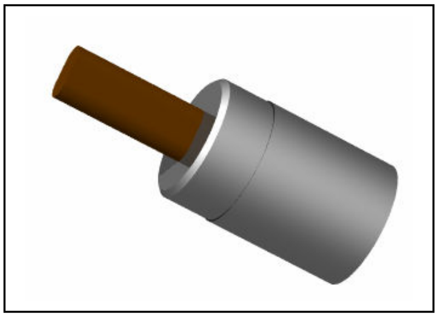
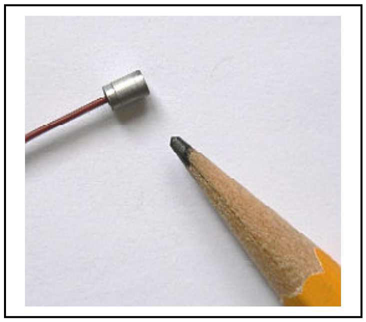
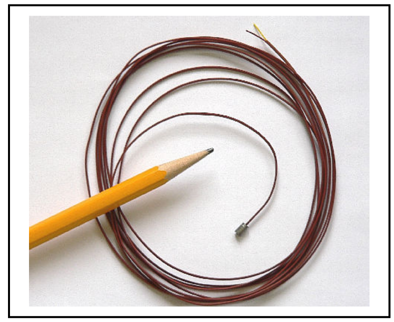
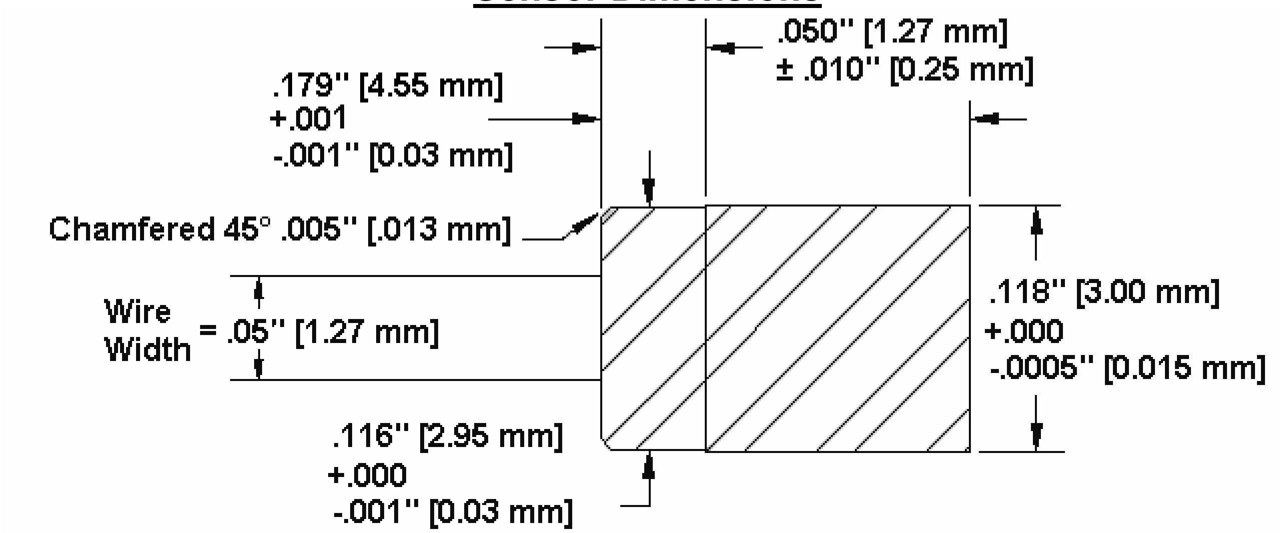
RJG's Press-Fit Cavity Temperature Sensor
Installation of Model TS-PF03-K (3 mm Version)

Our press-fit cavity temperature sensor model TS-PF03-K is made out of a plug of steel 3 mm in diameter and 4.5 mm long with 6 feet of 30 gage type K thermocouple wire extending out of the back. To install it in the mold drill a small hole for the wire, then mill a flat bottomed pocket with the tolerance necessary to press fit the device in from the cavity face. The steel of the sensor body is an H-13 with a hardness of 42-46 Rc. The sensors will withstand cavity pressures up to 30,000 psi. The Teflon wire coating allows the sensors to work in molds up to 450 °F. The sensor responds to the arrival of the flow front in 2 – 4 milliseconds. Once installed and textured its witness mark should be less than that of an ejector pin or flush-mount sensor.

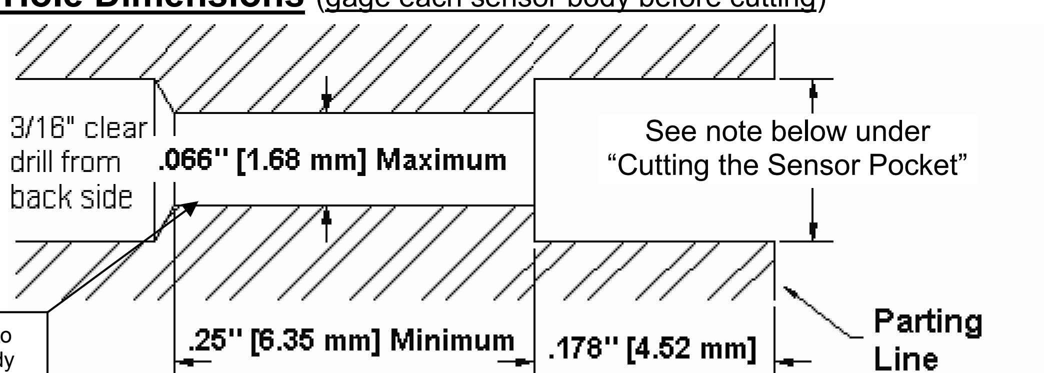




Sensor Dimensions



Nominal Hole Dimensions (gage each sensor body before cutting)

The wire channel does not need to be enlarged as shown. We provide this as an example that may simplify tooling.



This .066" maximum is specified to ensure support for the sensor body under pressure while allowing clearance for the .050" x .030" wire.

Cutting the Sensor Pocket

Diameter

The sensor is to be a press fit. The sensor diameter should be gauged and the hole diameter cut smaller for a .0005" press fit in steel and .001" press fit in aluminum.

If you make a mistake and machine the hole too large it may be possible to lock the sensor in place with black Locktite®. This was recommended to us by one tool shop but we have not tried it.

Depth

The sensor is designed to allow up to .005" of material to be removed from the sensor face for texturing or contouring. The hole depth specified leaves nominally .001" for later removal. Gauge the sensor length and cut the pocket depth to allow the correct amount of the sensor steel to be exposed for later finishing.

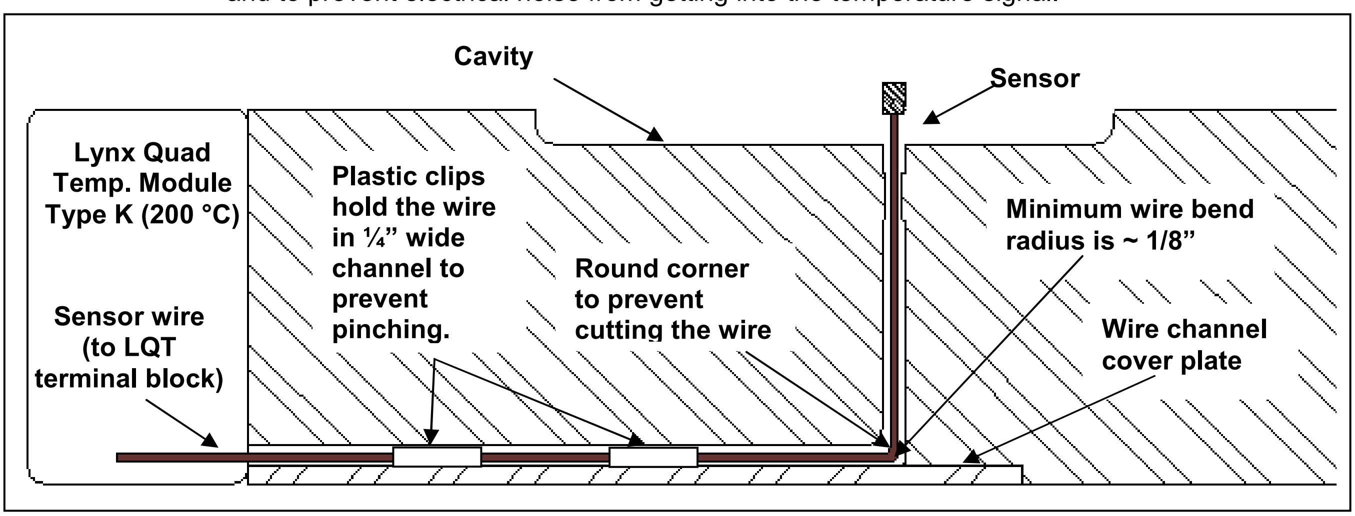
Even in flat cavity surfaces you may wish cut the hole for removal of the .005" of material in order to make the sensor respond quicker. The nominal response time of the sensor is ~8 mS but faster response times can be achieved by removing the extra material from the sensor face.

Installing the Sensor

After machining the wire hole and pocket, feed the wire through from the cavity face. Make sure the wire does not get damaged when the mold is turned on its side. The wire should be covered through channels all the way out of the mold and into the Lynx Quad Temperature Module (LQT) from the bottom. There should be no sharp corners that can cut the wire. If the wire is broken or cut too short it can be spliced with crimps (matching the wire colors). Do not pull on the wire with more than 6 pounds of force. Do not lay the wire in hot runner power channels. If you must do so put slip-on shield over the wire and up into the Lynx Quad Temperature module where it will be secured and grounded under the cable clamp.

After the wire is in position start the sensor into the hole and press it into place. Press the sensor in with a pin larger than the sensor diameter to avoid cracking the weld. Excess wire can be trimmed to length and stripped to match the terminal blocks in the LQT. Leave some extra wire in a loop inside the LQT in case you break the wire and need to strip it again. Once installed the only way to remove the sensor is to drill it from the front or punch it from the back, thus destroying it. Test the wire resistance with an ohmmeter during assembly of the mold. The red (-) wire should be ~1.8 Ω/ft. and the yellow ~4.6 Ω/ft. to the sensor face.

IMPORTANT: Bury the wires all the way into the Quad Temperature module so that they don't get destroyed and to prevent electrical noise from getting into the temperature signal.



Finishing the Sensor Face

If the cavity must later be surfaced or slightly contoured then you may remove up to 0.005" of material from the sensor face. If the sensor must be angled then the maximum angle is 5° assuming one side is left at full height (less buffing). Removing more will damage the thermocouple junction so that the sensor might not work. If more is required then a deeper pocket could be cut and the sensor recessed into the bottom of it leaving a boss on the part. Do not extend the sensor into the part or it may get pulled out at ejection. The sensor may be finished using EDM tools. The sensor wire must not exceed 450 °F (232 °C) but the sensor face can withstand typical grinding temperatures. Coolant may be used without damage to the sensor.

Checking Installed Sensors Before Attaching to LQT Terminals

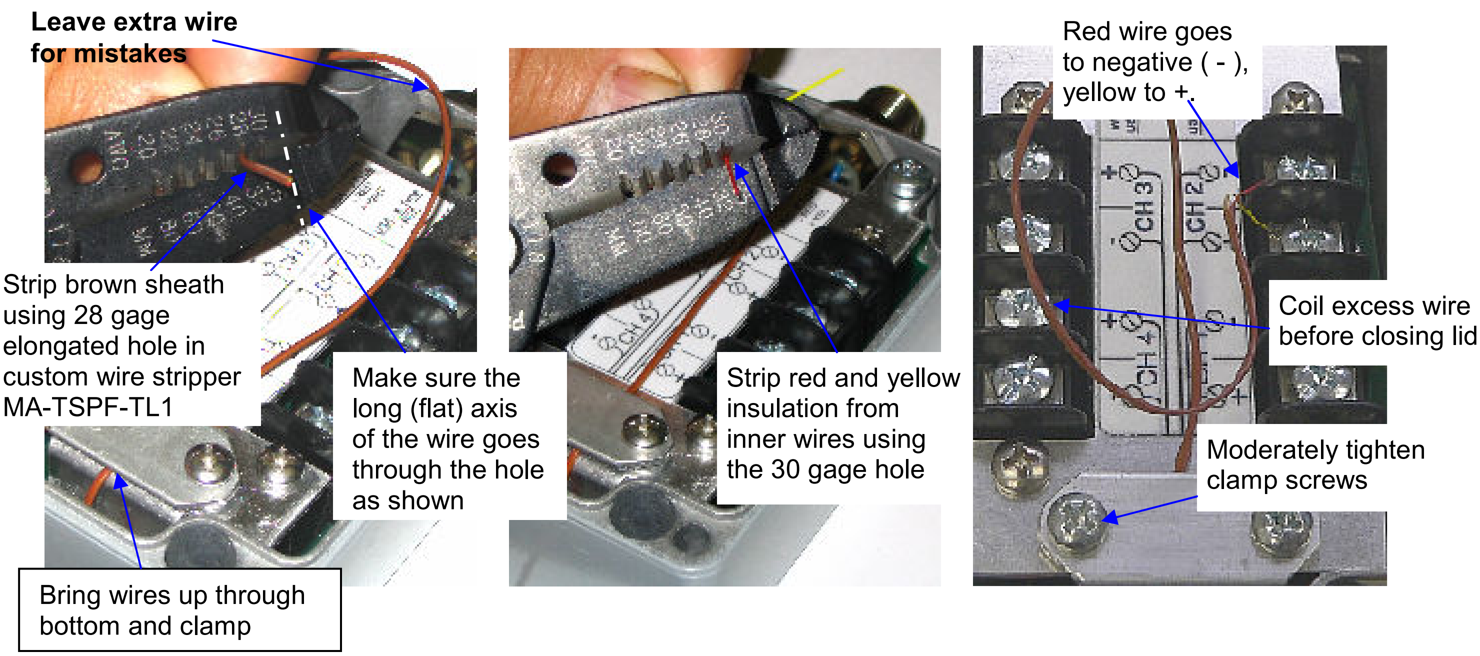
As mentioned above you can test the sensor using an ohmmeter. The red (-) wire should be ~1.8 Ω/ft. and the yellow ~4.6 Ω/ft. from between each lead stripped bare and the sensor face. Clip a mili-voltmeter's positive lead to the yellow sensor wire and negative to the red wire. Heat the face of the sensor slightly with a torch. The voltage reading on the meter should increase by 0.016 millivolts / °F (0.03 millivolts / °C). Without damaging the mold steel you should be able to raise the sensor temperature 64 °F to cause a +1 mV change.

Removing Sensors

The TS-PF03-K sensors are not easily removed without destroying the wires. A customer suggested the following: Double and slide the wire down the back hole. Fill the back hole with oil. Then drive a close-fit shaft into the hole against the oil. The hydrostatic shock should force the sensor out with minimal damage, if any.

Installation of Lynx Quad Temperature Module

- Be sure to "bury" the temperature sensor wires as shown in the diagram. This ensures that the sensors are permanently wired to specific channels in the Lynx Quad Temperature module. It also ensures that the wires cannot be snagged and broken and that they do not pick up electrical noise. If you run the wires next to hot runner power then use a slip-on braided shield grounded with the cable clamp inside the LQT.
- When assembling the mold and placing the wires in the channels use the plastic spacer tubes provided to ensure that they do not get pinched. If they get pinched and shorted the number you see on the eDART will be a sort of bulk steel temperature at the pinch point. If they get broken the eDART will read "Open".
- It has been difficult to mount the Lynx Quad Temperature module on small or hot molds. Try using a plate behind or recessed into the clamp plate. The channels can be milled in this plate and the Lynx Quad Temperature module mounted on. Contact RJG for the documents: "*Mounting Lynx Quad Temperature on Small or Hot Molds*" and "*Adding Connectors to RJG's Press-Fit Temperature Sensors*".



- If the need arises to splice the wire (because it gets cut too short, for example) then always use, as a first choice, the wire that came with the sensor.
- If you do not have extra wire cut from the sensor or from other RJG TS-PF03-K sensors then you must use "precision" grade (± 1°C) type K thermocouple wire.
- The wire alloy used for type K wire is not easy to solder. It requires special acid flux which has material safety issues. The best way to splice wire is to use tiny crimps.
- Try not to put splices in areas of temperature gradient; i.e. hotter on one side of the splice than the other. The actual voltage generated by thermocouples is created in the temperature gradient area of the wire so that is the portion of the wire that should be as "pure" as possible.
- Of course be certain to splice the leads to match the polarity: yellow goes to yellow, red to red.
- Contact RJG Support to obtain a copy of the document "*Thermocouple Wire Splicing or Lengthening Procedure*".

Application Notes for RJG's Press-Fit Cavity Temperature Sensor

Overview

In injection molding temperature of both the melt and mold are two of the four "Plastics Variables" that determine how the part is formed. These temperatures are commonly monitored only occasionally rather than on every shot. This is probably because the mold temperature controller and barrel temperature controls on the machine appear to be stable. Also many part characteristics are easily correlated to pressure in the cavity rather than temperature.

However temperature is critical in many parts and especially those made with semi-crystalline materials and requiring tight dimensional tolerances. Furthermore any changes in cycle time or breaks in cycle dramatically affect thermodynamic stability in injection molding. Achieving proper temperatures after a cycle break can take many cycles. So monitoring the temperature inside the cavity itself helps with problem diagnosis and be used to prevent parts made at the wrong temperature from being shipped.

Placement

- Locate the sensors near areas where short shots, dimensional errors or warp are likely to occur.
- Placing sensors in different areas of the part can show problems with non-uniform cooling.

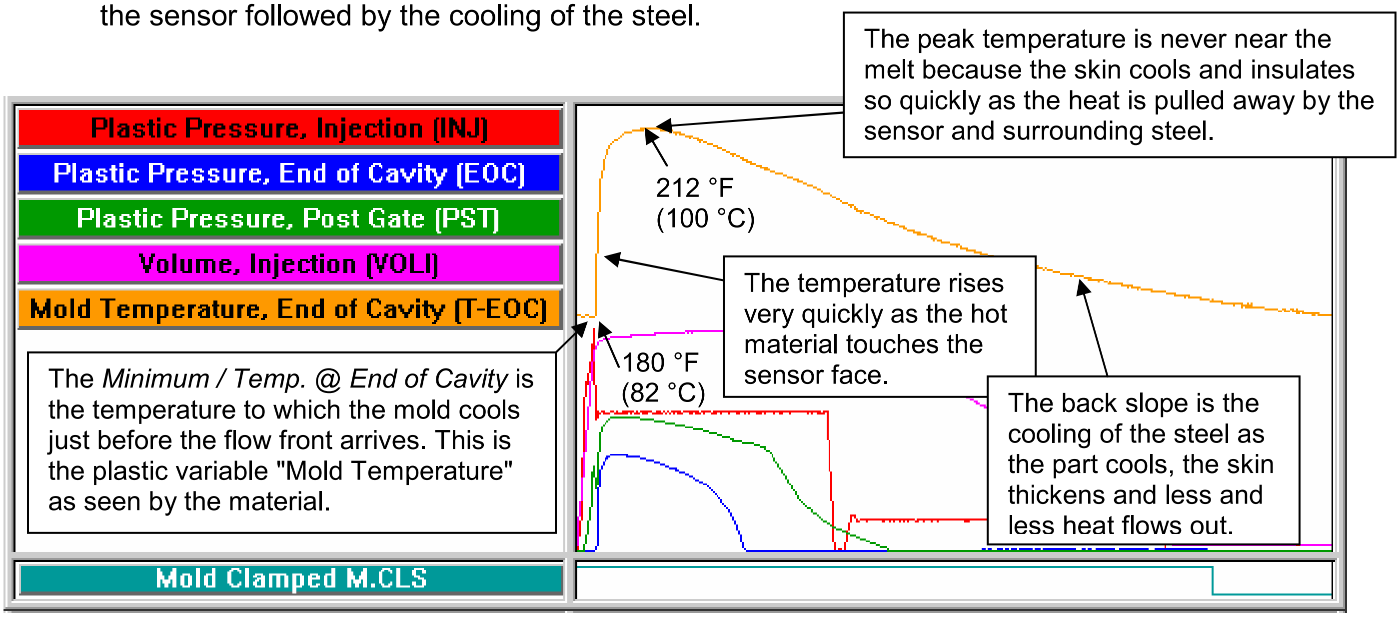
eDART Setup

- On the "Sensor Locations" page you will see one channel (number after the colon) for each sensor. Set the type to "Mold Temperature" and the location to the point closest to the sensor. Use one of the in-cavity values ("Post Gate", "Mid Cavity", "End of Cavity" or "Runner") depending on location. Add ids for each cavity.

- If you are not certain which channel is which sensor you can just lightly brush the cavity face where the sensor is with a torch flame. <u>Do not hold the flame on the sensor</u>. The value (in degrees C) should rise.

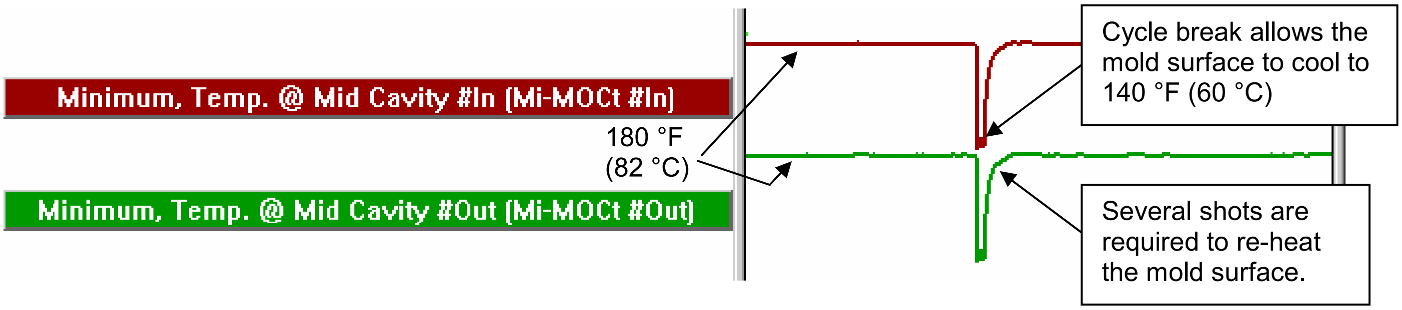
Analysis

- Here is a sample of a cycle graph showing a cavity temperature rise as the flow front reaches the sensor followed by the cooling of the steel.



- The sensor is in such tight contact with the cavity wall that it actually measures the steel temperature.

- The eDART computes a “Minimum” at each cavity temperature sensor. This is essentially the mold surface temperature at that point. Watch for oscillations and time to reach stabilization. Here is how the minimum (mold surface) drops in temperature and then returns over several shots as the mold warms up.



  This concept of looking for stability is one of the key uses for mold temperature sensors because the time to reach stability is often longer than you would think. It is important to know that the mold temperature is stable before you turn a process loose for “lights out” operation or before you sample parts for measurement.

- In semi-crystalline materials ensure that the part is being molded with the mold temperature (minimum in cavity) at the part’s specified working temperature.

- The eDART can compute relative number that shows changes in melt temperature. We call this “Effective Melt Temperature” (like Effective Viscosity”) because several poorly defined constants in the equation make it impossible to measure the actual melt temperature in degrees. Still, using the temperature curves, the eDART can estimate how much heat was removed from the mold. Knowing the “cold” temperature (minimum) it can then compute a value that shows changes in melt temperature. Much of the process (e.g. cycle time) must remain constant for this value to be of use. We can provide a document available that discusses the theory and use of “Effective Melt Temperature” in more depth.

- The eDART also computes a “Range” for each sensor which is the difference between peak and minimum. This correlates very roughly with changes in melt temperature, though the changes in “Range” are tiny. If everything else is constant a change in a “Range” number may indicate a heating or hot runner control problem.

- The eDART computes the time from start of fill until the melt arrives at the sensor. This is called “Process Time”, “Temp. @ ...” where “…” is the location of the sensor. You can observe the arrival time of the flow front there to determine actual in-cavity flow or balance of flow.

Containment

- Set alarms on “Minimum” temperature at each sensor to ensure that the mold temperature is within required limits. This will reject parts on startup until the mold surface reaches the specified temperature.

- Short Shot: If the sensor is placed at or very close to the point where a short always occurs, set alarms on the “Process Time / Temp @...” value at each sensor. This value is the most sensitive to shorts but depends on a constant flow rate.

  The “Range” value can also be used. A low “Range” (i.e. temperature rise) indicates that the material did not arrive at that point. Of course if the short shot occurs at different places depending on the flow then “Range” will not catch all short shots. We do not yet have a technique for picking the best lower level for range.

- An alarm on “Range” could also catch flash outside of the cavity such as in the parting line or around an insert. As the hot material gets into an area in which it should not be there should be a temperature rise.
- Alarms set on “Process Time” / “Temp. @...” can detect changes in flow. This can help with sorting out bad parts that are flow sensitive (e.g. textured parts etc.) or detecting improper process setups.
- Alarms (or Warnings) could be set on “Effective Melt Temperature” to capture possible changes in melt temperature. The “Range” value can also be used to divert parts though “Effective Melt Temperature is much more sensitive.

Control

- Temperature based control is best for any application where pressures are too low at the time a flow front arrives at a point in the cavity and a control decision must be made.
- The best use of temperature sensors for control at this time is with valve gates. This works especially well when there is little or no pressure at the point you wish to actuate a gate. For example you can open a gate when the flow front just passes the gate by placing a temperature sensor there. The sudden rise indicates the arrival of the flow front.
- In coining operations the eDART can be used to tell the machine to clamp up when the material has reached a known position.
- The temperature sensor “close” control on the eDART’s Valve Gate control can be used to close vents at the arrival of the flow front. Use for structural foam or large molds that need large vents. This would also work to close overflow gates.
- Temperature sensors can be used to control gas pins at the arrival of the flow front at a certain position.
- In all of the above control scenarios install the sensor slightly upstream to allow for some adjustment using the “+ volume” method.
- We have briefly tried machine transfer on temperature but have discovered, not surprisingly, that temperature transfer does control pressure well. While you can transfer the machine at the flow front arrival this does not directly control pack pressure.

  However temperature transfer may work very well in high speed, thin wall applications requiring a decoupled 1 type control method. Many of these processes build high pressures quickly at the gate with none at the end of fill by the time the machine needs to transfer. Using decoupled 1 the material can be driven to a known point in the cavity and then, when the eDART sees a temperature rise, transfer the machine. Accumulated runner pressure will fill and pack the part.

  In a decoupled 3 process temperature controlled transfer can stabilize pack pressures better than a decoupled 2 process (position transfer) when viscosity changes. But during steady state (no viscosity change) the “normal” pressure variation is greater than a D2 process.
