Date: 11/04/2008

Guidelines for Selecting the Right Hot Runnerless Molding Temperature Control System
By: Fred W. Schroeder, Sr. Product Engineer – Electronics, DME Company

With many choices for Hot Runnerless Molding Temperature Control Systems available today, how does one weigh the best selection for there companies needs? This article helps explore some concepts that one should consider before purchasing the next system.

First - Understand Your Company Environment:

First off, it directly depends on the specific mold requirements, the molder and the individual that specifies the purchase of a hot runnerless molding controllers. Let's divide up the major considerations in these categories.

Mold Requirements:

Single Cavity Molds: 1 or 2 zones
Small Molds: 5, 8 or 12 zones of control required.
Medium Molds: up to 48 zones required.
Large Molds: Up to and exceeding 128 zones required.

Molder Requirements:

Molder 1: There are low volume, prototype test runs, often in the mold tool room.
(This may be a requirement prior to sending the mold to a higher volume molding group.)
- Mold and control system is provided from an external source.
- Only the mold is provided from an external source; molder must supply controllers in-house.
- New design of mold and hot runner control system completely controlled by the molder.

Molder 2: One time quantity production runs – i.e. only make 1 million parts for consumer market.
- Mold and control system is provided from an external source.
- Only the mold is provided from an external source; molder must supply controllers in-house.
- New design of mold and hot runner control system completely controlled by the molder.

Molder 3: Continuous large volume. Part will be made frequently until part demand ends.
- Mold and control system is provided from an external source.
- Only mold is provided from an external source; molder must supply controllers in-house.
- New design of mold and hot runner control system completely controlled by the molder.

Second – Your Preferences; Often Dependent on Above Requirements:

Item 1: Initial purchase price; usually not thinking of long-term cost (although this should be considered).
Item 2: Reliability and ease of maintenance (although these qualities typically aren't verified). Most customers demand immediate service when controllers/modules go down, but are often reluctant to pay for it. Modularity and galvanic isolation become mandatory only after a complex problem is verified.
Item 3: Simple, external alarm & possibly some basic input closure to send modules to idle set point.
Item 4: Ease of operator use with very minimal training.
Item 5: On larger control systems, and on some medium systems, mold recipes that can be stored.
Item 6: On large systems, and on some medium systems, changing multiple set points simultaneously and adding or subtracting a value from multiple control modules simultaneously.
Item 7: On larger systems and on some medium systems, computer screens with graphics.
Item 8: Having a Master Control Unit send its controllers power level to Slaved controller modules. This allows two functions, 1 – if you loose a t/c, then you can continue to run production by linking the failed t/c zone to a similar zone. 2- if you exceed 15 amps on a zone, like on a large manifold, you can split heaters up on separate controllers but use only one t/c. This is also has a benefit. If you have a top and bottom heater on a manifold that exceeds 15 amps, then being able to make them "ONE" PID control loop with one t/c stops a problem of a top and bottom zone from fighting to control to a separate t/c in the same block of steel.

Third - Specific Issues to Consider:

Issue 1: Galvonic Isolation of each Zone of Control.

A major cost issue is galvanic isolation of at least 1500 Vrms for each thermocouple input from zone to zone and from the main system. This can become a nightmare in some situations with grounded versus ungrounded thermocouples. Electronic circuits that address this issue typically add about $50 to $100 per zone of cost to the Hot Runner Control System versus non-galvanic isolated systems. This feature can enable the thermocouple junction to physically touch the heater power at 240Vac and run. During heat-up, many controllers have dry-out routines which help bake moisture out of the heater. Moisture basically allows leakage current from the heaters 240 VAC to go to ground, and/or return through the thermocouple circuit. Once "dried out", the leakage current becomes almost non-detectable. When this dry-out procedure occurs, an ungrounded thermocouple will be either floating on the 240 VAC control power signal with proper galvanic isolation, or it will cause damage to the control system. Many Hot Runner Control Systems require Grounded T/C's which send this leakage current to ground, instead of allowing the thermocouple to float on the heater leakage current 240 Vac line voltage. Many systems start adding lower cost filtering circuits to the thermocouple inputs to minimize this effect, but this does not completely eliminate the problems associated with this issue.

Issue 2: Minimum Downtime of Entire System

The bottom line is that customers need to have minimum downtime. Any features that Hot Runnerless Molding Controls can contribute to help maximize machine uptime and enable processors to efficiently produce good production parts may be considered necessary. Anything that detracts operators from this primary task should be scrutinized. Key questions that should be asked are: Will the extra features be useful to the operation? Will all the information be useful to maintain satisfactory productivity? When the features are needed, will an operator be able to competently utilize the features? For example, features such as rewiring of a mold's thermocouples if they are reversed with another zone seem intriguing, but will they really save time or cost even more time in the long run? If the mold goes to production wired wrong, will this eventually cause down time in troubleshooting because the issue was not documented properly? Why not wiring the mold correctly to begin with, fix the wiring problems in the tool room before putting these type of quick software fixes on a problem? Isn't this what quality control is all about? Maybe just having a diagnostic tool to show possible problems in the tool room would be good enough.

Issue 3: System Cost

Many customers begin by using cost as the primary factor – especially in today's economy - to make a final selection on which Hot Runner System to purchase. The reality is that the system cost is dependent on the volume of parts being made. It's important to ask what will be the cost of the Hot Runner Control System per production part. For example, if 5 million parts are planned for the life of a particular mold, then it may be prudent to spend less than $0.01 per part on a Hot Runner Control System. If that's the case, your control system total should not exceed 5,000,000 x 0.01 = $50,000 dollars. If you can reuse the Hot Runner Control Systems on other molds, then this cost will be even lower. If you have a (Complex Computer Required Driven) Hot Runner Control System go down for several days, how do you handle the downtime costs versus the robust and reliable fully modular system?

Issue 4: Controllability

Typically, controllability issues relate more to the mechanical and heater design than to the Hot Runnerless Control System. The reason for using PID-type controllers is that the method allows variations of designs to be controlled by a single type of computer algorithm. A well-designed nozzle with proper thermal response is necessary from the beginning. A simple example would be a light dimmer switch in a home. Typically, when the dimmer switch is on, light can be adjusted from off to full brightness in a single full turn. This concept could be related to a good Hot Runner Nozzle Design. For example, if there's a new type of light bulb that is installed that only uses an eighth of a turn on the dimmer switch to go from off to complete brightness, then additional turning does nothing more. It is more difficult now to set your room brightness to a fourth brightness because you only have an eight turn to divide into 25% increments. A well-designed nozzle should strive to always control to the desired set point between 15% to 85% output power. This is not always possible, but it is desired. Remember that a simple plant line voltage difference can have a significant effect on a PID control response. For example, take a standard 1,000 Watt heater rated at 240 VAC. If you run this heater in a plant with 208 VAC, the maximum available heater wattage is dropped to

750 Watts. This is a 25% drop in available power to heat the zone. Some PID controller algorithm's have special features, such as overshoot control, which helps reduce Temperature overshooting of the set point and Temperature undershooting of set point during initial heat up or during set point changes.

Issue 5: Controller Output

Heater Dry Out Methods: There are different approaches to this problem. The basic concept is as follows; when a heater is first started up, some residual moisture is inherent in the ceramic insulator material that the heater element is constructed from. This moisture causes the ceramic material to allow a small amount of the 240Vac voltage to "leak" to ground. When excessive amounts of moisture are in the heater, this leakage current (in milli-amps) can get large and lead to premature heater failures. The dry out methods attempt to slow down the heating process to allow the moisture to escape from the heater in a controlled method to prolong heater life. DME's proprietary SmartStart® and Patented GFI Dryout routines have been the industry standards for well over 20 years.

Electrical Control Output Type: There are many electrical methods for controlling temperature. The main ways found in the Injection Molding industry for 240 Vac typically use an electronic device called a Triac to control the   Heater Load. The typical control methods are as follows: time proportioning, zero cross and phase angle firing.

> *Time Proportioning* is technically the easiest to implement. In microprocessor terms it is implemented many times with a method called PWM or Pulse Width Modulation. It was traditionally used with mechanical contactors, which would have a typical 10 second cycle time. The percent power to the load, for example 10% would be turning ON the contactor for 1 second then OFF for 9 seconds. This method is alright for very large and slow heat up time loads. These loads usually take over 30 minutes to heatup and require large amperage draws. They call for 100% power for over 20 minutes before the control algorithms kick in. On small fast loads however, this leads to premature heater failures. Because fast loads heat up quickly in less than several minutes, this 1 second on then 9 seconds off create hot spots in the heater that can actually be measured. This constant fluctuation in temperature causes thermal shock to the heating elements by turning them red hot then cooling down to black color for every time proportion cycle. Mechanical contacts have a minimum ON time of about 500 Millisecond to prevent the contacts from burning out. Solid State Relays and Triacs can control to half line cycle (the 240VAC line cyles at 50 or 60 Hertz) or less using zero cross or phase angle firing routines in conjunction with Time Proportioning Output Controls. These devices can use shorter cycle times, but still cause the ON time OFF time thermal shock problems.
>
> *Zero Cross Triac with proprietary spaced out cycle time control.* These routines vary from product to product. The idea is similar to time proportioning expect that the ON and OFF times can be spread out over the entire cycle time of the Controllers Output Control to reduce the thermal shock to the heating element. Using the example above at 10% output, the 1 second on versus 9 seconds off would be spread out over the entire cycle time. Another example would be 100 line cycles to equal 0 to 100% Power. At 10% power, every 10^{th} line cycle would fire followed by 9 line cycles off until 100 available cycle period is completed. This concept is today's most robust, reliable and proven method available. DME's proprietary Select Cycle® has been the industry standard in the industry for well over 20 years.
>
> *Phase Angle Firing.* This method can be the best at reducing thermal shock to the heating element but is not the most robust or reliable as the other methods. Phase Angle firing allows the Electronic circuit to turn on anywhere in the 240VAC 50/60Hertz line cycle. An entire 0 to 100% power adjustment can be made in a single cycle.   However, issues arise from this method. For starters, the electronic device that is controlling the load needs to dissipate more heat to control this load. There is also electrical noise that is produced in the forms of EMI, RFI inherent when firing anywhere but in the zero cross point in the 240VAC line cycle. This method can also imbalance the power drawn from a single cycle which effects "power factors", which can make the cost of your electricity more expensive from the utility companies. This method can be beneficial during dry out routines, but only if one side of the heater is neutral and if the other phase angle fired side can clip the peak to below 40Vdc. The problem is on a three phase system, a phase can be floating above ground and the 40Vdc peak is really above 300 Vdc with respect to ground. This leakage current then is based on the 300Vdc peak, not the below 40Vdc peak produced across the controlled phase going to the load.

Issue 6: Can One Hot Runnerless Molding Controller be used for All Molds?

Stand Alone Hot Runerless Molding Control Issues: Such a broad question is dependent on the types of molds, machines and hot runner controls one is referring to. If an answer had to be selected, it would be 'no'. Unless a company standardizes a strict regulation on what can run from one of its Hot Runnerless Molding Controllers, then this ideal control system will not happen. Variations of Mold Wattages and Zone Counts are very different. Mold Connections are very different. Power Line voltages vary throughout the world. Many small nozzles pull less than 5 amps while some large manifolds require up to 30 amps. Some molds require less than 12 zones of control while very large cavity molds may require over 120 zones of temperature control. Many PC based Hot Runner Control Systems have problems with the very fast sub-millisecond response algorithms to fire the triac and maintain complex inter-zone communication functions. Some customers prefer the larger manifolds to be wired starting at zone 1, 2, etc, while others prefer starting the nozzle drops at zone 1, 2, etc. Most molders do not have control over these parameters and simply receive molds which they must run to produce parts.

Integrating Hot Runnerless Molding Controls into the Injection Molding Machine Issues: SPI Protocol is a very good starting point to attempt to standardize a communications protocol to handle integrating auxiliary components into injection machine control panels. The SPI protocol, however, does not have a standard command set to handle complex commands and inter-module communications settings. SPI is not a worldwide accepted standard, as many European companies want protocols based on Euromap. With the SPI protocol, custom commands sets could be submitted to the committee and new devices could start addressing these issues. Limitations with SPI are that it is not a Multimaster protocol, which means the control center must constantly ask for status rather than have messages come from an external source as changes occur. Trying to integrate a standard Hot Runnerless Control system into an injection molding machine has the same issues already discussed above on the stand alone controls.

Fourth - The DME Advantage:

DME company is committed to our customers “Every Step of the Way”. Our products take all aspects of our customers needs seriously with the top goal of a robust, reliable and cost effective solution to all your Injection molding needs.

We have seen many competitive products come and go thru the years. The DME Control System products are proof of our long term commitment, with current supported Legacy Smart Series™ controllers and models still running in production since the mid 1980's. Obsolete products like the Series I, II and other controllers since the mid 1970's. DME still repairs and provides calibration services for most of these products. This is an unheard of commitment in the electronics industry.

DME has also lead the way in standardizing the Injection Mold Hot Runner Connections and still maintain standards that allow customers to connect to molds made from many years prior.

DME's commitment to all the issues mentioned can be seen in the recent new Integrity™ fully modular Hot Runnerless Controller Systems for high cavitation runnerless injection molds. This platform will meet your issues and be flexible with coming new Graphical Interface Options and communications options.