In Grid No. 16 being at the bottom LH side of the inlet face of the Evaporator Core. The positions and thermocouple numbers for the Evap Core Grid should match across the Evaporator Core, this makes the Evap Out Grid No. 1 in the top LH side, but on the outlet face of the Evaporator Core, then the thermocouple numbers and positions will match. Use 30 gauge wire routing the thermocouple wire along evaporator tubes to reduce the blockage of airflow.

**4.1.13.8 Front Evaporator Air Outlet.** Locate the thermocouple at the center point of the air stream without making contact with the evaporator pipes, tubes, or fins.

**4.1.13.9 Front Evaporator Air Outlet Grid.** Locate a thermocouple in each of the locations in Table 2.

Table 2: Front Evaporator Air Outlet Grid Thermocouple Locations

|                                      |                                  |
|--------------------------------------|----------------------------------|
| Front Evaporator Outlet-Grid Average | Front Evaporator Air Out Grid 9  |
| Front Evaporator Air Out Grid 1      | Front Evaporator Air Out Grid 10 |
| Front Evaporator Air Out Grid 2      | Front Evaporator Air Out Grid 11 |
| Front Evaporator Air Out Grid 3      | Front Evaporator Air Out Grid 12 |
| Front Evaporator Air Out Grid 4      | Front Evaporator Air Out Grid 13 |
| Front Evaporator Air Out Grid 5      | Front Evaporator Air Out Grid 14 |
| Front Evaporator Air Out Grid 6      | Front Evaporator Air Out Grid 15 |
| Front Evaporator Air Out Grid 7      | Front Evaporator Air Out Grid 16 |
| Front Evaporator Air Out Grid 8      | -                                |

**4.1.13.9.1** Thermocouples shall be located on the evaporator in a 16 point grid as seen in Appendix A, Figure A16. The locations and numbering of the Outlet Grid is set to the have the No. 1 thermocouple in the top LH side position of the outlet face of the Evaporator Core which would be called the Evap Out Grid. The rest should be numbered Left to Right ending with Evap Out Grid No. 16 being at the bottom RH side of the outlet face of the Evaporator Core. The positions and thermocouple numbers for the Evap Core Grid should match across the Evaporator Core, this makes the Evap In Grid No. 1 in the top RH side, but on the inlet face of the Evaporator Core, then the thermocouple numbers and positions will match. Use 30 gauge wire routing the thermocouple wire along evaporator tubes to reduce the blockage of airflow.

**4.1.13.10 Rear Evaporator Air Inlet.** Locate the thermocouple at the center point of the air stream without making contact with the evaporator.

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**4.1.13.11 Rear Evaporator Air Inlet Grid.** Locate a thermocouple in each of the locations in Table 3. Alternately, a 4 point grid may provide sufficient data provided the grid follows a diagonal pattern across the evaporator face if a match inlet and Outlet Grid is not required.

**Table 3: Rear Evaporator Air Inlet Grid Thermocouple Locations**

|                                       |                               |
|---------------------------------------|-------------------------------|
| Rear Evaporator Air In - Grid Average | Rear Evaporator Air In Grid 5 |
| Rear Evaporator Air In Grid 1         | Rear Evaporator Air In Grid 6 |
| Rear Evaporator Air In Grid 2         | Rear Evaporator Air In Grid 7 |
| Rear Evaporator Air In Grid 3         | Rear Evaporator Air In Grid 8 |
| Rear Evaporator Air In Grid 4         | Rear Evaporator Air In Grid 9 |

**4.1.13.11.1** Thermocouples shall be located on the evaporator in a 9 point grid as seen in Appendix A, Figure A17. The locations and numbering of the Inlet Grid is set to have the No. 1 thermocouple in the top RH side position of the inlet face of the Evaporator Core which would be called the Evap In Grid. The rest should be numbered Right to Left ending with Evap In Grid No. 9 being at the bottom LH side of the inlet face of the Evaporator Core. The positions and thermocouple numbers for the Evap Core Grid should match across the Evaporator Core, this makes the Evap Out Grid No. 1 in the top LH side, but on the outlet face of the Evaporator Core, then the thermocouple numbers and positions will match. Use 30 gauge wire routing the thermocouple wire along evaporator tubes to reduce the blockage of airflow.

**4.1.13.12 Rear Evaporator Air Outlet.** Locate the thermocouple at the center point of the air stream without making contact with the evaporator.

**4.1.13.13 Rear Evaporator Air Outlet Grid.** Locate a thermocouple in each of the locations in Table 4.

**Table 4: Rear Evaporator Air Outlet Grid Thermocouple Locations**

|                                       |                                   |
|---------------------------------------|-----------------------------------|
| Rear Evaporator Outlet - Grid Average | Rear Evaporator Air Outlet Grid 5 |
| Rear Evaporator Air Outlet Grid 1     | Rear Evaporator Air Outlet Grid 6 |
| Rear Evaporator Air Outlet Grid 2     | Rear Evaporator Air Outlet Grid 7 |
| Rear Evaporator Air Outlet Grid 3     | Rear Evaporator Air Outlet Grid 8 |
| Rear Evaporator Air Outlet Grid 4     | Rear Evaporator Air Outlet Grid 9 |

**4.1.13.13.1** Thermocouples shall be located on the evaporator in a nine (9) point grid as seen in Appendix A, Figure A17. The locations and numbering of the Outlet Grid is set to have the No. 1 thermocouple in the top LH side position of the outlet face of the Evaporator Core which would be called the Evap Out Grid. The rest should be numbered Left to Right ending with Evap Out Grid No. 9 being at the bottom RH side of the outlet face of the Evaporator Core. The positions and thermocouple numbers for the Evap Core Grid should match across the Evaporator Core, this makes the Evap In Grid No. 1 in the top RH side, but on the inlet face of the Evaporator Core, then the thermocouple numbers and positions will match. Use 30 gauge wire routing the thermocouple wire along evaporator tubes to reduce the blockage of airflow.

**4.1.13.14 Front Heater Core Air Inlet.** Locate the thermocouple at the center point of the air stream without making contact with the heater core.

**4.1.13.15 Front Heater Core Air Inlet Grid.** Locate a thermocouple in each of the locations in Table 5.

**Table 5: Front Heater Core Air Inlet Grid Thermocouple Locations**

|                                        |                                    |
|----------------------------------------|------------------------------------|
| Front Heater Core Inlet - Grid Average | Front Heater Core Air Inlet Grid 5 |
| Front Heater Core Air Inlet Grid 1     | Front Heater Core Air Inlet Grid 6 |
| Front Heater Core Air Inlet Grid 2     | Front Heater Core Air Inlet Grid 7 |
| Front Heater Core Air Inlet Grid 3     | Front Heater Core Air Inlet Grid 8 |
| Front Heater Core Air Inlet Grid 4     | Front Heater Core Air Inlet Grid 9 |

**4.1.13.15.1** Locate thermocouples at locations as defined by the requestor. Thermocouple locations of Inlet and Outlet Grids are typically matched.

**4.1.13.16 Front Heater Core Air Outlet.** Locate the thermocouple at the center point of the air stream without making contact with the heater core.

**4.1.13.17 Front Heater Core Air Outlet Grid.** Locate a thermocouple in each of the locations in Table 6.

**Table 6: Front Heater Core Air Outlet Grid Thermocouple Locations**

|                                             |                                     |
|---------------------------------------------|-------------------------------------|
| Front Heater Core Air Outlet - Grid Average | Front Heater Core Air Outlet Grid 5 |
| Front Heater Core Air Outlet Grid 1         | Front Heater Core Air Outlet Grid 6 |
| Front Heater Core Air Outlet Grid 2         | Front Heater Core Air Outlet Grid 7 |
| Front Heater Core Air Outlet Grid 3         | Front Heater Core Air Outlet Grid 8 |
| Front Heater Core Air Outlet Grid 4         | Front Heater Core Air Outlet Grid 9 |

**4.1.13.18** Locate thermocouples at locations as defined by the requestor. Thermocouple locations of Inlet and Outlet Grids are typically matched.

**4.1.13.19 Rear Heater Core Air Inlet.** Locate the thermocouple at the center point of the air stream without making contact with the heater core.

**4.1.13.20 Rear Heater Core Air Inlet Grid.** Locate a thermocouple in each of the locations in Table 7.

**Table 7: Rear Heater Core Air Inlet Grid Thermocouple Locations**

|                                           |                                   |
|-------------------------------------------|-----------------------------------|
| Rear Heater Core Air Inlet - Grid Average | Rear Heater Core Air Inlet Grid 5 |
| Rear Heater Core Air Inlet Grid 1         | Rear Heater Core Air Inlet Grid 6 |
| Rear Heater Core Air Inlet Grid 2         | Rear Heater Core Air Inlet Grid 7 |
| Rear Heater Core Air Inlet Grid 3         | Rear Heater Core Air Inlet Grid 8 |
| Rear Heater Core Air Inlet Grid 4         | Rear Heater Core Air Inlet Grid 9 |

**4.1.13.20.1** Locate thermocouples at locations as defined by the requestor.

**4.1.13.21 Rear Heater Core Air Outlet.** Locate the thermocouple at the center point of the air stream without making contact with the heater core.

**4.1.13.22 Rear Heater Core Air Outlet Grid.** Locate a thermocouple in each of the locations in Table 8.

**Table 8: Rear Heater Core Air Outlet Grid Thermocouple Locations**

|                                            |                                    |
|--------------------------------------------|------------------------------------|
| Rear Heater Core Air Outlet - Grid Average | Rear Heater Core Air Outlet Grid 5 |
| Rear Heater Core Air Outlet Grid 1         | Rear Heater Core Air Outlet Grid 6 |
| Rear Heater Core Air Outlet Grid 2         | Rear Heater Core Air Outlet Grid 7 |
| Rear Heater Core Air Outlet Grid 3         | Rear Heater Core Air Outlet Grid 8 |
| Rear Heater Core Air Outlet Grid 4         | Rear Heater Core Air Outlet Grid 9 |

**4.1.13.22.1** Locate thermocouples at locations as defined by the requestor. Thermocouple locations of Inlet and Outlet Grids are typically matched.

**4.1.13.23 Heater Core (Front)/(Rear).** Locate a thermocouple in each of the locations in Table 9.

**Table 9: Heater Core (Front)/(Rear) Thermocouple Location**

|                                          |                         |
|------------------------------------------|-------------------------|
| Heater Core (Front) Return at Thermostat | Rear Heater Core Inlet  |
| Front Heater Core Inlet                  | Rear Heater Core Outlet |
| Front Heater Core Outlet                 | -                       |

**4.1.13.23.1 Technique 1.** See Figure A2. Use a thermocouple well (stinger) in the heater hoses as close as possible to the inlet and outlet.

**4.1.13.23.2 Technique 2.** See Figure A3. Use a piece of welded junction thermocouple (K24-2-505) wire. Fold the junction end in a Z shape and place on heater hose nipple; apply a small amount of room temperature vulcanizing (RTV) sealant (GM Part Number 12346240 or equivalent) on the wire before sliding heater hose over the thermocouple. Consider replacing the spring clamp with a worm gear clamp. The Z shape will prevent the wire from slipping back while the hose is being installed, and will maintain the junction in the midpoint of the fluid flow. Allow sufficient time for the RTV to cure before applying pressure or vacuum to the system. This technique should only be used for non-invasive testing, e.g., competitive, saleable, or show vehicles.

**Warning: DO NOT** use thermocouple wire with an extruded outer jacket. The system pressure will force coolant into the jacket and a leak will occur.

**4.1.13.24 Heater Air Discharges.** Locate a thermocouple in each of the locations in Table 10.

**Table 10: Heater Air Discharges Thermocouple Locations**

|                                             |                                                        |
|---------------------------------------------|--------------------------------------------------------|
| 1 Heater Front Left Module/Duct Connection  | 2 Heater Front Right Inboard Outlet                    |
| 2 Heater Front Left Outboard Outlet         | 3 Heater Front Right Center Outlet                     |
| 3 Heater Front Left Center Outlet           | 4 Heater Front Right Outboard Outlet                   |
| 4 Heater Front Left Inboard Outlet          | Heater 2 <sup>nd</sup> Left Console/Under Seat Outlet  |
| 1 Heater Front Right Module/Duct Connection | Heater 2 <sup>nd</sup> Right Console/Under Seat Outlet |

**4.1.13.24.1** Heater ducts are classified in two configurations: simple and distributed as shown in Figure A20. A simple duct is central to the HVAC module. A distributed duct travels cross car to occupy the region above or forward of the left or right occupants feet.

Install a left and right thermocouple to represent the temperature performance of the heater discharge air exiting the module. These two thermocouples shall be located in the center of the duct at the module/duct connection. In a vehicle with a simple duct, the outlet thermocouple shall always be located in the center of the duct at least

25 mm upstream of the outlet opening. With a distributed duct, the outlet thermocouples shall be located in the interior of the duct at the major outlet openings. If the vehicle is equipped with under floor or through the console ducts, the outlet openings are considered major openings. The thermocouple will be positioned in the center of the duct of each opening and 25 mm upstream of the discharge opening.

**4.1.13.25 Air Conditioning (A/C) Air Discharges.** Locate a thermocouple in each of the locations in Table 11.

**Table 11: Air Conditioning (A/C) Air Discharges Thermocouple Locations**

|                                                 |                                               |
|-------------------------------------------------|-----------------------------------------------|
| A/C Front Left Module/Duct Connection           | A/C Front Right Center Module/Duct Connection |
| A/C Front Left Outlet                           | A/C Front Right Center Outlet                 |
| A/C Front Left Center Module/Duct Connection    | A/C Front Right Module/Duct Connection        |
| A/C Front Left Center Outlet                    | A/C Front Right Outlet                        |
| A/C Front Center Central Module/Duct Connection | A/C 2 <sup>nd</sup> Left Console Outlet       |
| A/C Front Center Central Outlet                 | A/C 2 <sup>nd</sup> Right Console Outlet      |

**4.1.13.25.1** Install a thermocouple to represent the temperature performance of the A/C discharge air exiting the module at each A/C module/duct interface. These thermocouples shall be located in the center of the duct at the module/duct connection. The thermocouples for the outlets will be suspended at center of duct 25 mm behind the duct endpoint. If the outlet has a shut-off valve, the thermocouple will be located between the shut-off and the movable turning vanes, with care taken that the thermocouple will not be moved by the operation of either system.

**4.1.13.26 A/C Air Rear Discharges.** Locate a thermocouple in each of the locations in Table 12.

**Table 12: A/C Air Rear Discharges Thermocouple Locations**

|                   |                   |
|-------------------|-------------------|
| A/C Rear Outlet 1 | A/C Rear Outlet 4 |
| A/C Rear Outlet 2 | A/C Rear Outlet 5 |
| A/C Rear Outlet 3 | A/C Rear Outlet 6 |

**4.1.13.26.1** A thermocouple will be suspended at center of duct 25 mm behind the duct endpoint. If the outlet has a shut-off valve, the thermocouple will be located between the shut-off and the movable turning vanes, with care taken that the thermocouple will not be moved by the operation of either system.

**4.1.13.27 Defogger Air Discharges.** Locate a thermocouple in each of the locations in Table 13.

**Table 13: Defogger Air Discharges Thermocouple Locations**

|                                           |                                             |
|-------------------------------------------|---------------------------------------------|
| Defogger Left Side Module/Duct Connection | Defroster Right Center Windshield           |
| Defogger Left Side Window                 | Defroster Right Windshield                  |
| Defroster Left Windshield                 | Defroster Right Side Module/Duct Connection |
| Defroster Left Center Windshield          | Defogger Right Side Window                  |

**4.1.13.27.1** Install a thermocouple to represent the temperature performance of the defogger discharge air exiting the module at each defogger module/duct interface. These thermocouples shall be located in the center of the duct at the module/duct connection. The thermocouples for the outlets will be suspended at center of duct 25 mm behind the duct endpoint.

**4.1.13.28 Heater Rear Air Discharges.** Locate a thermocouple in each of the locations in Table 14.

Table 14: Heater Rear Air Discharges Thermocouple Locations

|                      |                      |
|----------------------|----------------------|
| Heater Rear Outlet 1 | Heater Rear Outlet 3 |
| Heater Rear Outlet 2 | Heater Rear Outlet 4 |

**4.1.13.28.1** Install thermocouples in the major outlet openings. If the vehicle is equipped with under floor or through the console air ducts, the outlet openings are considered major openings. The thermocouple will be positioned in the center of the duct of each opening and 25 mm upstream of the discharge opening.

**4.1.13.29 Breath Level.** Locate a thermocouple in each of the locations in Table 15.

Table 15: Breath Level Thermocouple Location

|                                     |                              |
|-------------------------------------|------------------------------|
| Breath Front Left                   | Breath 2 <sup>nd</sup> Right |
| Breath Front Left Center            | Breath 3 <sup>rd</sup> Left  |
| Breath Front Right Center           | Breath 3 <sup>rd</sup> Right |
| Breath Front Right                  | Breath 4 <sup>th</sup> Left  |
| Breath 2 <sup>nd</sup> Left         | Breath 4 <sup>th</sup> Right |
| Breath 2 <sup>nd</sup> Left Center  | Breath 5 <sup>th</sup> Left  |
| Breath 2 <sup>nd</sup> Right Center | Breath 5 <sup>th</sup> Right |

**4.1.13.29.1 Technique 1.** The temperature sensor(s) for each seat position shall be installed at a height 70 cm above the seat at the point where the seat base and back meet, and 15 cm forward of a vertical line starting where the seat base and back meet. See Appendix A, Figure A5 and Figure A6. If rear window design allows direct overhead sun load to impinge on thermocouples, tilt couples forward as necessary to avoid direct impingement. Do not coil end of thermocouple; they are to be hung straight down.

**4.1.13.29.2 Technique 2.** At the request of the Test Engineer, a four (4) thermocouple breath grid may be used for the front seating positions where Thermocouple 1 is located for the front seating positions as described in 4.1.13.29.1 (see Appendix A, Figure A6 and Figure A7). The four (4) thermocouples increase the robustness of the test data regarding the variation of air nozzle aim position. The four (4) thermocouples are to be electrically connected in parallel to report an average temperature value. This mechanical average results in accurate temperature measurement when one of the four (4) thermocouples inadvertently becomes electrically open, hence instrumentation reliability is better than a single thermocouple.

**4.1.13.29.3 Technique 3.** At the request of the Test Engineer, a two (2) thermocouple breath grid may be used for the front and rear seating positions where Thermocouple 1 is located for each seating positions 100 mm left of the location described in 4.1.13.29.1 (see Appendix A, Figure A8).

**4.1.13.30 Vehicle Footwell Temperatures.** Locate a thermocouple in each of the locations in Table 16.

**Table 16: Vehicle Footwell Temperatures Thermocouple Locations**

|                                           |                                             |                                            |
|-------------------------------------------|---------------------------------------------|--------------------------------------------|
| Floor Front Left - Grid Average           | Center 2 <sup>nd</sup> Floor - Grid Average | Floor 4 <sup>th</sup> Left - Grid Average  |
| Left Floor Forward Center                 | Center 2 <sup>nd</sup> Floor Forward        | Left 4 <sup>th</sup> Floor Forward         |
| Left Floor Forward Outboard               | Center 2 <sup>nd</sup> Floor Left           | Left 4 <sup>th</sup> Floor Outboard        |
| Left Floor Forward Inboard                | Center 2 <sup>nd</sup> Floor Right          | Left 4 <sup>th</sup> Floor Inboard         |
| Left Floor Rear Outboard                  | Floor 2 <sup>nd</sup> Right - Grid Average  | Floor 4 <sup>th</sup> Right - Grid Average |
| Left Floor Rear Inboard                   | Right 2 <sup>nd</sup> Floor Forward         | Right 4 <sup>th</sup> Floor Forward        |
| Floor Front Right-Grid Average            | Right 2 <sup>nd</sup> Floor Inboard         | Right 4 <sup>th</sup> Floor Inboard        |
| Right Floor Forward Center                | Right 2 <sup>nd</sup> Floor Outboard        | Right 4 <sup>th</sup> Floor Outboard       |
| Right Floor Forward Inboard               | Floor 3 <sup>rd</sup> Left - Grid Average   | Floor 5 <sup>th</sup> Left - Grid Average  |
| Right Floor Forward Outboard              | Left 3 <sup>rd</sup> Floor Forward          | Left 5 <sup>th</sup> Floor Forward         |
| Right Floor Rear Inboard                  | Left 3 <sup>rd</sup> Floor Outboard         | Left 5 <sup>th</sup> Floor Outboard        |
| Right Floor Rear Outboard                 | Left 3 <sup>rd</sup> Floor Inboard          | Left 5 <sup>th</sup> Floor Inboard         |
| Floor 2 <sup>nd</sup> Left - Grid Average | Floor 3 <sup>rd</sup> Right - Grid Average  | Floor 5 <sup>th</sup> Right - Grid Average |
| Left 2 <sup>nd</sup> Floor Forward        | Right 3 <sup>rd</sup> Floor Forward         | Right 5 <sup>th</sup> Floor Forward        |
| Left 2 <sup>nd</sup> Floor Outboard       | Right 3 <sup>rd</sup> Floor Inboard         | Right 5 <sup>th</sup> Floor Inboard        |
| Left 2 <sup>nd</sup> Floor Inboard        | Right 3 <sup>rd</sup> Floor Outboard        | Right 5 <sup>th</sup> Floor Outboard       |

**4.1.13.30.1** Floor grids of five (5) temperatures in each front and three (3) temperatures in each rear footwell area shall be installed according to Figure A5, Figure A6, Figure A11, Figure A12, and Figure A13. Front floor grids are to be laterally centered within their footwell and located to the centerline of the grid 150 mm rearward of the leading edge of the brake pedal. Rear floor grids are to be centered side to side, and 50 mm forward of the rear seat. When a under seat rear foot duct is present, adjust the rear floor grid as necessary to ensure no thermocouple receives direct impingement (within 100 mm) of heated air from the floor duct. The thermocouples are to be at a height of 30 mm above the floor. Front and rear floor grids should be constructed from reinforced sheet rubber (2 mm minimum) according to Figure A11, Figure A12 and Figure A13. If reinforced sheet rubber is not available, use a comparable material. Use K type thermocouple wire for all grids. Secure grids to the floor mat with tape or equivalent. Once secured to floor mat, outline floor mat onto carpet using some form of marker or equivalent so location is not lost.

#### **4.1.13.31 Climate Control Sensor Air Temperature.**

**4.1.13.31.1** Place a Thermocouple as close to the sensor as possible without making contact with the device, for each of the locations in Table 17.

**Table 17: Climate Control Sensor Air Temperature Thermocouple Locations**

|                        |                        |
|------------------------|------------------------|
| In Car Sensor Inlet 1  | In Car Sensor Inlet 2  |
| In Car Sensor Outlet 1 | In Car Sensor Outlet 2 |

**4.1.13.31.2** The following thermocouple locations are to be installed by a technique defined by the requestor. See Table 18.

**Table 18: Thermocouple Locations for Technique Defined by Requestor**

|                                                   |                                             |
|---------------------------------------------------|---------------------------------------------|
| Main (left) A/C System Duct Sensor Temperature    | Right Heater System Duct Sensor Temperature |
| Right A/C System Duct Sensor Temperature          | Rear A/C System Duct Sensor Temperature     |
| Main (left) Heater System Duct Sensor Temperature | Rear Heater System Duct Sensor Temperature  |

**4.1.13.32 Temperature Body Mass.** Weld a thermocouple to outboard driver seat track (portion that moves with the seat) half way between the forward and rearward seat attachment bolts.

**4.1.14 Refrigeration System.**

**4.1.14.1 Compressor Inlet.** Locate a thermocouple probe in the pressure line within (50 to 75) mm of the compressor and midpoint of the flow stream using one of the following techniques.

**4.1.14.1.1 Technique 1.** Weld a port on the pressure line. Drill a hole in the pressure line large enough for a 1.6 mm (1/16 in) diameter thermocouple probe (leak check weld before proceeding). Use a bored through fitting for temperature only measurements or special pressure and temperature fitting to capture both data readings. See Figure A4.

**Note:** Do not use Teflon (a polytetrafluoroethylene) on refrigerant fittings – Thread locking compound similar to Loctite 272 is suggested.

**4.1.14.1.2 Technique 2.** Drill and tap the compressor block fitting to accept NPT of fitting being installed. Use a bored-through fitting for temperature only or special pressure and temperature fitting to capture both data readings. See Figure A4.

**Note:** Do not use Teflon (a polytetrafluoroethylene) on refrigerant fittings - Loctite 272 is suggested.

**Note:** Be sure to identify the block fitting as being sweated to the aluminum tubing. If an operator drills and taps a fitting that is not sweated (can be referred to as a Lock-Block), the operator can create a leak path between the tubing and the block.

**4.1.14.1.3 Technique 3.** Clamp weld thermocouple junction to pipe with a small worm gear clamp. Be sure to clamp only the welded tip, trying not to create a new junction with the exposed wire. Wrap the clamped thermocouple (TC) and clamp with No Drip insulation tape. This minimizes the influence of other heat sources or air-cooling of the thermocouple. This technique should only be used for non-invasive testing, e.g., competitive, saleable, or show vehicles.

**4.1.14.1.4 Technique 4.** Braze a small (approximately 10 mm x 10 mm x 1 mm) copper square onto the end of the thermocouple probe and apply heat transfer paste similar to OMEGATHERM High Temperature High Thermally Conductive Paste (a heat transfer tape) on the copper square and then cable tie the copper square and thermocouple to the pipe. Wrap the clamped thermocouple junction with No Drip tape or equivalent insulation tape. This minimizes the influence of other heat sources or air-cooling of the thermocouple. This technique should only be used for non-invasive testing, e.g., competitive, saleable, or show vehicles.

**4.1.14.2 Compressor Outlet.** Locate a thermocouple probe in the midpoint of the flow stream in the pressure line. See 4.1.14.1.

**4.1.14.3 Condenser Inlet and Outlet.** Locate thermocouple in the pressure line within (50 to 75) mm of the condenser header and midpoint of the flow stream. See 4.1.14.1.

**4.1.14.4 Front Before Expansion Device (BXD) Inlet.** Locate thermocouple probe in the pressure line within (50 to 75) mm of the expansion device and midpoint of the flow stream. See 4.1.14.1.

**4.1.14.5 Front Evaporator Inlet and Outlet.** Locate thermocouple probe. Ideal is inside the module. Practical is as close to the evaporator as possible, or as directed by the requestor for alternate locations. See 4.1.14.1.

**4.1.14.6 Accumulator/Dehydrator Inlet.** Locate thermocouple probe in the pressure line within (50 to 75) mm of the accumulator/dehydrator and midpoint of the flow stream. See 4.1.14.1.

**4.1.14.7 Receiver Drier Outlet.** Locate thermocouple probe in the pressure line within (50 to 75) mm of the receiver drier and midpoint of the flow stream. See 4.1.14.1.

**4.1.14.8 Rear BXD Inlet.** Locate thermocouple probe in the pressure line within (50 to 75) mm of the expansion device and midpoint of the flow stream. See 4.1.14.1.

**4.1.14.9 Rear Evaporator Inlet and Outlet.** Locate thermocouple probe. Ideal is inside the module. Practical is as close to the evaporator as possible, or as directed by the requestor for alternate locations. See 4.1.14.1.

**4.1.15 Under Thermostat.** Locate thermocouple near wax pellet of the coolant system thermostat. This location has its challenges with integrated thermostat housings, reverse flow systems, and buried under manifold thermostats.

**4.1.16 Engine Fan Clutch - Engine.** Install a thermocouple 20 mm from sensing device.

**4.1.17 Left/Main and/or Right Cooling Fan Discharge.** Locate three thermocouples placed equally around the fan discharge in the air stream midway between the center-point and the shroud diameter, without making

contact with the cooling fan assembly, away from external heat sources, and shaded from radiation sources (exhaust components) if needed. These three thermocouples will become one channel for an average. See Figure A24.

Consider using the radiator air outlet 5-point grid to capture total bulk air temperature entering the vehicle's engine compartment, particularly for transverse engine configurations with an exhaust directly adjacent to the fan shroud (see Best Practice THMINT-17). The supplier shall work with the GM Thermal Development Engineer to comprehend this requirement.

**4.1.18 Left and/or Right Cooling Fan Motor Rear Bearing.** Weld a thermocouple to bearing case in the area of bearing.

**4.1.19 Left and/or Right Cooling Fan Motor Front Bearing.** Weld a thermocouple to bearing case in the area of bearing.

**4.1.20 Left or Right Cooling Fan Motor, Internal.** Install thermocouples adjacent to the most endangered components inside the fan motor by considering the specific temperature limits: self-generated heat, and heat flow.

**4.1.21 Front End Heat Exchanger.**

**4.1.21.1 Radiator Coolant Inlet and Outlet.**

**4.1.21.1.1 Technique 1.** See Figure A2. Use a thermocouple well (probe or stinger) in the radiator hoses as close as practical to the inlet and outlet.

**4.1.21.1.2 Technique 2.** See Figure A3. Use a piece of welded junction thermocouple (K24-2-505) wire. Fold the junction end in a Z shape and place it on the radiator hose nipple. Apply a small amount of room temperature vulcanizing (RTV) sealant on the wire before sliding the radiator hose over the thermocouple. Consider replacing the spring clamp with a worm gear clamp.

**Note:** The Z shape will prevent the wire from slipping back while the hose is being installed, and will maintain the junction in the midpoint of the fluid flow. Allow sufficient time for the RTV to cure before applying pressure or vacuum to the system. This technique should only be used for non-invasive testing, e.g., competitive, saleable, or show vehicles.

**Warning: DO NOT** use thermocouple wire with an extruded outer jacket. The system pressure will force coolant into the jacket and a leak will occur.

**4.1.21.2 Charge Air Cooler Inlet and Outlet.** Locate thermocouple in the cooler pipe within (50 to 100) mm of the air cooler inlet and outlet.

**4.1.21.2.1 Technique 1.** Drill and tap the cooler pipe to accept a pipe thread (often National Pipe Thread (NPT)) of the fitting being installed. Use a bored through fitting for temperature measurements.

**4.1.21.2.2 Technique 2.** See Figure A3. Use a piece of welded junction thermocouple (K24-2-505) wire. Fold the junction end in a Z shape and place it on the air cooler hose nipple. Apply a small amount of RTV sealant (GM Part Number 12346240 or equivalent) on the wire before sliding the air cooler hose over the thermocouple.

**Note:** The Z shape will prevent the wire from slipping back while the hose is being installed, and will maintain the junction in the midpoint of the fluid flow. Allow sufficient time for the RTV to cure before operating the system. This technique should only be used for non-invasive testing, e.g., competitive, saleable, or show vehicles.

**Warning: DO NOT** use thermocouple wire with an extruded outer jacket. The system pressure will allow a leak to occur.

**4.1.21.2.3 Technique 3.** Drill the cooler pipe In and Outlet then fix (solder or bond) screw nut to enable a thread fitting to be installed. Use a bored through fitting for temperature measurements.

**4.1.21.3 Low Temperature Radiator Coolant Inlet and Outlet.** See 4.1.21.1 for a description of common techniques.

**4.1.21.4 Charge Air Cooler Inlet - Grid Average.** Locate the thermocouple in the locations in Table 19.

**Table 19: Charge Air Cooler Inlet - Grid Average Thermocouple Locations**

|                                      |                                |
|--------------------------------------|--------------------------------|
| Charge Air Cooler Inlet Grid Average | Charge Air Cooler Inlet Grid 3 |
| Charge Air Cooler Inlet Grid 1       | Charge Air Cooler Inlet Grid 4 |
| Charge Air Cooler Inlet Grid 2       | Charge Air Cooler Inlet Grid 5 |

**4.1.21.4.1** Install thermocouples using Teflon (a polytetrafluoroethylene) coated wire. Numbering of individual leads should be from left to right, top to bottom when viewed from the driver's seat, like a book. See Figure A10. A wire grid of approximately 3.2 mm (1/8 in) diameter is recommended to support the thermocouple so that the grid survives the rigors of parts replacement. There should be at least 6 mm free lead length at each thermocouple off the surface. Care must be taken not to restrict airflow with the routing of thermocouples. Mechanical Averaging into one channel can be accomplished by using an averaging box that connects each individual thermocouple to a single thermocouple wire channel. All thermocouples used for averaging must be equal length. See Figure A9.

**4.1.21.5 Charge Cooler Outlet - Grid Average.** Locate the thermocouple in the locations in Table 20.

**Table 20: Charge Cooler Outlet - Grid Average Thermocouple Locations**

|                                       |                                 |
|---------------------------------------|---------------------------------|
| Charge Air Cooler Outlet Grid Average | Charge Air Cooler Outlet Grid 3 |
| Charge Air Cooler Outlet Grid 1       | Charge Air Cooler Outlet Grid 4 |
| Charge Air Cooler Outlet Grid 2       | Charge Air Cooler Outlet Grid 5 |

**4.1.21.5.1** Install thermocouples using Teflon (a polytetrafluoroethylene) coated wire. Numbering of individual leads should be from left to right, top to bottom when viewed from the driver's seat, like a book. See Figure A10. A wire grid approximately 3.2 mm (1/8 in) diameter is recommended to support the thermocouple so that the grid survives the rigors of parts replacement. There should be at least 6 mm free lead length at each thermocouple off the surface. Care must be taken not to restrict airflow with the routing of thermocouples. Mechanical Averaging into one channel can be accomplished by using an averaging box that connects each individual thermocouple to a single thermocouple wire channel. All thermocouples used for averaging must be equal length. See Figure A9.

**4.1.21.6 Condenser Air Inlet Grid.** Locate the thermocouple in the locations in Table 21.

**Table 21: Condenser Air Inlet Grid Thermocouple Locations**

|                              |                             |
|------------------------------|-----------------------------|
| Condenser Inlet Grid Average | Condenser Air Inlet Grid 7  |
| Condenser Air Inlet Grid 1   | Condenser Air Inlet Grid 8  |
| Condenser Air Inlet Grid 2   | Condenser Air Inlet Grid 9  |
| Condenser Air Inlet Grid 3   | Condenser Air Inlet Grid 10 |
| Condenser Air Inlet Grid 4   | Condenser Air Inlet Grid 11 |
| Condenser Air Inlet Grid 5   | Condenser Air Inlet Grid 12 |
| Condenser Air Inlet Grid 6   | -                           |

**4.1.21.6.1** Install thermocouples using Teflon (a polytetrafluoroethylene) coated wire. Numbering of individual leads should be from left to right, top to bottom when viewed from the driver's seat, like a book. See Figure A10. A wire grid approximately 3.2 mm (1/8 in) diameter is recommended to support the thermocouple so that the grid survives the rigors of parts replacement. There should be at least 6 mm free lead length at each thermocouple off the surface. Care must be taken not to restrict airflow with the routing of thermocouples. Mechanical Averaging into one channel can be accomplished by using an averaging box that connects each individual