The Molding Process

LESSON 5: Operation Controls

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There are many different types of injection molding machines used in the manufacturing world. This lesson will cover the major control functions that are common to all of them.

Each machine has some form of electronic control device used to regulate the order of operations in its cycle. Most of the move-ments of the machine are powered by hydraulics. The first two objectives of this lesson will discuss the interaction of the machine and the injection controls. The remaining objectives will cover the specific controls used to set the major variables of time, temperature, pressure, and distance.

Objectives of Lesson 5

1. Understand different types of machine control
2. Understand basics of hydraulics and machine movements
3. Understand basics of electric servo drives and machine movements
4. Learn how pressures are used to control the molding process
5. Learn how timers are used to control the molding machine
6. Learn how machine and the mold temperature is controlled
7. Position, speed and force settings effect on the molding process

Objective One

The Controls

Controlling the injection molding process requires meticulous attention to various parameters. Setting up your temperatures, pressures and speeds correctly will allow you to maintain a consistent process that produces high-quality results at the determined cycle time.

Technical advancements in molding machine controls provides users smart systems such as artificial intelligence (AI) and real-time monitoring which enhances the efficiency and reliability of injection molding processes. Continuous efforts to learn and utilize these systems to optimize your processes will contribute to the overall success and competitiveness of your company.

Elements of Control.

1. **Temperature Control:**
    a. **Melt Temperature Control:** Plastic melt control is essential for uniform (homogenous) plastic melt. Maintaining the correct temperature prevents incomplete melting or thermal degradation.
    b. **Mold Temperature Control:** Mold temperature affects part crystallinity, shrinkage, and cycle time. Maintaining consistent mold temperatures are important to the dimensional and mechanical characteristics of the molded product.

2. **Injection Speed Control:** Injection speed affects melt viscosity and the filling pattern of the part. Adjusting injection speed can prevent flow lines and trapped air.
3. **Cool Time Control:** Cooling time is the time required to solidify the part. Cool time influences warp, pin push, dimensions and the overall process cycle time.
4. **Screw Recover Control**
    a. **Speed Control:** Rotational speed (RPM) of the screw affects the material's shear. Screw speed is the result of material, additives, and screw design.
    b. **Back Pressure Control:** Back pressure ensures proper mixing of the molten plastic. Back pressure improves the consistency of the shot by preventing voids within the molded part.
5. **IMM Calibration:** regular calibration of the injection molding machine is crucial for maintaining accuracy in the process. Calibration includes the molding machine's pressure, temperature, timing and positions. .
6. **Monitoring and Control Systems:** utilizing the machines monitoring and control systems allows real-time tracking of various parameters. Monitoring of process parameters facilitates actions such as part rejection or press alarming reducing the potential for defect products escaping to your customers.

Exercise One

Monitors

On several machines, document the following parameters and their range and state if the monitor is on.

Machine Number			
Material Type			
First Barrel Temp & Range			
Fill Time & Range			
Cushion Size & Range			
Screw Speed & Range			
Back Pressure & Range			
Does machine have AI?			

Instructor Date

Objective Two - Understand basics of hydraulics and machine movement

IMM Hydraulics

High pressures are required to close the clamp, rotate the screw, and inject the plastic. The hydraulic system on the molding machine provides the high pressures and controls to accomplish these functions.

Hydraulic Pump

The heart of the hydraulic system is the pump. A common type of pump is the sliding vane pump (Figure 1) The vanes catch the oil in a large volume on the inlet side, and squeeze it into a small volume on the outlet side, creating the high pressure.

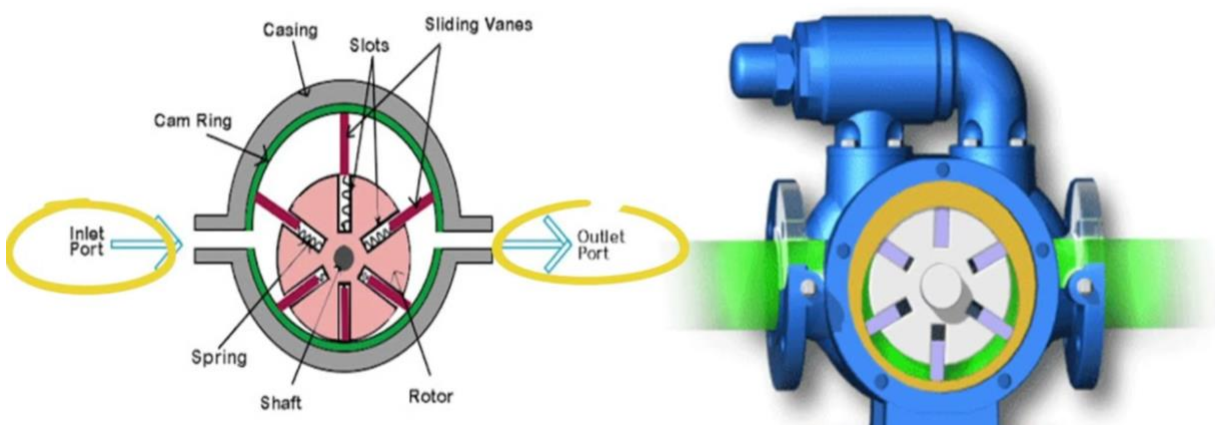


Figure 1 - Sliding Vane Type Pump Cut-away

It is important to understand the difference between speed, volume, and pressure. Smaller pumps can operate at higher pressure than larger pumps, the pressure depends on the torque of the pump shaft and how the pressure relief valves are set.

Pressure Relief Valves

In Figure 2, the relief valve opens automatically when the relief pressure is reached. The relief valve returns some of the outlet fluid to the inlet side of the pump. Most machine hydraulic systems are capable of generating 2,000 psi.

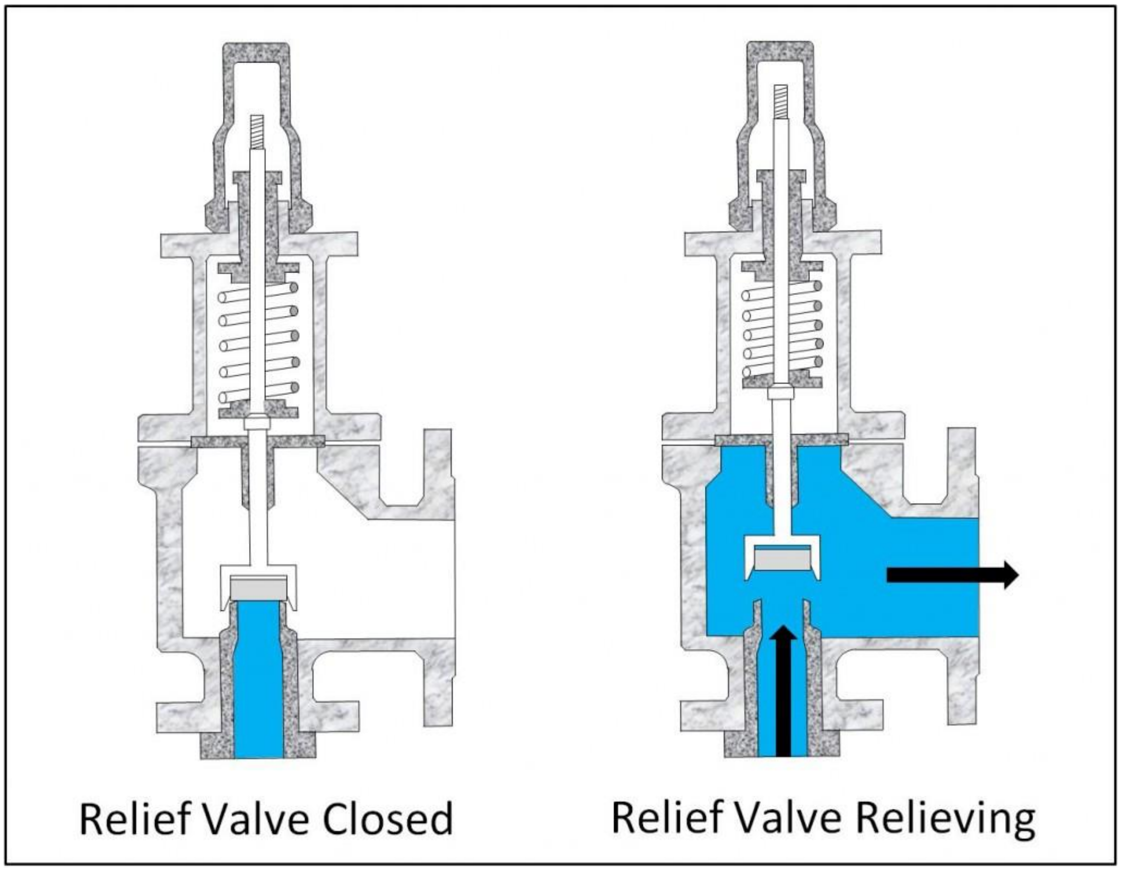


Figure 2 - Pressure Relief Valve

Exercise Two

Hydraulic Pumps

On several machines, describe where the pumps are located and how many there are on each machine.

Machine Number	Location of Pumps	Number of Pumps

Instructor Date

Pressure Controls

Injection molding machines utilize a hydraulic pump or servo motor to control the injection of molten plastic into the cavity, and to hold it there while it cools.

The pressures are generated by the pump that while idling, the output from the pump is diverted, under low pressure, back to the reservoir (Figure 3).

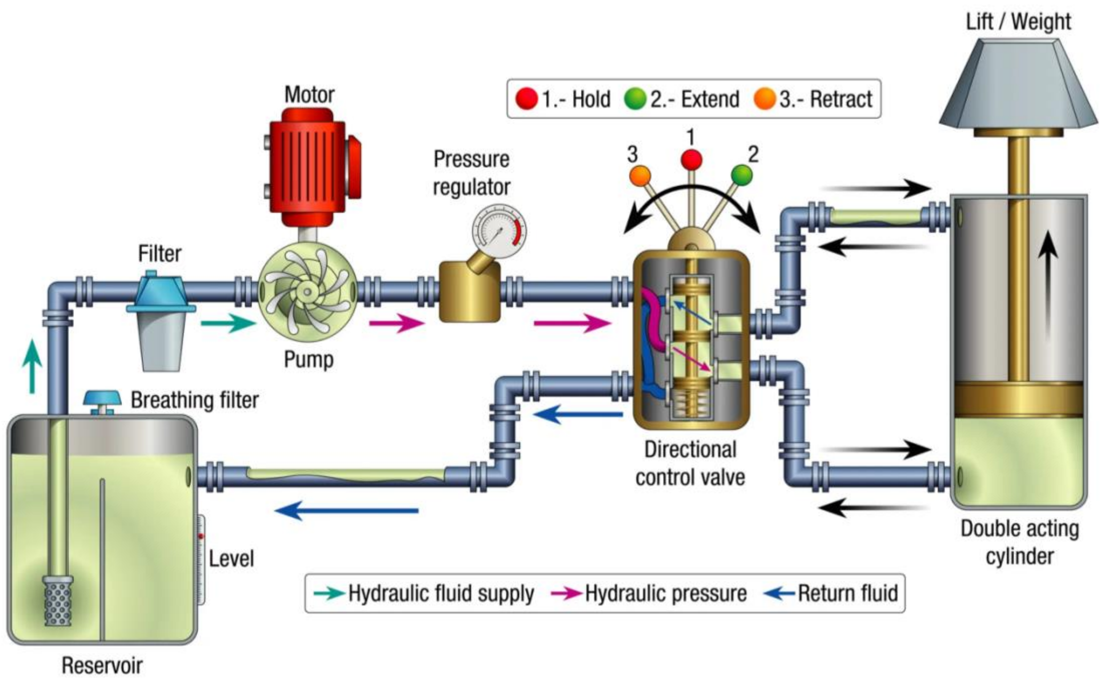


Figure 3 - Diagram of IMM Oil Flow

A problem with standard hydraulic machines is their limited supply of hydraulic pressure to acuate cylinders and motors. If there is a need to run multiple actions simultaneously, for example opening a mold while rotating the screw, the available pressure is divided between the two actions. If multiple actions need to occur, machine manufacturers will add hydraulic accumulators (Figure 4) to a molding machine to provide stored hydraulic energy to the hydraulic system which allows technicians to operate multiple hydraulic actions simultaneously.

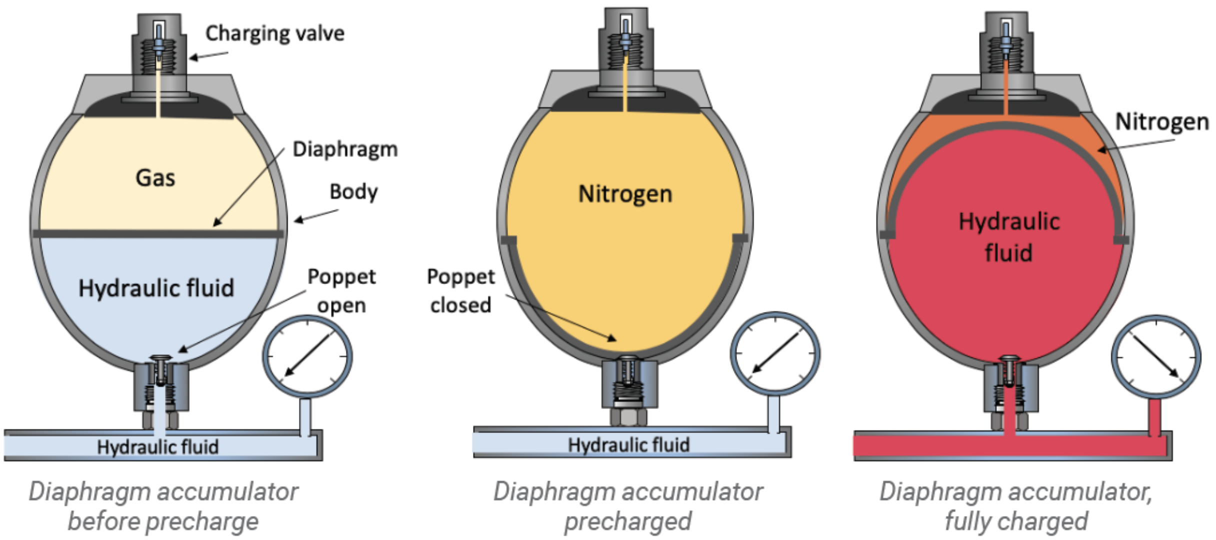


Figure 4 - Hydraulic Accumulator

Movement Controls

Hydraulic movement occurs via oil flow to one side of a hydraulic actuator. The control of the oil is managed by the electromagnetic movement of a spool in a solenoid. This spool directs the flow of oil to the cylinder. The diagram in Figure 5 shows how the flow is directed through the hydraulic system.

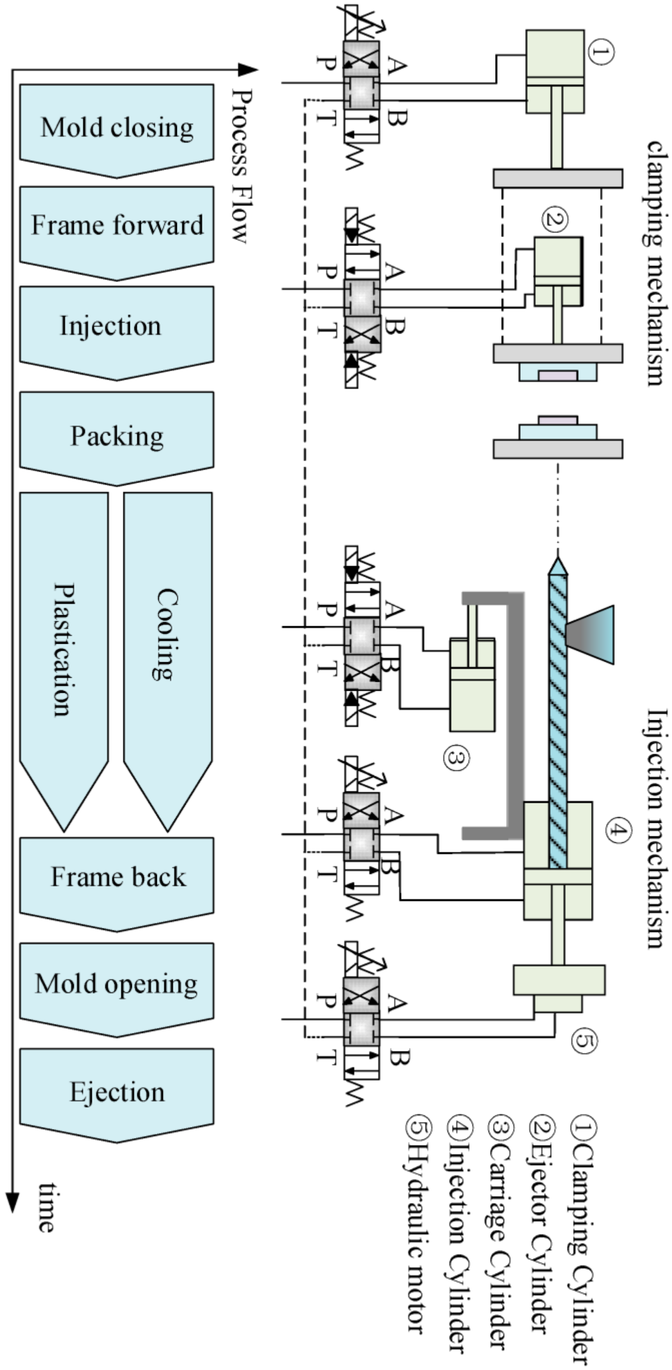


Figure 5 - Valve Actions & Movements

Objective 3 - Understand basics of electric servo drives and machine movements

Electric Machine Configurations

Full Electric – these molding machines have their three main axes (clamp, injection, and metering) driven by servo motors.

Hybrid – these molding machines have one or more of their main axes driven by hydraulics with at least one electric-driven axis.

Servo Hydraulic – these molding machines incorporate a servo motor to drive the hydraulic pump, which then acts like a standard hydraulic molding machine.

Benefits of Electric Machines:

- Energy Efficiency – electric machines require 40 to 55% more efficient than equivalent hydraulic machines.
- Repeatability – electric machines are 10x more repeatable than hydraulic machines.
- Noise Levels – hydraulic machines generate 90-100 decibels (dB) whereas electric machines generate 60-70dB.
- Speed/Acceleration – Comparing standard machines, the speed and acceleration of an electric machine is greater than a hydraulic machine. However, hydraulic machines that incorporate accumulators (pressure

storage devices) can, at a greater cost, perform as an electric machine.

- Parallel Movements – Because each servo driven axis is unique to its movement, multiple movements can occur simultaneously. Hydraulics, on the other hand, have to share the available pressure which often requires the axis to operate in series.

An electric drive system (Figure 6) consists of:

- HMI control panel
- PLC controller
- Servo controller
- Sensor
- Servo motor

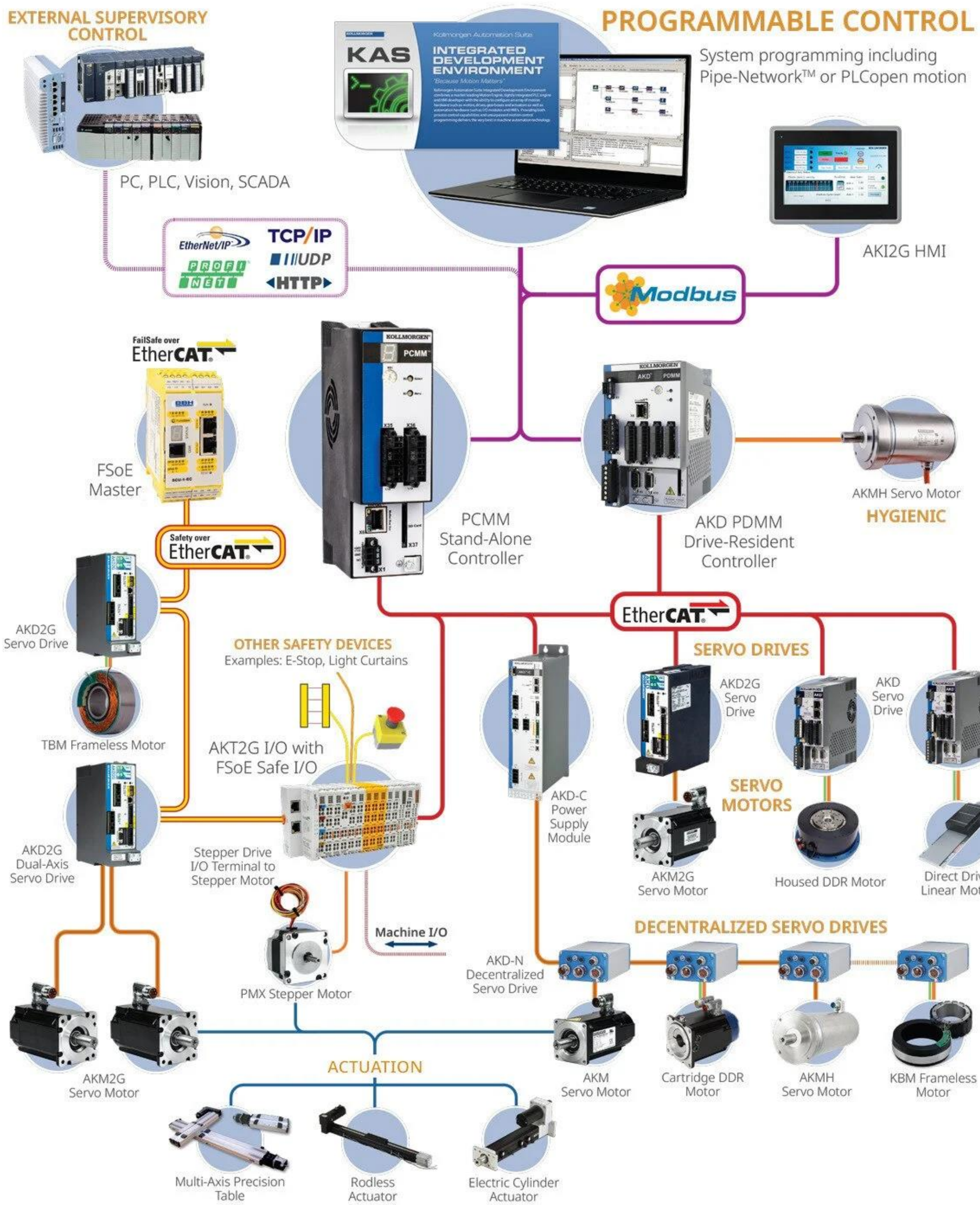


Figure 6 - Servo Drive Control System

Rotary to Linear Movement

The movement of the clamp, screw and ejectors is the result of rotational movement that is translated to linear movement via a ball screw (Figure 7).

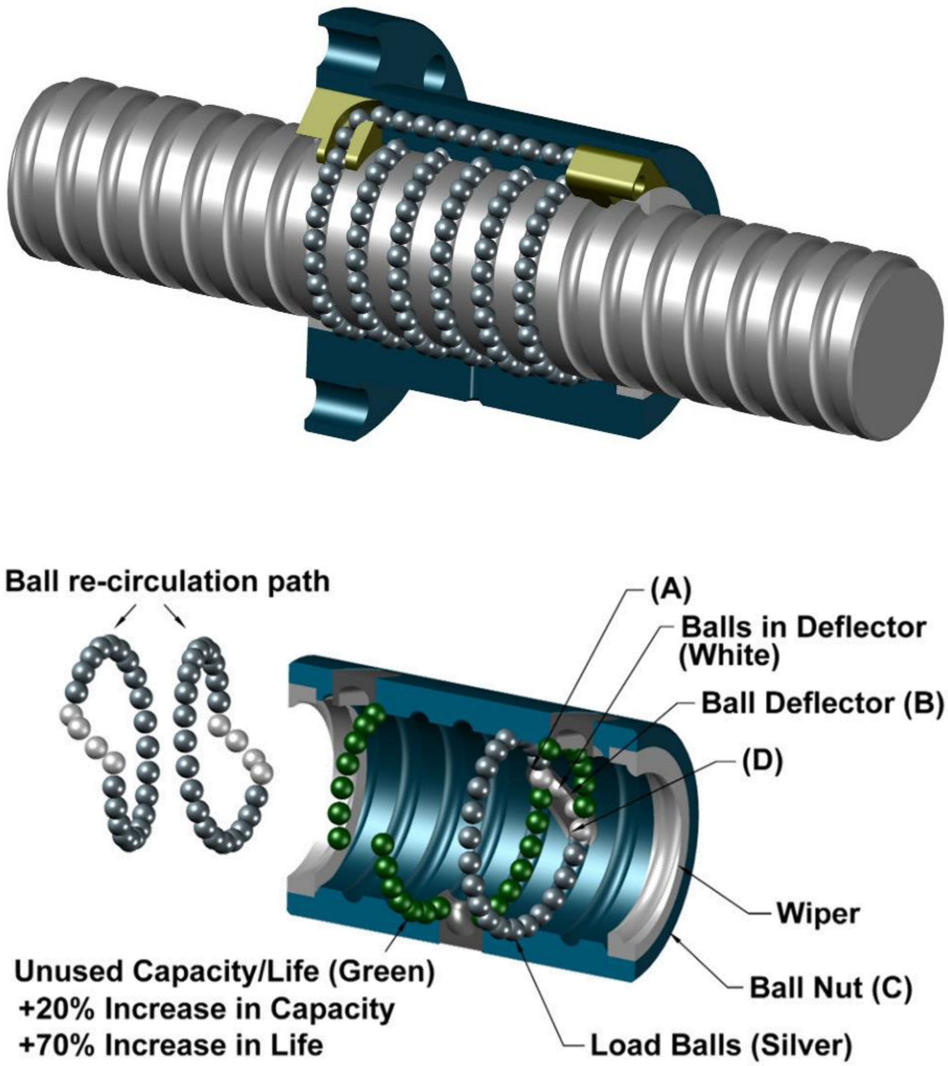


Figure 7 - Ball Screw Action

Exercise Three

Press Types

Review eight different machines on your production floor and identify the machine number, machine brand (e.g. Toshiba) and place a "Yes" in the cell to identify the type of machine (hydraulic, electric, or hybrid).

Machine Number	Brand & Tonnage	Hydraulic	Electric	Hybrid

Instructor Date

Objective Four - Learn how pressures are used to control the molding process

Regardless of the type or brand of molding machine, they all control pressures (or forces) to safely close/open the mold, fill/pressurize the mold and eject the molded part. This section will discuss these movements and the associated safeties.

Clamp Pressures

The most economically produced part is the part that is molded the quickest. Consequently, technicians should move the clamp the shortest distance and as fast as possible. Here is where the dilemma begins. Technicians believe it is okay to ignore mold protection to achieve faster cycle times.

To set mold protection, there are three things to consider which are:

1. Where to start mold protection | mold protection should start at the point where the two mold halves engage each other
2. Where to end mold protection | there is a position where the mold halves touch, often called high pressure lock up or the 'kiss' point
3. What are the speeds and pressures used between these two points | depending on the complexity of the mold, between these two points you can vary the

pressures and speeds to achieve a fast closing cycle that is protective of the mold and machine

How does one check their skills at setting mold protection? I have often heard technicians say they will put a sprue on the face of the mold or a ‘zip’ tie around a leader pin and close the mold. If the machine alarms, then mold protect is set correctly.

What this tells us is, if there is something obstructing the mold that is a ¼ inch thick, we can catch it. However, what if you have a delicate core pin, say a pin that has a diameter of 0.013 inch and it were to break and fall into the mold, wouldn’t you expect your mold protection to ‘catch’ this event instead of locking up on the core pin?

A better way to check mold protection is to decrease your high pressure lock up position to a set value, while the press is running, and expect it to alarm. For electric machines and machines less than 300T, if the press is set-up correctly you can decrease this position by 0.003 inch and the press will alarm. For larger hydraulic presses, you should be able to decrease the position by 0.01 inch and the machine should alarm.

A last note on clamp movement, unless the machine is designed with built in ‘ramps,’ you should begin and end the mold movements slowly to avoid ‘shocking’ the press during the movements.

Injection Pressures

There are two key points for the injection of 'melt' into a mold: we inject a **<u>volume</u>** of 'melt' into the mold at a given **<u>time</u>**.

Let's start with the concept of 'velocity' control. During the injection process, we want the machine to utilize all of its available pressure to meet the velocity (fill time) requirements.

For example, let's say our molding process requires 13,000psi to inject a volume of material in 0.8 seconds. During our next production run, the material is more viscous (harder to inject) and our process requires 14,000psi to inject the same volume of material at 0.8 seconds. The fill time is the same for both material lots but the pressure to achieve the time is greater for the more viscous material.

Once the required volume (shot) is achieved, the machine transfers from Velocity to Pressure control, this position is known as the V-P position. There are only two transfer options that should be used which are 'positional' control or 'cavity' control. The cavity control utilizes cavity pressure or cavity temperature sensors to determine the required volume.

Many machines will allow you to control the V-P by the options stated above and two additional options: 1) Time Control and 2) Pressure Control. These two should only be used as safety backups and require 'parallel cut-off' to be switched on.

Volume

Barrel capacity or shot volume varies between machines with different size screws. In Figure 8, the smallest syringe is 2ml and the largest is 20ml. Of course with all four syringes you can measure and dispense 2ml of fluid but your accuracy of drawing 2ml in the 20ml syringe is going to be less than if you were using the 2ml syringe. Likewise, drawing 20ml of fluid is not possible in the 2ml syringe (unless you draw 2ml ten times).

Figure 8 - Syringe Shot Volumes

This example demonstrates the difficulty in moving a mold from one machine to another, you must replicate the same shot volume and residence time, as well as many other process variables.

Hold Pressure

Once the process achieves its V-P transfer, the process begins to hold pressure on the cavity to make up material while the part shrinks in the mold. This process continues until the gate freezes, not allowing additional material in the mold.

Back Pressure

As the screw is rotated, it augers material down the screw and through the check ring depositing material in front of the screw. As the screw augers the material, pressure builds up in front of the screw which pushes the screw backward.

Back pressure is the amount of resistance applied against the screw which increases the pressure required to push the screw backward. Hence, back pressure. Increasing the back pressure can have positive effects on the melt such as:

1) a denser shot of material with an added benefit of pushing gases out of the melt
2) a denser shot reduces the variability of the melt making a more consistent molded part
3) the shear associate with working the material harder improves the homogeneity of the melt

There is a fine line that you need to maintain, too much shear to the material can degrade the material causing burning of the material and the breaking of the polymer chains which decreases the mechanical properties of the material. Check the material suppliers recommendation when developing your molding process.

Ejection Pressure

The pressure required to demold the part should be just enough to push the part off the core without hesitation or damage to the part.

Exercise Four

Pressures

Review eight different processes on your production floor and document their pressure settings.

Part Wall Thickness	Inj. Pressure at V-P	Hold Pressure	Back Pressure	Ejection Pressure

Instructor Date

Objective Five - Learn how timers are used to control the molding machine

Cycle Timers

In this section we will identify several different types of machine timers. A detailed discussion of the complete machine cycle is covered in the next lesson. Graphical representation in shown in Figure 8.

Fill Time Monitor

The fill time is the amount of time the machine is injecting melted plastic into the cavities regardless of the pressure required to fill the cavity. The fill time monitor manages the time required to fill the cavity so that a change in material viscosity, a sudden decrease in shot volume, or a blocked cavity will cause the machine to shut down without damaging the mold or machine.

This timer is set to a company predetermined tolerance after the machine stabilizes. After all, this timer is not meant to 'determine' part quality but to notify a technician when something has changed.

Hold Timer

The hold timer takes over when the fill of the part is approximately 96 to 98% full. The hold time is the amount of time that machine holds pressure on the plastic and is determined via a gate freeze study.

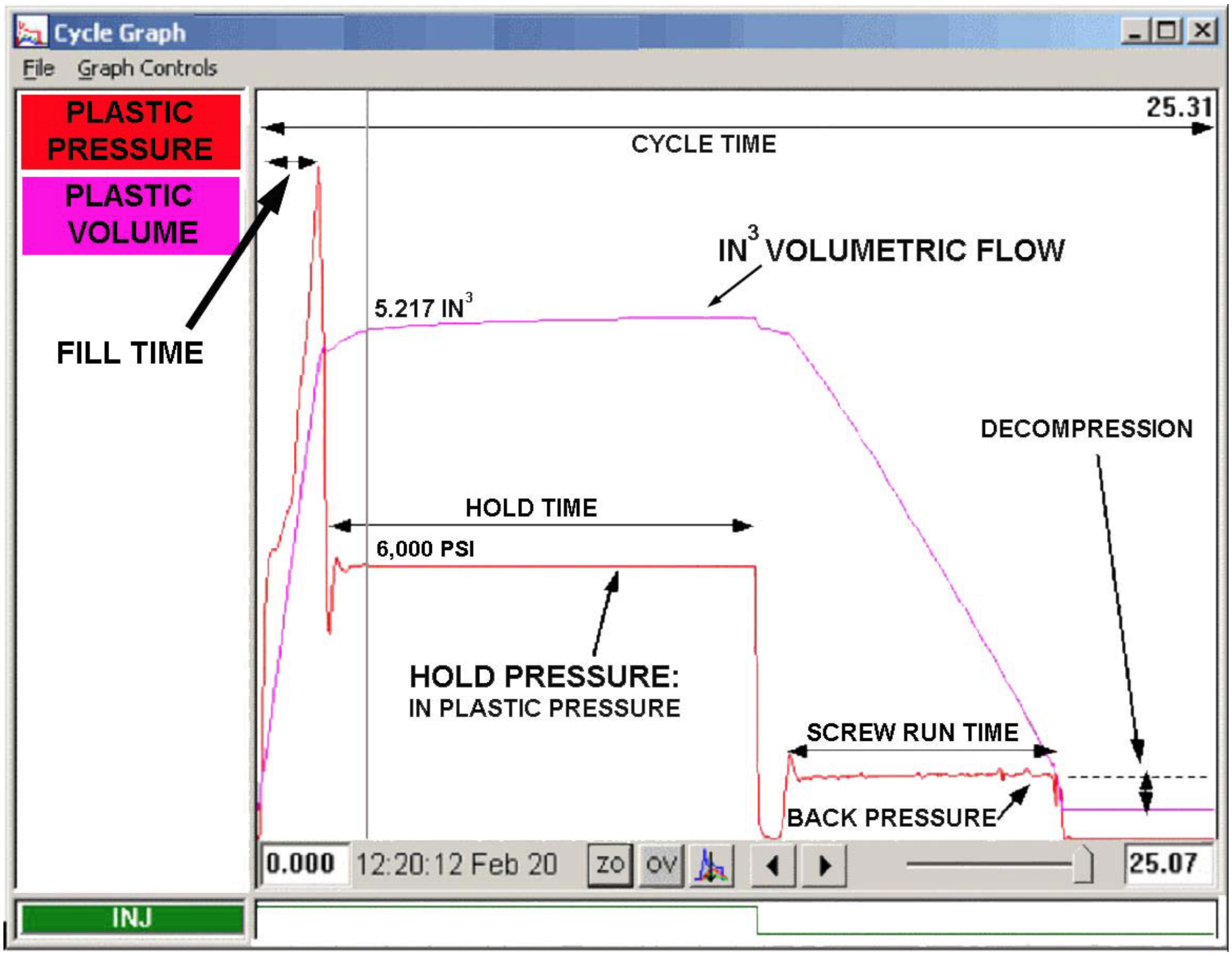


Figure 9 - Graphical Display of Timers

Cooling Timer

On most machines the cooling timer starts when the hold pressure timers has completed. The cooling time continues until the part is solidified at which time the mold opens to eject the parts.

Mold Open Timer

Mold open timers are generally used to allow enough time for the parts to drop after ejection.

Exercise Five

Timers

On five different brands or models of machines, write down their labels for the timers listed in the table.

Machine & Model	Fill Time	Hold Time	Cool Time

Instructor Date

Objective Six - Learn how Machine and Mold Temperature is Controlled

How Barrels, Hot Runners and Molds are Heated

In all instances, when we are heating the barrel on the injection unit of the molding machine or the mold, we are heating steel through processes known as conduction and convection (Figure 10).

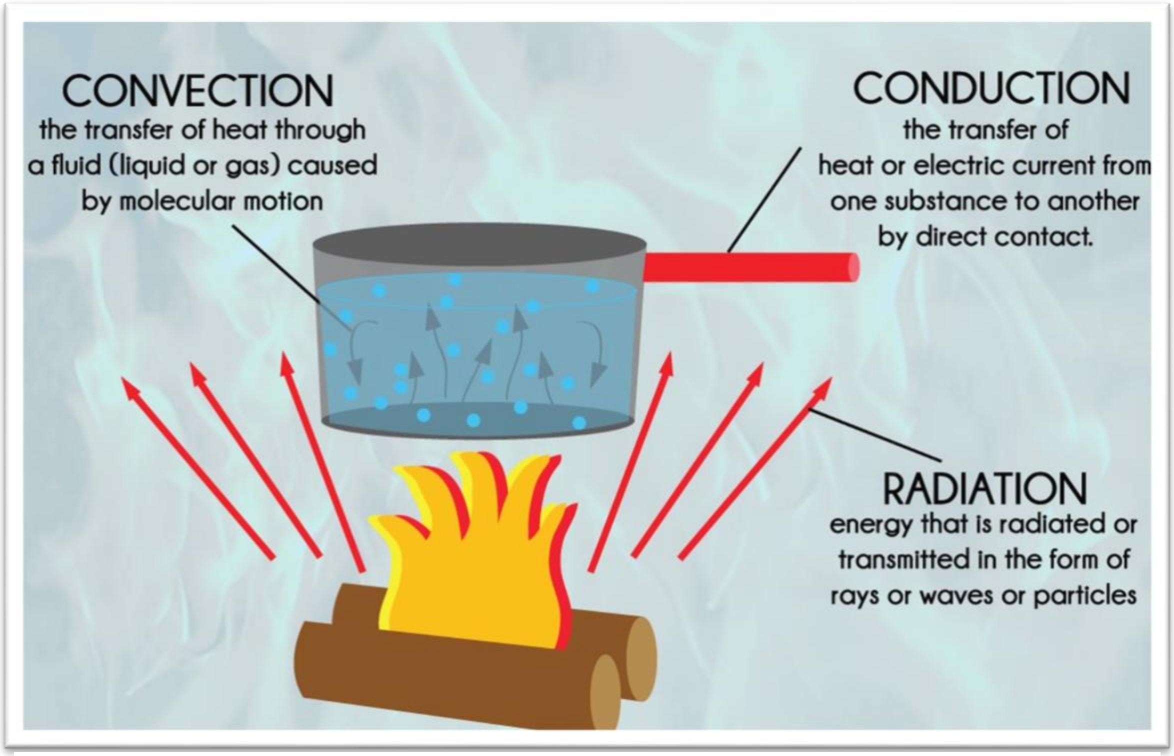


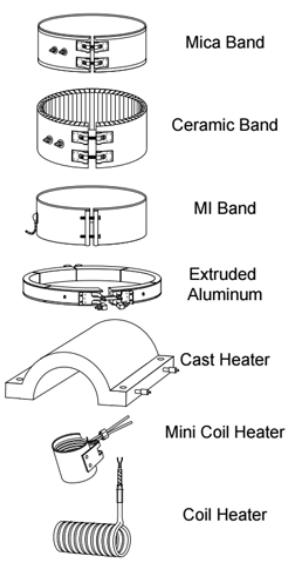
Figure 10 - Types of Heat Transfer

Barrel and Hot Runner Heating

Electrical heating is accomplished by energy flowing through a resistive grouping of wires which transfers energy to heat. These groupings of resistive wires are called 'heater-bands.'

There are many different types of heater bands (Table 1) and not all types of heaters are good for all applications.

Table 1 - Heater Specifications



	Max Watt Density	Max Sheath Temp	Min/Max Diameter	Min/Max Width
Mica Band	55 W/in^2	900° F	3/4" to 44"	5/8" to 15"
Ceramic Band	65 W/in^2	1400° F	2" to 44"	1" to --
MI Band	230 W/in^2	1400° F	1" to 28"	1" to 7"
Extruded Aluminum	40 W/in^2	650° F	3-1/2" to --	3/4" to 4"
Cast Heater	45 W/in^2	1350° F	1" to 48"	2-1/2" to 36"
Mini Coil	75 W/in^2	1200° F	1/8" to --	.040" to --
Coil Heater	75 W/in^2	1200° F	1/8" to --	.040" to --

Consequently, when we replace a worn heater band, it is important to replace it with a 'like' band. For example, from the table, you can see that we could easily replace a worn ceramic heater band with a mineral insulated (MI) heater band. Doing so may cause a problem for our process because of the difference in Watt Density (W/in^2). If we simply swapped out these bands, the controller could have a hard time managing the power supplied to the heater band causing too much variation in our process.

So, when replacing heater bands, make sure you are replacing 'like-for-like' based on the machine manufacturers recommendations.

Heater Band Components

Heater bands are simple devices that consist of terminal boxes or wires, insulation, resistance wires, protective housings and if large enough, a strap for tightening the heater band onto the barrel of a machine (Figure 11).

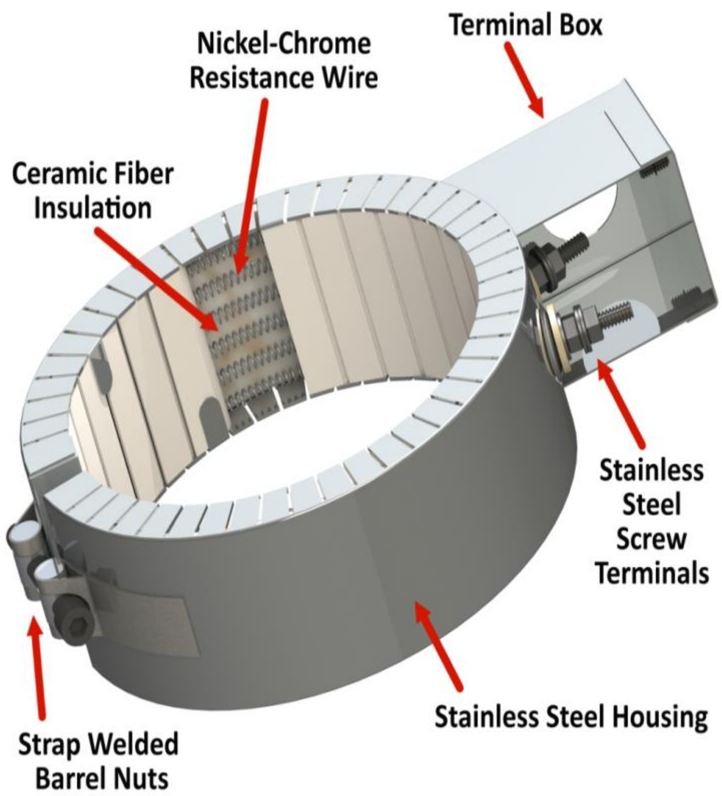


Figure 11 - Heater Band Components

Thermocouples

Thermocouples provide feedback to a controller in the form of potential difference (Figure 12). A thermocouple consists of two wires of equal length but different metals. On one end they are connected together at a 'hot' junction and on the opposite end the feed into a device at a 'cold' junction that can measure the number of electrons of each wire at the cold junction from which it can calculate the temperature based on the difference (potential) between both wires. The most common types of thermocouples used in our industry is the 'Type J' which consists of iron wire for the positive leg and constantan wire (Cu-Ni) for the negative leg.

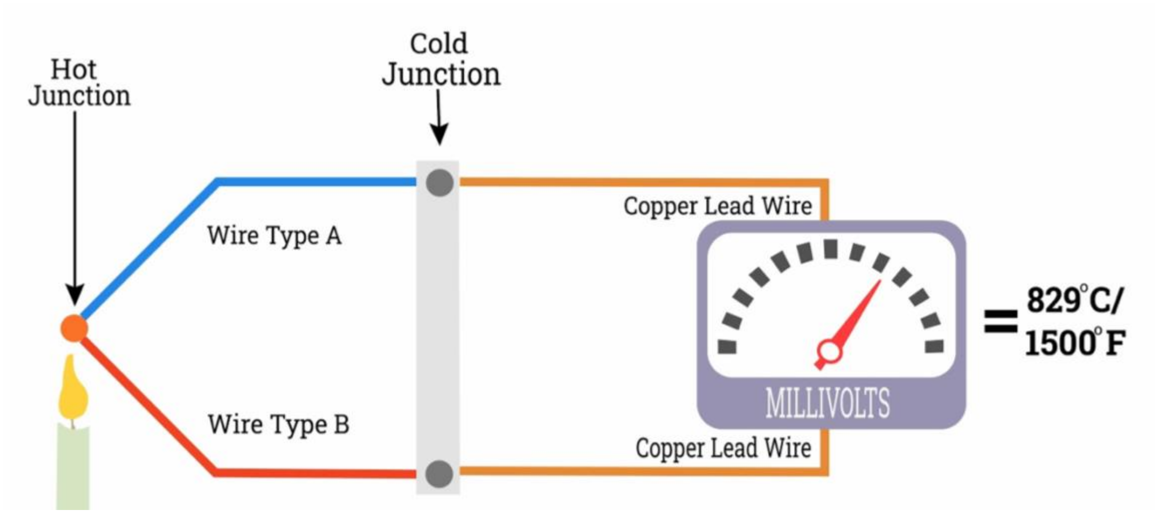


Figure 12 - Thermocouple Schematic

When replacing thermocouples, always make sure you replace it with the same type.

Proportional-Integral-Derivative (PID) Control

There are three elements to PID control which are:

- Proportional control, which reacts to current error
- Integral control, which addresses accumulated past errors
- Derivative control, which predicts future errors

When heater bands or thermocouple are changed the PID should be tuned which is generally well defined in the machine manufactures manual. The key is to take your time or you will re-run the process after it fails. Figure 13 shows the PID process.

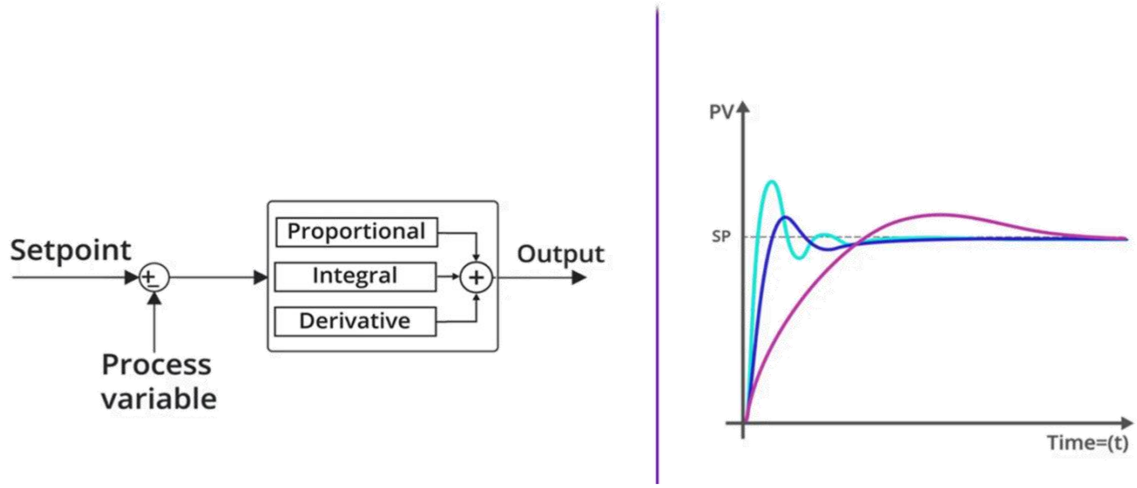


Figure 13 - PID Process

Feed Throat Temperature

As the barrel is heated, heat is conducted to the feed throat section of the barrel. Control of the feed throat temperature is critical for the consistency of the molding process.

The feed throat temperature is controlled by a one-way valve that allows coolant, typically water, to flow through a water jacket when the machine calls for cooling (Figure 14).

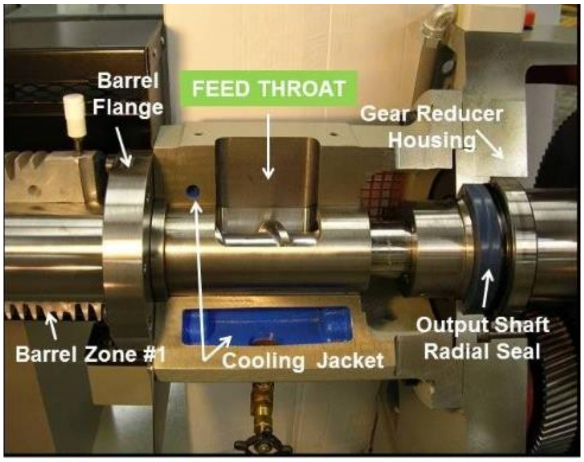


Figure 14 - Feed Throat Cooling

Coolant is conveyed through the cooling jacket via a one-way solenoid driven valve that is controlled by the molding machine.

A common failure is the feed throat temperature not heating, which occurs when particles interfere with the seal that closes the valve (Figure 15).

Figure 15 - Solenoid Cooling Valve

Mold Temperature

There are two typical types of mold heaters:

- Standard temperature control units with operating temperatures from 40F to 250F
- High temperature control units with operating temperatures from 70F to 500F

Figure 16 - Inside a TCU

Hoses

Hoses range from fiber braided elastomer coated hoses to metal braided hoses. The fiber braided hoses are assembled with push-loc connectors (Figure 17) to which a quick disconnect connector is applied that attaches to the mold. Typically, the male connectors are on the mold and the female connectors are on the hoses.

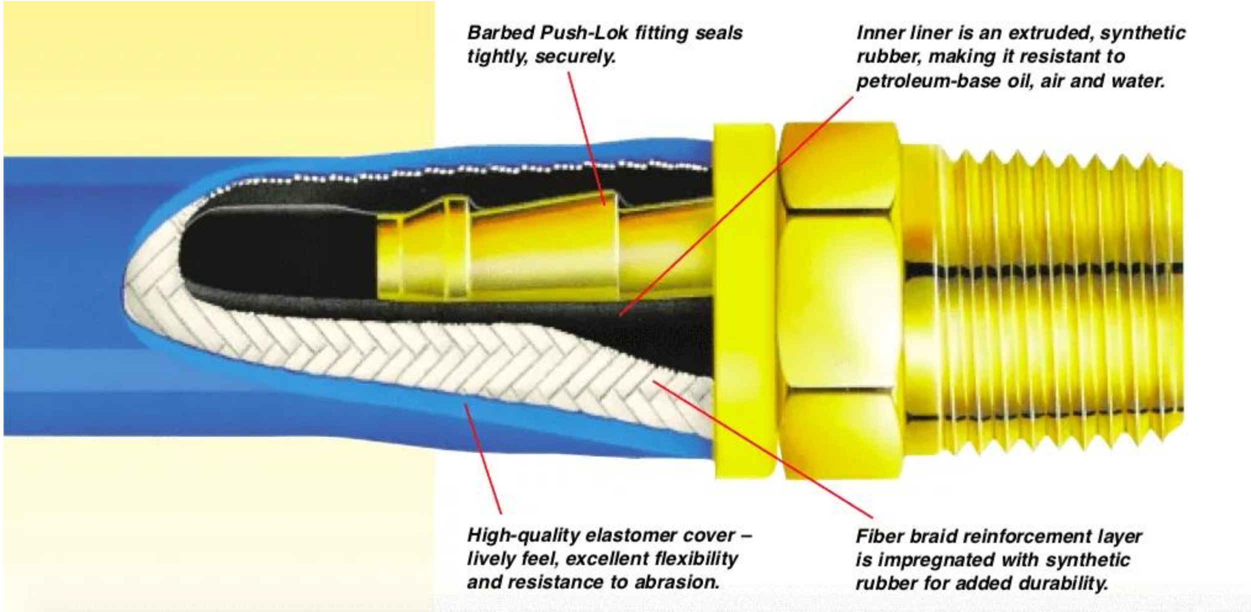


Figure 17 - Push-Loc Hose

Hoses can be purchased in many colors and most molding shops utilize 'blue' hoses as 'to process' and red hoses 'from process.'

Manifolds

Manifolds transfer conditioned water from the TCU to the individual lines on the mold. There is a wide variety of manifolds available from straight aluminum square tubes with ports on them to plastic manifolds with individual flow control monitoring (Figure 18).

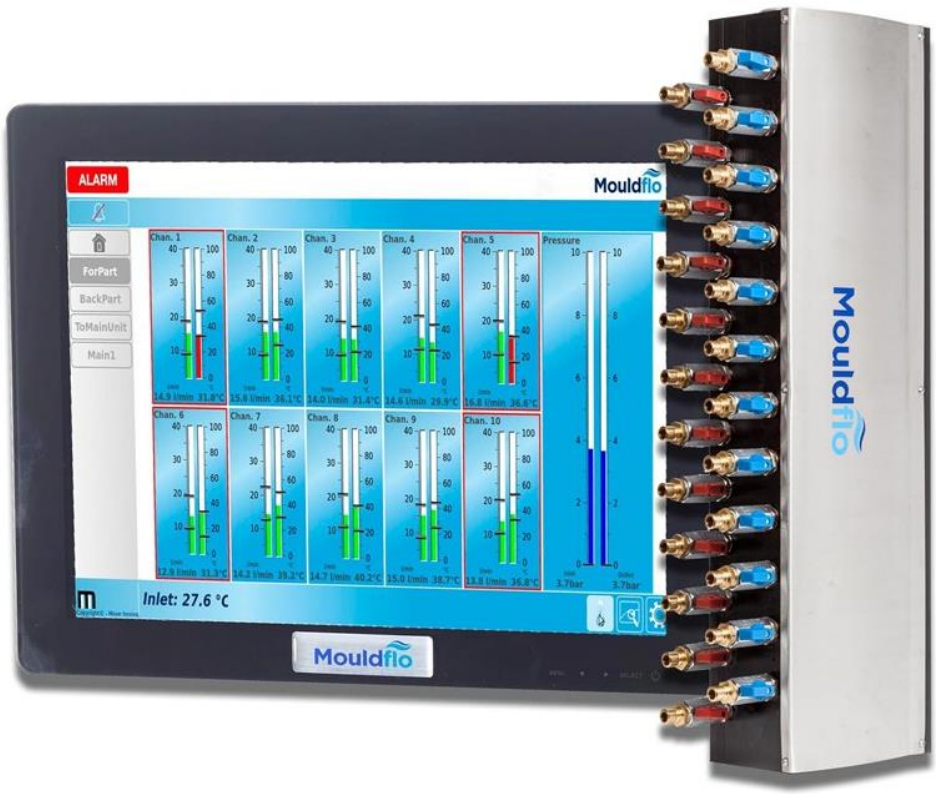


Figure 18 - Flow Control Manifolds

Waterline Setup

As mentioned earlier, most companies use a 'blue' hose for to process or 'in' and a 'red' hose for from process or 'out.' There are three key points to remember when setting up a molds coolant lines:

1. Coolant lines should be as short as possible and do not coil them up
2. Avoid 90-degree connectors if possible as they produce recirculation zones that causes a reduction in pressure

3. Tie up water lines so they don't interfere with other components of the process such as chutes, robots, and guarding

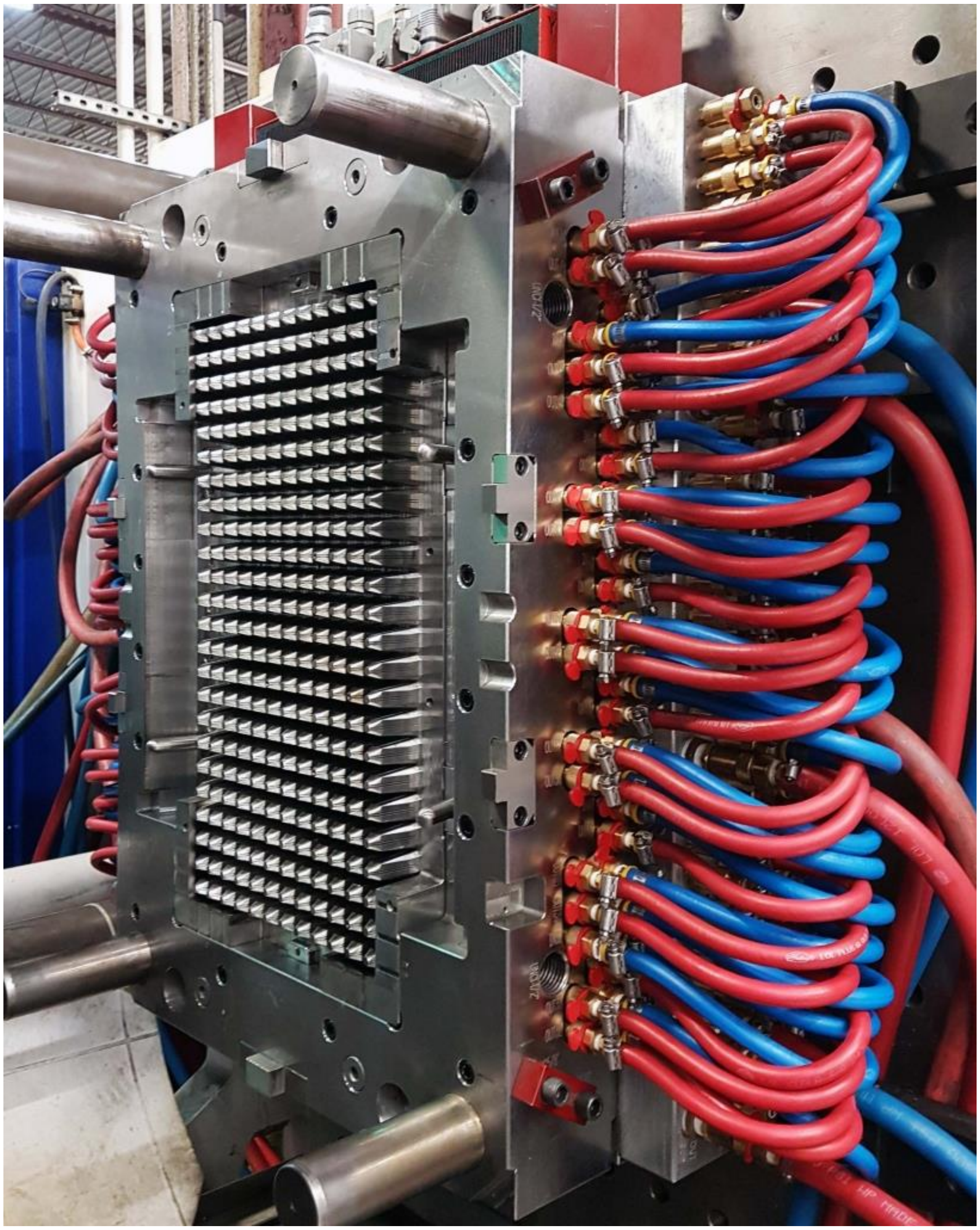


Figure 19 - Water Line Example

Exercise Six

Temperatures

Record the barrel set points and their energy draw, generally shown in percent, on four machines of varying tonnage and make.

Machine & Size				
Nozzle Temp				
Front Zone				
Front Zone %				
Middle Zone				
Middle Zone %				
Rear Zone				
Rear Zone %				
Feed Throat				
Feed Throat %				

Instructor Date

Objective Seven – Position, Speed and Force Settings Effect on the Molding Process

Earlier in this module you have learned about the individual components of the molding machine and their functions. Now, we will integrate your learnings into the functional aspects of the process by understanding how these components interact with each other to deliver a process that meets your expectations.

Every movement on your molding machine is effected by position, speed and force. The key to using these settings is to understand inertia, which is the tendency of an object to resist any change in its state of motion.

For example, if you have a hydraulic molding machine with a large mold and you do not ramp your closing speeds and forces you will likely be slamming your mold shut causing a loud bang when the mold shuts. Of course, because of the banging noise you respond by slowing the whole process down which increases your cycle time making less money for your company.

So, what do you do? You ramp the speeds and adjust the positions and forces in order to have a fast, safe movement of all machine functions.

Clamp Movement

There are three typical positions in the clamp close movement which are:

- Mold Open Position
- Mold Protection Start Position
- Mold Lockup Position

Mold Open Position should be the smallest opening to allow the removal of parts. If you are running your machine without a robot, the open position should be just large enough for the parts to eject and fall without bouncing off the A-side of the mold.

If the parts are removed by an operator, the mold should open just far enough for the operator to remove the parts without touching hitting the mold with their arms, hands or part(s).

If a robot is removing the runner, parts or both from the mold, the opening should be large enough for the end of arm to enter the molding area, grasp the plastic and exit the mold without damage to the end-of-arm-tooling (EOAT), parts or mold.

Mold Protection Start Position is the position where you start low pressure close. This position should start at the point where mold damage could occur. If a mold has slides, it would be the point just before the slides engage.

Mold Lockup Position is the position where mold protection stops and high pressure starts. It is also known as the touch point or zero position. In operation, you should be able to stop mold close by decreasing this position by 0.003 inch for small to medium sized machines (≤300 tons) and 0.01 inch for larger machines (>300 tons).

When setting these positions, make sure your mold is cleaned and greased so that a dry or dirty mold will stop mold movement.

A point to remember, a dirty or dry mold will cause mold protection alarms. So, if you get mold protection alarms and you do not see parts or runners clamped in the mold, don't increase speeds or pressures. Instead, inspect the mold for cleanliness and lubrication, there is a good chance the machine is 'seeing' enough friction to cause the alarm. By the way, if you lose a TCU, this will also cause a mold protection alarm as a result of friction (mold swelling).

Mold Close Speed should be as fast and safe as possible. For large molds, you might add a ramp up speed. What I mean by this is if you were to start mold close at 100% of the machine capability, it might be too much for the machine to control. However, if you have a lower close speed for 0.125 inches, this might give the machine enough control to smoothly get to speed. The same occurs when slowing down.

Mold Close Pressure should be set as low as possible to maintain a smooth closing sequence and mold protection. This may require a higher speed, at lower pressures during mold protection to maintain the smooth movement. The key is to remember it is a safe movement.

Ejector Movement

Most machines give you some control over ejector positions which can include:

- Ejector back position is the position of the ejection system when the ejector plate is in the full back position
- Ejector forward position is the set position when the ejectors are as forward as needed to demold the parts
- Intermediate ejector back position is the set position that the mold retracts to for multiple ejector strokes

Because there is a high probability of mold damage if a mold is closed with the ejectors forward, molds are built with safety or push back pins that force the ejectors back if the mold was closed with the ejectors forward. These pins contact the 'A-half' of the mold in a non-critical area. Another option is to install ejector back switches on the mold as another level of mold protection.

Ejector Speed is dependent on the geometry of the part and the speed of the process. A 6-second molding cycle will require a very fast ejection process where as a 50-second molding cycle with complex geometry may require a slow ejection process to avoid damaging the part during demolding.

Ejector Pressure is often related to the number of cavities in the mold. A single cavity mold may require much less pressure for demolding than a 128 cavity mold.

Injection

Process settings for injection should be as fast as possible given the mold geometry, venting and available pressure. Generally, you utilize two positions for the injection process which are screw full back and VP transfer positions. However, on occasion you might use 'suck-back' which is a position that occurs after screw recovery. Be leery of 'suck-back' as it may suck air into the nozzle tip which could lead to splay problems.

Most machines allow for multiple injection positions to slow or speed up the flow of material during the injection process. These variants should be used with caution. Ideally, you use one speed for the entire process. Speed variations effect melt viscosity which can increase the variation in the molded part.

Injection Speed

The injection rate should be a single velocity and as fast as cosmetically possible. There are times when multiple speeds are required such as maintaining a constant velocity on the flow front of flat plates.

Injection Pressure

During injection, the press should be able to utilize its available pressure. Once the speeds and positions are set, the pressure should be monitored in order to avoid over-pressurizing the mold in the event that one cavity blocked off.

Exercise Seven

Movements & Setup

Record your observations of machine movements and water line setup for four machines of varying tonnage and make. In the cell write 'Good" or "Not Good."

Machine & Size				
Mold Close				
Mold Open				
Mold Protect				
Ejection				
Robot Takeout				
Water Lines A-half				
Water Lines B-half				

Instructor Date

Self-Test

1. How does a pressure relief valve work?
   a. It takes extra work from the system to relieve the system
   b. It is a set point that diverts oil when a predetermined setting is reached
   c. It releases steam from the system
2. The manifold block holds these hydraulic components:
   a. Oil filters
   b. Oil pumps
   c. Limit switches
   d. Valves
3. Hydraulic core pulls are mounted to the:
   a. Mold
   b. Stationary platen
   c. Ejector plate
   d. Machine base
4. When an injection mold is first opened it is best to open it:
   a. Fast
   b. Slow

5. A properly set clamp will kick into high pressure mode:
    a. When the mold starts to close
    b. When the mold starts to slow down
    c. A fraction of an inch before the mold faces touch
6. The most common way to specify the size of the clamp end of a machine is by its:
    a. Tonnage
    b. Maximum clamp stroke
    c. Maximum shut height
7. Will a mold that is 20” x 26” fit into a machine with 24” x 24” tie bar spacing?
    a. Yes
    b. No
8. If there is no mold in the machine, can the two platens be brought into contact with each other?
    a. Yes
    b. No
9. The thickest mold a machine can handle is determined by the:
    a. Maximum shut height
    b. Tie bar spacing
    c. Platen size

10. Feed throat temperature is important because:
    a. It is where the material starts melting
    b. Too high a temperature causes ‘balling’ in the feed throat
    c. Too low a temperature causes the material to freeze
11. Injection speeds should be ramped for optimal performance.
    a. True
    b. False
12. Always use 90-degree fittings when water molds.
    a. True
    b. False
13. Properly set mold protection should cause mold protect alarms when the mold needs grease.
    a. True
    b. False
14. Thermocouples monitor temperature
    a. True
    b. False

Glossary

Clamp Cylinder - hydraulic cylinder responsible for moving linkages and opening and closing the machine.

Daylight - the distance between opened mold halves or platens.

Hydraulic Core Pull - the hydraulic system used to slide cores in and out of the mold.

Linkages - the mechanical component arms that make up a toggle clamp.

Manifold Block - steel block on the machine that houses the hydraulic valves.

Platen - large, steel vertical plates on the clamp end of the machine.

Tie Bars - large, steel bars used on the clamp end of machine to connect and support the platens.

Hydraulic Valve - a valve used to divert hydraulic fluid to various hydraulic cylinders or motors to control their motion.

Ball Screw – a method of linear movement that re-circulates balls through a connector the drives the mating feature.

TCU – Temperature Control Unit