Working with the Machine

LESSON 1: Setting up the Machine

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Productivity in injection molding means keeping your machines running, making good parts hour after hour. A good setup can save hours of process troubleshooting later. In this lesson, we will look at some of the devices and techniques you should use to set up your machines quickly, safely and correctly.

Objectives of Lesson One

1. Learn how to record the setup information
2. Learn how to set the clamp controls
3. Learn how to set the heats
4. Learn how to set the pressures, strokes, and process timers
5. Learn how to document a process and move the process to a different machine

Objective One

Recording Setup Information

Sampling

When a new injection mold arrives at a molding shop, there is no information regarding how to run the mold. The first time a mold runs is called a sample.

Sampling is done to determine the functionality of the mold, how the parts reflect the design specifications, and the machine control settings needed to run the job well.

Sampling requires the molding technician to work from scratch adjusting machine controls deliberately to refine the process until a quality part is produced.

Setup Sheets

Sampling takes time to develop process settings that produce quality parts. Once these settings are found, how do we document them so we can reproduce the results?

We document the process settings so we can replicate our results. The documented settings make it easier to set up the molding machine.

Most shops use a setup sheet or process control sheet to record and save sample information, Figure 1 is an example of a setup sheet.

Item	Part No.	Mold No.	Mold Type	Pcs./Mold	Mold Drawing #
Material	Pc. Wt.	Shot Wt.	Overall Cycle Pcs/Hr.	Clamp & Shot Size	Make & # of Press

Set	Clamp Fwd. Slow LS-2 Mold Protection		Timers in Sec.	Injection High or Total Injection		Mold Mounting Data	Eye Bolts Size & No.				
	Pressure Buildup LS-3 Prefill Closed			Injection Low			Mold Shot Height (in.)		Water Data		
Clamp Cycle	LS-5 Clamp Fast Reverse			Cooling - Cure			Horizontal-in(eye Bolt Side)			Water Temp - Cavity	
	LS-6 Clamp Slow Down			Melt - Decompress			Vertical-In.			Water Temp - Core	
	LS-7 Clamp Rev. Stop			Clamp - Open			Spacer Size		Temp. Cavity Position	1	
	LS-8 Clamp Overstroke			Air Ejection - on/off			Pull Backs or K.O. Rods Size and No.			2	
	LS-20 Hyd. Eject		Temp. Cylinder, Nozzle, and Nozzle Valve	Front, Zone #1			Mold Weight			3	
Clamp Data	Press Daylight			Middle, Zone #2			Time to Place Mold			4	
	Clamp High/Clamp Low			Rear, Zone #3		Mold Placement	Sling Type Size & No.		Temp. Core Position	1	
	Clamp Open-Slow/Fast			Rear, Zone #4			Lift Size			2	
Pressures, Feed and Speeds	Injection High			Time to Reach Settings			Type of Hold Down Clamps			3	
	Injection High-Squeeze			Melt Temp.			Heels			4	
	Injection Hold			Nozzle Temp.			No. of Hold Down Clamps		Misc. Columns Needed		
	LS-25 Setting			Nozzle Valve Temp.			Hold Down Clamp Spacing - Cavity				
	Back Pressure			Nozzle V. Actuated			Hold Down Clamp Spacing - Core				
	Injection Feed			Throat Temp.			"Screw Jacks" Bottom Supports				
	Cushion		First Shot	First Shot Feed for Runnerless Mold			Torque on Clamp Bolts				
	Injection Speed Setting			Mold Warm-up Time		Removal	Core & Cavity Temp.				
							Cover with Moldsaver				
	Screw RPM			Hot Runner Warm-Up Time			Time to Remove Mold				

Figure 1- Setup Sheet

Molding machines have memory storage devices, such as a memory card or a hard drive to which we can save machine settings.

Most of the time, molds are installed into molding machines they had previously ran in. The setup sheet or machines memory provides a good starting point for setting the machine controls. The setup data is helpful, but often needs slight adjustments, within the defined process range, to achieve good parts. These adjustments may be required due to machine wear or plastic properties (material lot changes) that have changed over time.

If the mold is running in a 'new' machine, different from the one it was qualified, a new setup sheet should be made. This is especially true if the other machine differs by manufacturer, clamp or shot size. Hydraulic pump outputs, servo motors, clamping pressures, and control systems vary from machine to machine.

Log Sheets

Many companies use molding log sheets (Figure 2). These sheets record process adjustments to the controlled parameters. If a problem occurs on the shift, the technician can check the log sheet to see what adjustments previous shifts made. Experienced technicians can spot trends on the log sheet that helps troubleshoot repetitive problems.

Some shops also incorporate a shift logbook. During the shift, any machine problems, part quality problems, or control changes are noted into the logbook, which accompanies a verbal report to the next shift. Good communication saves time and effort, logbooks and verbal reports aid in the sharing of knowledge.

Machine #				Mold #					Material			
Date												
Shift	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd
Heats												
Nozzle Front												
Nozzle Rear												
Nozzle Front												
Adapter												
Manifold												
Zone 1												
Zone 2												
Zone 3												
Zone 4												
Melt												
Mold Temp												
Front												
Rear												
Times												
Clamp												
Inj. High												
Inj. Low												
Fill Time												
Screw Rec.												
Total Cycle												
Pressures												
Clamp (tons)												
Inj. High												
Inj. Low												
Back												
Other												
Feed (in.)												
Cushion (in.)												
Shot Weight												

Figure 2 - Log Sheet

Objective Two

Setting the Clamp Controls

During setup, it is important to set the clamp and ejector movement in a way that protects the mold from damage. Later, when the mold is cycling repeatedly, you can refine the clamp movements to improve mold protect and attempt to minimize cycle time.

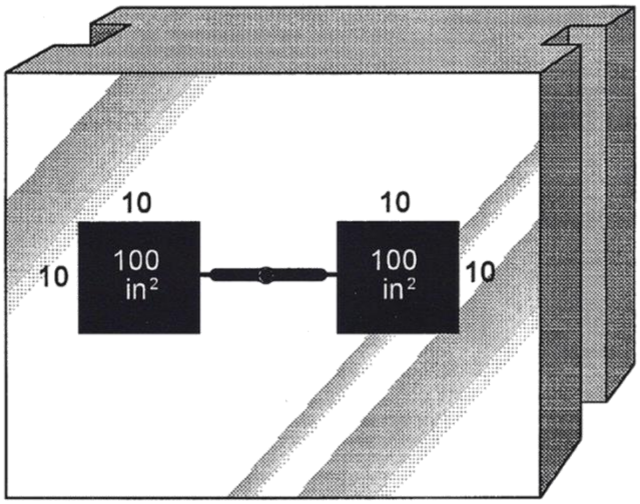
Clamp Speeds and Pressures

Different machines use different control scales to set the specific speeds and pressures. Some machines use a percentage scale, "1" for the slowest speed or pressure, and "100" for the fastest speed or highest pressure the machine can generate. Other machines use increments of velocity (in/s or mm/s) and pressure (hydraulic or plastic), you need to become familiar with the clamp speeds and pressure settings on your machines.

In this lesson we talk about setting speeds as slow, medium, or fast; and setting pressures as low, medium, or high.

Before attempting to move the clamp, set the high and low clamp pressures. The engineering department will often give a starting point recommendation for the high clamp pressure setting on a new mold.

If no data is available, start by calculating the required tonnage by multiplying the projected area of the part(s) and runner(s) by four (4) tons per square inch to get the clamp tonnage (Figure 3).



Projected Area of Parts - $100\ in^2 + 100\ in^2 = 200\ in^2$

Clamp Tonnage = Projected Area of Parts $\times$ 4 tons/in^2
= $200\ in^2 \times 4$ tons/in^2
= 800 tons of Clamp Force

Figure 3 - Clamp Force

Next, set the low clamp pressure as low as possible. This will minimize the potential for mold damage if a part should not fully eject. Use just enough pressure to move the clamp mass and overcome frictional resistance from the tie bars and leader pins. If a lower pressure will work, use it. Ideally, the machine would be set with enough sensitivity to alarm when the molds leader pins become 'dry.'

Mold Open Distance

The first clamp movement that needs to be set is the mold open distance (Figure 4). Once the mold is properly installed, aligned, and clamped, set the initial mold open distance to at least twice the height of the core.

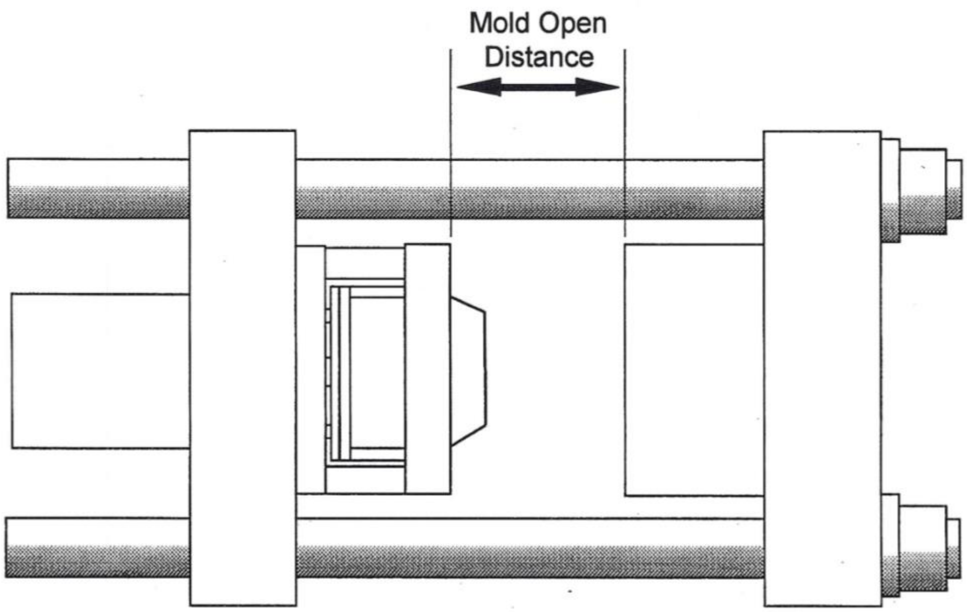


Figure 4 - Mold Open Distance

On molds with cores that are shallower than the sprue height, set the mold open stroke to a distance slightly greater than the core plus the sprue together. This will allow the parts enough room to clear the mold and drop into the bin, or be removed by hand.

On some semi-automatic jobs, the mold will need to be opened further to allow people enough room to grasp and remove the part from the mold. Likewise, if the machine utilizes a robot to remove the parts, the mold needs to open enough for the robot arm to safely enter and exit the mold.

Mold Opening Stroke

Figure 5 illustrates the mold open stroke. The first segment of mold opening is the 'slow mold breakaway.' This segment break the seal, or vacuum, as the part is released from the cavity half of the mold. The breakaway speed is kept slow so the molded part is not damaged. Start with a slow mold breakaway distance of about one-half inch.

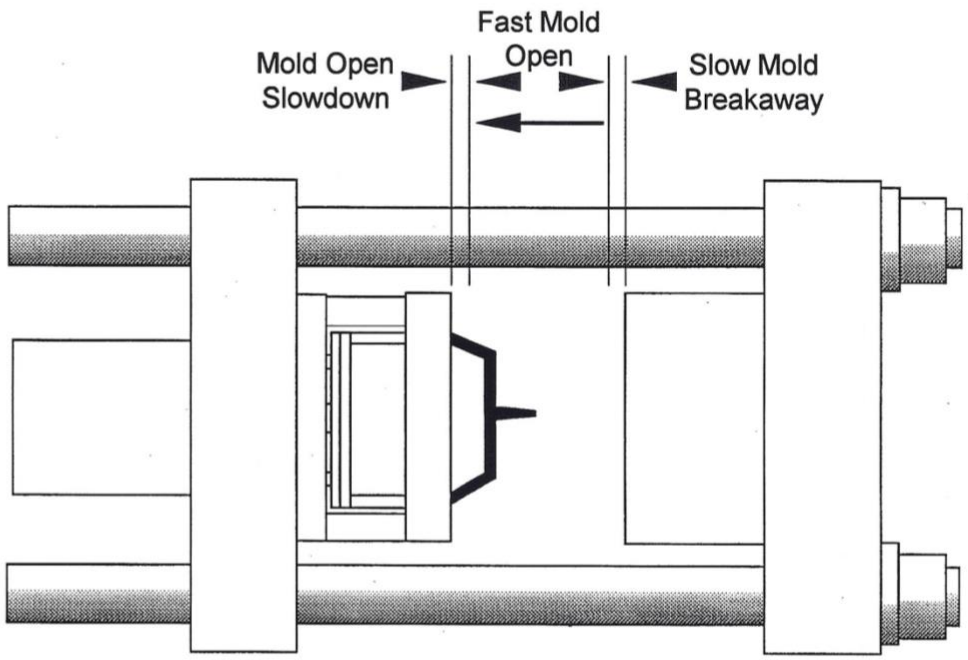


Figure 5 - Mold Opening

Most of the mold open distance should be traveled at high speed. Allow the mold to move at high speed from the end of 'slow mold breakaway' to 'mold open slowdown.'

If the mold opened all the way at full speed, the strain of going from full speed to a dead stop would shock the clamping systems. Slow the mold down to low speed a few inches before the end of the mold opening stroke.

Mold Open Timer

Initially, set plenty of time on the mold open timer. This will ensure that the mold stays open long enough for the part to eject properly. Later, the mold open time will be reduced to minimize the cycle time.

Mold Closing

Closing the mold from stopped to full speed close can be a shock to clamping systems. Starting with a slow close at a for approximately the first inch can improve performance with less wear to the molding machine. Once the mold is moving, you can close at higher speeds.

If the mold halves contact at high speed, a loud bang will be heard when the mold haves crash together likely causing damage to the mold faces. It is critical that we slow the mold well before the mold faces come together. For hydraulic presses, you need to counteract the momentum by starting the slow down sooner. Once a safe slow down distance has been established, the slow down point can be gradually set closer to the stationary mold half until the overall closing stroke is optimized.

Locking the Mold

The mold has been closing under low pressure and approximately 0.003” before the mold faces contact, high pressure will engage to lock the mold fully. If the press goes into high pressure lockup when the moveable mold half is too far away, a stuck part or runner will be crushed under full clamping pressure, which can damage the molds parting lines, cores and cavities.

It is very important to set the machines ‘High Pressure Lockup’ position sensor just large enough to allow high pressure to lock up the mold. The position sensor should initially be set low enough so the clamp will not go into high pressure. Then the position should slowly be increased until the clamp locks up. Then, add another slight increase in the position to ensure the clamp locks up every cycle. This procedure should be completed after the mold has come up to heat otherwise the mold expansion can throw off this position. Likewise, if the press has been running and is now alarming out for mold protect alarms AND you find nothing in the mold, verify that your temperature control unit (TCU) has not shut off.

Exercise One

Mold Protection

On several machines, document the high pressure lock up position (HPL). Next, decrease the position until the mold doesn't lock up, document this position. Return the machine to running condition. Lastly, calculate and document the variation by subtracting the 'Decreased HPL Position' from 'Present HPL Position.'

Machine Number	Present HPL Position	Decreased HPL Position	Variation

Instructor Date

Ejection

Most machines allow parts to fall out of the mold into a bin or onto a conveyor. Generally, the initial ejector plate movement should be set at least as far as the height of the tallest core. This will probably be reduced later. For now, this will ensure the part is ejected and falls freely from the core. Figure 6 shows the clearance needed for the part to be ejected.

If the part is being removed by hand, or if the machine is using a sprue picker or robot arm, set the ejector plate movement just large enough to break the seal between the part and the core. The part can then be grasped and lifted off the mold core. Usually 0.250 inch is enough movement to break the

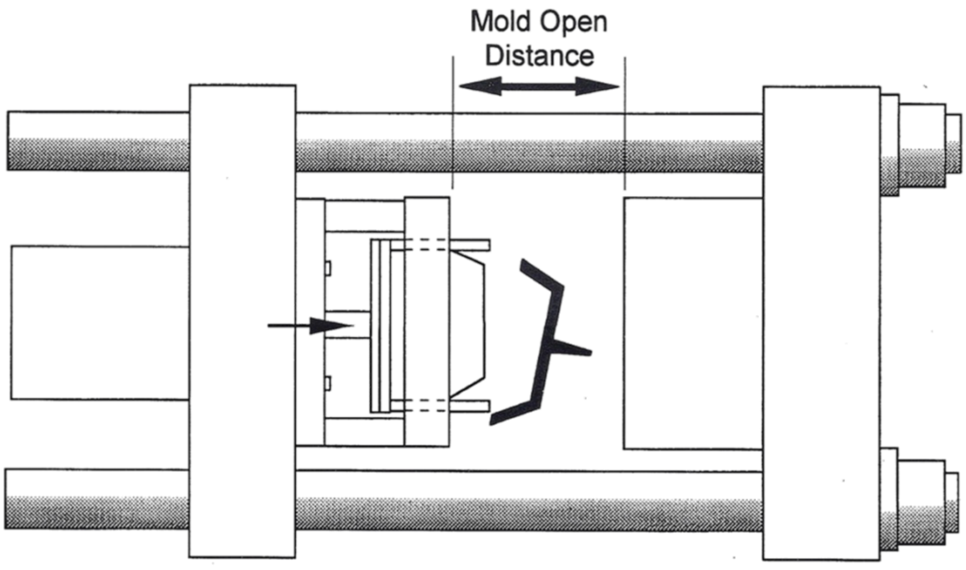


Figure 6 - Part Ejection

seal between the part and core.

Exercise Two

Ejection

On several machines, watch the part(s) as it is ejected. Estimate how much clearance there is between the part and the stationary mold as it is ejected.

Machine Number	Part Being Ejected	Clearance

Instructor Date

Objective Three

Setting the Heats

The temperatures used on the molding machine are set according to the type of plastic being molded. Plastics such as polyethylene can be run anywhere from 350° to 530°F. High temperature plastics may require process temperatures greater than 700°F. It is important to know the safe temperature range for the plastic you are molding. These ranges can be found in manufacturers temperature charts or processing manuals.

Initial Sample

For new molds, the initial barrel temperatures should start in the lower to middle range, which can be adjusted later as needed. The reason for starting at the lower temperatures is less energy consumption and shorter cycle times.

Starting with excessively low temperatures can increase the risk of screw damage if the plastic is too cold to move. It is safer to jog (suck back) the screw slowly during startup to make sure that it will turn easily if low initial barrel temperatures are used.

Starting at the higher temperature range may cause discoloration due to longer residence time but may be required if molding thin walled parts.

Once a job has been run, the heat settings can be recorded on the setup sheet for future use. Figure 7 shows an example of the different heat settings and heat soak times from a setup sheet for a polystyrene molding job.

Part: Cassette Case						Material: Polystyrene						
Barrel and Nozzle Temperatures								Mold Temp.			First Shot	
Front Zone	Middle Zone	Rear Zone	Nozzle Temp.	Nozzle Valve Temp.	Melt Temp.	Throat Temp.	Heat Soak Time	Front Half	Floating Half of Cores	Back Half	Mold Warm-up Time	Hot Runner Warm-up Time
450°F	430°F	400°F	450°F	N.A.	460°F	90°F	1 hr.	100°F	N.A.	120°F	30 min.	1 hr.

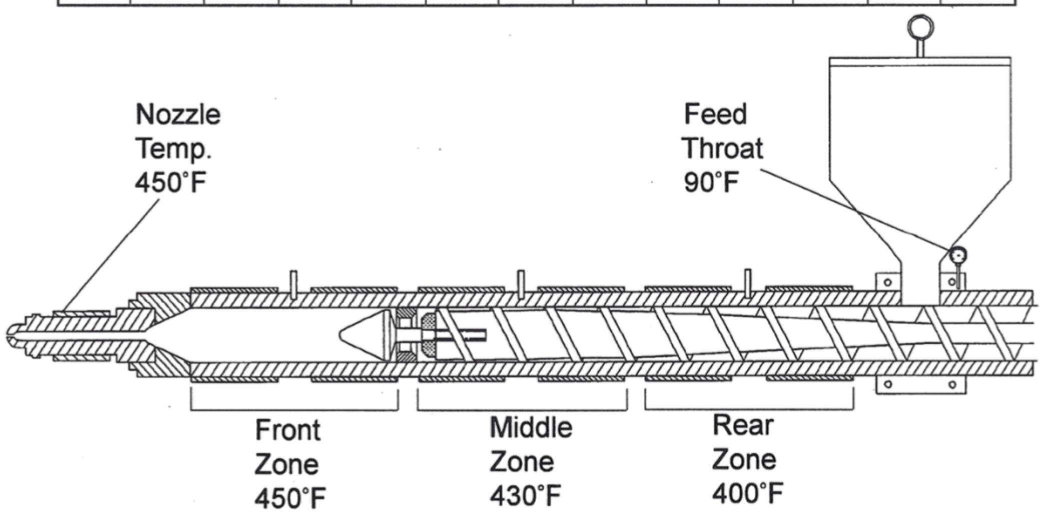


Figure 7 - Heat Settings & Soak Times

Barrel Temperatures

Each zone of the barrel is heated by a separate electric heater bands and controllers. The different temperature settings along the barrel are referred to as the heat profile. In the previous example, the front zone temperature was set close to the desired melt temperature. The temperature settings decrease 20° to 30°F per zone toward the rear of the barrel. The rear zone temperatures are set lower so that the plastic heats more gradually. Keeping the rear of the barrel cooler also decreases the chances of melting the plastic in the feed throat. There are times or materials that will require a reverse profile, it is good to refer to the material suppliers recommendations for temperature and profile settings.

Nozzle Temperatures

Since the nozzle is relatively small, its temperature setting does not affect the overall melt temperature. Set the initial nozzle temperature close to the front barrel temperature. Nozzle temperature can be raised later to avoid freeze off or lowered to minimize drooling.

Melt Temperature

Parts with tight tolerances (less than +/- 0.004”) require accurate and consistent melt temperatures. Consequently, it is important to know the actual melt temperature. In cases where high screw rotation is required, the melt temperature may be higher and on jobs where a lot of material is being processed, the actual melt temperature may be lower than the temperatures set on the temperature controllers.

One way to measure melt temperature is to purge a melt puddle to which you insert a fast response thermocouple that is attached to a thermometer that can record the highest temperature achieved. A company called Plastix sells

Mold Temperatures

The mold must be maintained at a stable temperature cycle after cycle. Mold temperature is controlled by coolant, water or oil running through internal mold channels. The coolant may be heated or chilled. Either way, the mold is still much cooler than the plastic being injected into it. Most setups start with a mold temperature in the middle of the recommended range. It may be raised later to improve flow, or decreased to improve cycle time. The two halves of the mold may even be set at different temperatures to cure problems such as parts sticking in the mold, or part warpage.

Heat Soaking

There are three areas in the system where a sizeable mass of steel needs to be heated. In these areas, the temperatures must be allowed extra time to stabilize after the set points have been reached. The three areas are the barrel, the mold, and the hot runner manifolds. Each one needs additional time for the total mass to come up to temperature, this process is called heat soaking (Figure 8).

M old and barrel temperatures directly influence the machine control parameters. Wait until the mold and barrel are at their equilibrium temperatures before setting injection speed or pressure. If injection speed and pressure are set first, they will need to be changed as temperatures continue to rise.

Some setup sheets have spaces where the minimum recommended heat soak times can be listed. Small machines might only need twenty to thirty minutes while larger machines are often allowed to heat soak an hour or two after the set points have been reached.

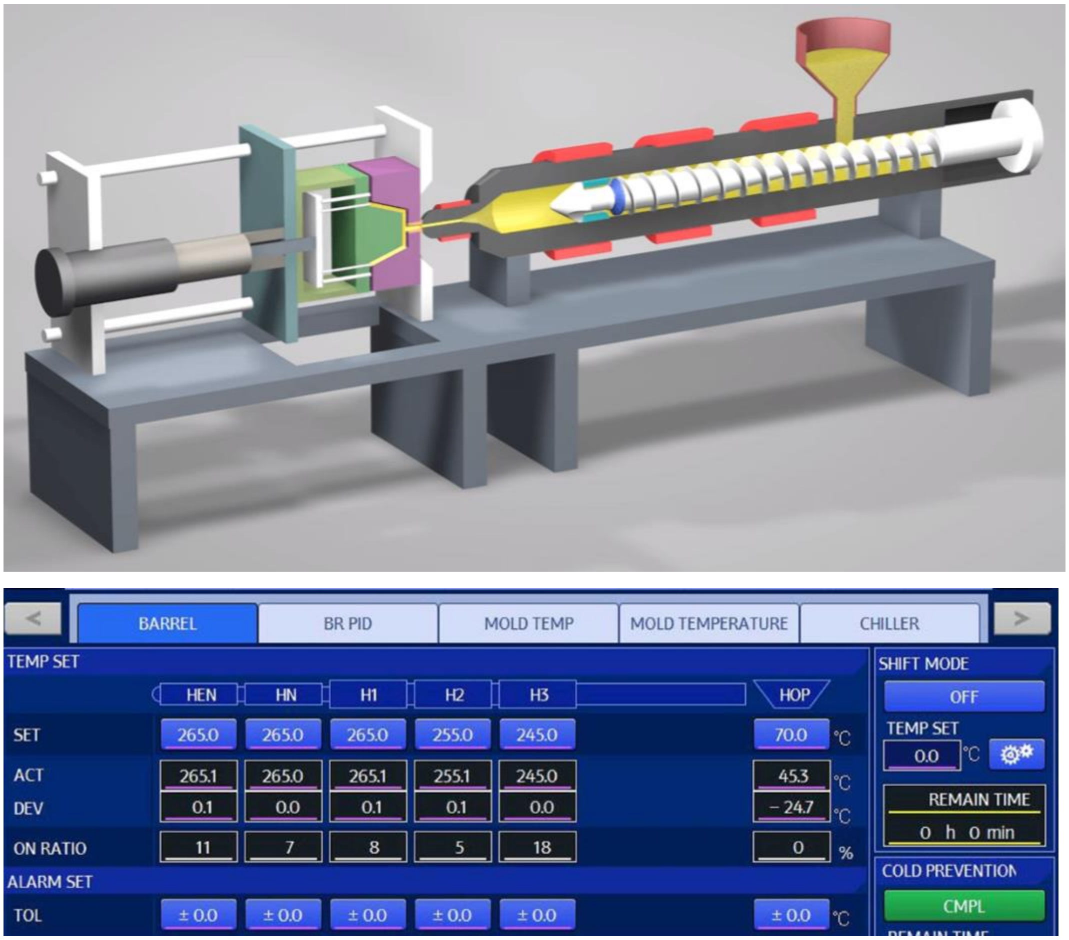


Figure 8 - Heat Soaking

Exercise Three

Temperature Settings

On several machines, record the following temperature settings.

Machine Number	Barrel Temperature			Nozzle Temperature	Mold Temperature
	Zone 1	Zone 2	Zone 3		

Instructor Date

Objective Four

Pressures, Strokes, and Cycle Timers

Setting up for Sampling

When preparing to sample a mold, many of the remaining machine controls must be preset to some starting values in order to run the molding machine. Most of these starting point settings must be estimated, the following guidelines can be used as preliminary settings for the machines controls.

Be sure to check the material supplier's processing guide for suggested processing conditions.

Initial Machine Settings for Sampling

Shot Size.................................. Large

Back Pressure .... Low

Screw Speed .... Medium

Injection Speed .... Medium

Hold Pressure .... Low

Hold Time .... Long

Mold Open Time .... Long

A detailed set of sampling procedures will be covered in a later lesson.

Timers

Initially, the timers should all be set longer than anticipated. This generally removes "time" as a potential factor in the development process. Times that are too short can cause confusion during startup as they can create short shots, sink marks, or warp even if the pressure and speed controls are set properly. Excessively long cycle times generally will only affect dimensional accuracy. The cycle times can be reduced later once a relatively good part is coming out of the mold.

Shot Size

Use a large enough initial shot size to ensure enough material is available to fill the cavity, decompression is to be used as needed. Later, after first shots are made, if the screw bottoms out and the cavities do not fill, increase the shot size until a cushion is achieved.

Back pressure should start around 500 plastic pressure (ppsi) and increased to improve shot to shot variation.

Screw rpm should be set so the screw recovers just before cool time is completed.

Injection speed is the velocity required to inject a volume of material into the mold at a given time. Velocities should initially be set to medium so that short shots will be produced first and then filled out as the sampling continues.

If the first shot flashes the mold, the transfer position will need adjusting. It is preferred fill the cavity under injection velocity and add hold pressure to pack the part out. The point where this occurs is the Velocity to Pressure transfer, the VP.

Plastic materials are non-Newtonian meaning the flow easier as the velocity is increased, always run as fast as possible.

Exercise Four

Timers

On several machines, record the current settings for the following timers.

Machine Number	Hold Time	Cool Time	Screw Rotate Delay Time	Eject Delay Time	Close Delay Time

Instructor Date

Pack Pressure – Hold Time

Once the part is filled under velocity, pressure is applied to pack out the part, at a reduced injection rate. Once packed, hold pressure is applied to keep the cavity full while the part shrinks. This continues until the gate is froze at which time the process changes to 'cool time.'

Cool Time – Mold Temperature

Cool time is dependent on melt temperature and mold temperature. A hot mold requires more cool time and a cold mold requires less. In both cases, the cool time has to be sufficient for the plastic to solidify and eject from the mold without deformation.

Mold temperature affects mold filling and cooling. Hard to fill molds may require hotter melt and mold temperatures.

Exercise Five

Pressure Settings

Examine several machines, describe the exact location of each of the following and record the current settings.

Machine Number	Transfer Pressure	Transfer Position	Hold Pressure	Back Pressure	Screw RPM

Instructor Date

Objective Five

Documenting and Moving to Another Press

Documenting the Process

Once the process is developed and meets your customers requirements, it needs to be documented. The goal of documentation is to relay important information to the production floor so they can set up and run the molding process. The key point in the previous sentence is 'important' as this means different things to different people/companies.

Setting Pressures, Feeds, and Speeds from a Setup Sheet

Molding machines use a combination of position sensors, timers, velocities, pressures and temperatures that in the right combination mold good parts.

Speeds, or velocities, often have a corresponding pressure and time associated with it. For example, we may have entered our injection velocities at 4 in/s for a stroke of 3 in. add to the velocity a monitor for transfer pressure and fill time and if the molding machine doesn't make the stroke position or has too high of pressure the monitor will stop the process before damage occurs.

Setting Cycle Timers from a Setup Sheet

Most machines only approximately four timers to control a machine. These are Injection Delay Time, Hold Time, Cool

Time and Screw Recovery Time, which are typically set within a tenth or hundredth of a second.

Set ups for a Different Machine

The molding technician may be required to run an existing process/machine combination in a different machine. Depending on machine differences, some settings may be nearly identical, while others impossible to transpose.

Temperatures are the result of actual temperatures (melt and water) documented during development.

Machine tonnage can be adjusted to match the original machine.

Shot sizes are a set volume and the key is to replicate the volume from the original process. The danger is if you move to a larger machine, does the new machine have too much volume causing too much residence time.

Injection speed is the result of available pressure to meet the fill time requirement of the original press. Larger barrel sizes generally have less available pressure and you might find yourself pressure limited. If this is the case, do not move to that machine unless you can decrease the transfer pressure.

Other techniques can be used, such as proportioning. For example, if the injection pressure on the first machine was set at 60 (on a 1 to 100 scale) and the second machine used a direct pressure, (from l to 20,000 psi) then a proportion calculation can be made. In this case 60 is to l00 as X is to

20,000. Therefore, X (the desired pressure setting on the new machine) is equal to 12,000 psi.

You should use as much information from the original setup sheet as possible. The more often you go back and forth between different machines, the easier the transition becomes. A new setup sheet should always be made for the specific machine mold/machine combination.

Self-Test

1. Sampling a new mold:
   a. Requires sample, metrology and reporting time
   b. Is commonly done by new technicians
   c. Is not usually necessary if the mold is designed well
2. If all the information on the setup sheet is programmed into the machine controls, the process should produce acceptable parts.
   a. True
   b. False
3. What is the common rule for setting clamp tonnage per unit of projected area?
   a. 3-4 tons/in^2
   b. 7-8 tons/in^2
   c. 10-12 tons/in^2
4. Mold open distance stroke is initially set greater than:
   a. The core height
   b. 2x the core height
   c. 4x the core height

5. Slow mold breakaway is important because it:
   a. Breaks the vacuum seal on the parts
   b. Saves clamp stroke energy
   c. Improves the cycle time
6. When closing the mold, how far should the mold halves be apart when the high pressure is activated?
   a. 1.000 inch
   b. 0.125 inch
   c. 0.003 inch
7. The heats on a machine have just reached their startup set points. What will happen if parts are molded immediately?
   a. Good parts will be made and downtime will be minimized
   b. No soak time could break the screw
   c. The melt isn't homogenized, shear is required
8. The recommended melt temperature range for a material is 300° - 500°F. Where should the initial sample temperature be set?
   a. 300°F. - this will save energy
   b. 400°F. - this is a safe starting point
   c. 500°F. - this will melt the plastic fast so the machine can be started sooner

9. A molding machine has been set according to the set-up sheet data and has heat soaked. The molded parts have sink marks, what should be done first?
   a. Increase the hold pressure slightly
   b. Increase hold time by 0.5 seconds
   c. Verify there is a cushion
10. An existing mold is set up in a machine that is larger than the one it ran in before. Which one of the following parameters would be the most important to replicate from the old set-up sheet?
   a. Fill time
   b. Shot Volume
   c. Hold time

Glossary

Heat Soak - the extra time used to heat the barrel or mold completely after the set points have been reached.

Log Sheet - an information sheet containing the problems encountered and the solutions or parameter changes used to correct them.

High Pressure Lockup (HPL) - the clamp position where the clamp transfers to high pressure to reach tonnage.

Projected Area - the total area of parts and runners.

Sampling - the trial procedures used to determine the initial molding parameters for a new mold.

Set-up Sheet - the sheet that documents the important molding parameters used to run the mold successfully.