The Molding Process

LESSON 1: Injection End Parts and Their Functions - I

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This lesson is the first in a series on the subject of plastic injection molding. It starts with an introduction to the major components of the machine's injection end. The basic outline of the process, as shown in Figure 1, is to feed plastic pellets into a heated barrel where they are melted. The molten plastic is then injected under high pressure into the cavity of a steel mold, where it solidifies and is removed as a finished part.

The injection end of the machine is responsible for melting, mixing, and transporting the plastic into the mold. All modem molding machines use a screw that rotates to plasticate (mix and melt) the material. The screw can also move forward (reciprocate), without rotating, to inject the plastic. Because of the nature of the screw movement, these machines have become known as reciprocating screw injection molding machines.

Objectives of Lesson One

1. Learn the names of the basic parts of the injection end of the molding machine.
2. Understand how the screw functions inside the barrel.
3. Learn the location of the temperature control components on the machine.

Objective One

Major Injection End Parts

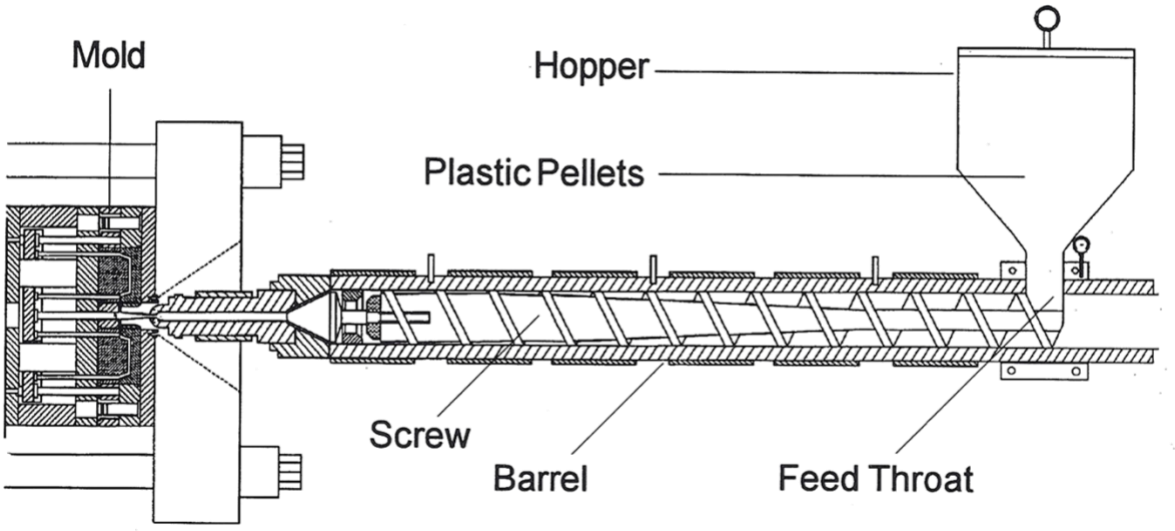

Figure 1 - Screw, Barrel and Mold

The Feed Throat

Plastic from the hopper is gravity fed into the back of the heated barrel through the feed throat. The feed throat has a water cooling jacket around it to keep it cool. The temperature of the throat must be kept low enough so that the heat from the barrel does not cause the plastic to melt in the throat.

The Barrel

The barrel is a thick steel cylinder capable of containing high pressures. It is wrapped in electric heater bands that heat the

barrel to assist in melting the plastic as it travels down the screw.

The Screw

The screw is made of very hard and tough steel, and is either highly polished or chrome plated to allow the plastic to move down it more freely. Its purpose is to feed the plastic down the barrel toward the mold, mixing and melting the plastic as it turns. When the barrel is full, the screw stops rotating and begins the forward (reciprocating) motion. It then acts like a ram to inject the plastic into the mold.

Screw Drive Components

Figure 2 shows the drive systems behind the screw that are responsible for its movement. Most machines use a hydraulic motor linked to gears that rotate the screw. A high-pressure pump feeds oil to the hydraulic motor to turn the motor and the gears that rotate the screw.

The very end of the screw is connected to a hydraulic piston. When the proper valve is opened, high pressure oil is fed to the piston driving it forward. This creates the injection stroke movement. Notice that, in Figure 2, the entire screw and piston can slide back and forth through the gears. This feature allows the screw to rotate and reciprocate (inject the plastic into the mold) without disengaging from the gears.

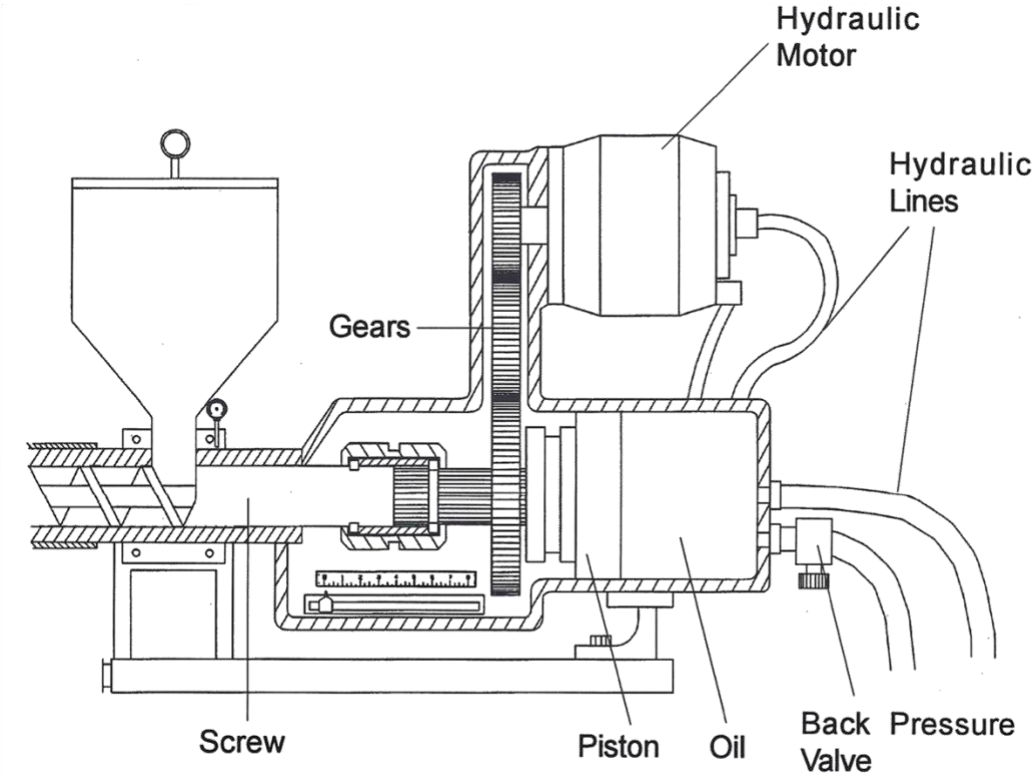

Figure 2 - Hydraulic Screw Drive System

Non-return Valve

The non-return valve is located at the tip end of the screw. Its function is to prevent the plastic from flowing backwards in the barrel during injection.

There are two general types of non-return valves that are used in injection molding. The most common type of non-return valve is the ring type. The ring is part of the screw tip that is threaded into the end of the screw. Its purpose is to stop plastic from flowing back down the screw flights during injection. As the screw rotates the ring is pushed forward, allowing the plastic to flow through the ring and fill the front of the barrel (Figure 3).

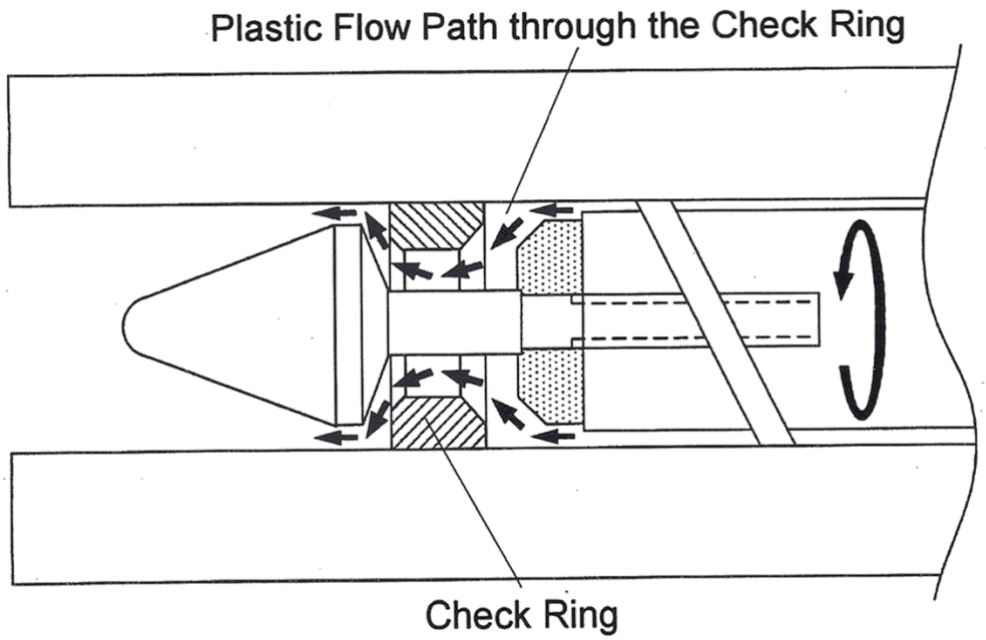

Figure 4 - Ring Type Non-Return Valve - Forward Position During Screw Rotation

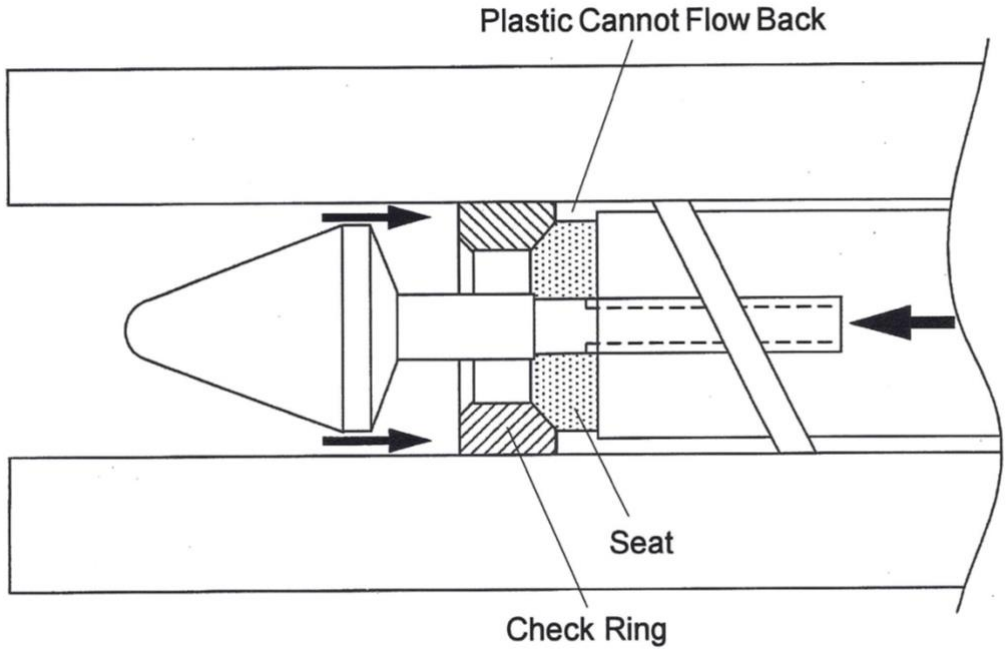

Figure 4 - Ring Type Non-Return Valve - Seated Position during Injection

During injection, the ring is pushed back causing it to press against the seat and block off any back-flow (Figure 4). This allows the screw to generate full pressure against the plastic during injection.

Another type of non-return valve is the ball type valve shown in Figure 5.

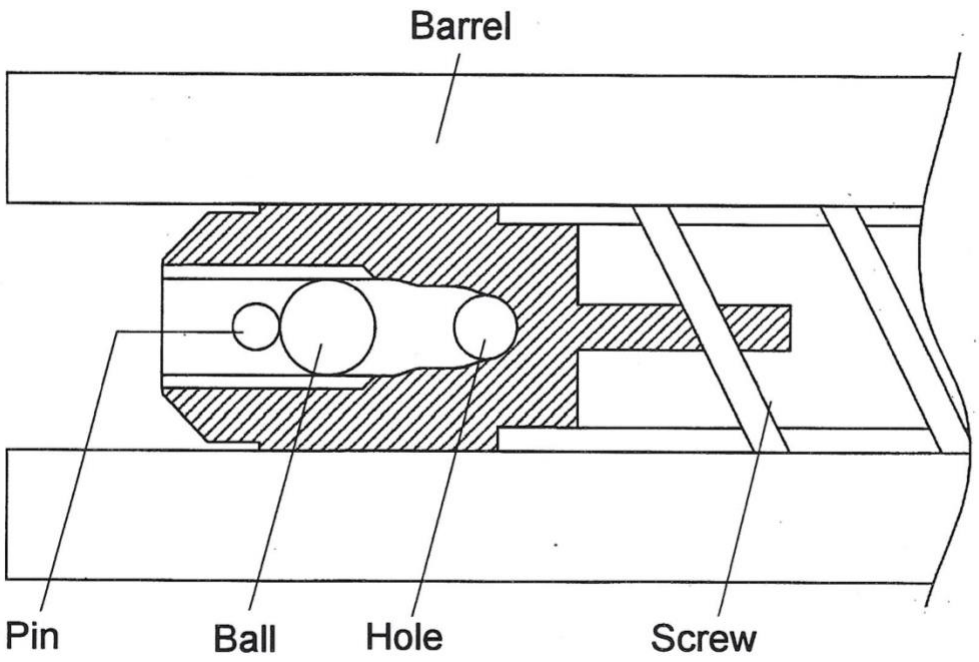

Figure 5 - Ball Type Non-Return Valve

The ball type valve works in much the same way as the ring type, except the ball moves forward and back to allow plastic to flow forward, and prevent it from flowing backward.

Non-return valves occasionally become damaged, or clogged with foreign material. This situation can cause the plastic to leak past the valve. If this happens, the screw may not be able

to apply enough pressure to the cavity. This may result in poor quality parts. The non-return valve and screw tip assembly will then need to be cleaned or replaced.

Exercise One

Unplanned Shutdowns

In your shop, find a used non-return valve. If it has solidified plastic on it, melt the plastic off. Check the surface of the valve for damage. Also check to see if it is clogged with foreign material (e.g., metal fragments). Note the conditions below. After completing the inspection, put a check in the appropriate box or boxes. If you cannot find an old screw tip assembly, ask a maintenance person to locate one for you.

Observation	Observed (yes/no)
Nicks on the ring	
Nicks on the seat	
Cracks	
Excessive Wear on Outside of Ring	
Broken Screw Tip	
Ring is Clogged	

Instructor Date

The Nozzle

The nozzle is the last part of the injection system that the plastic flows through before it enters the mold. It is screwed into the nozzle adapter that makes up the end of the barrel (Figure 6). When the injection unit is moved forward, the nozzle seats against the sprue bushing in the mold.

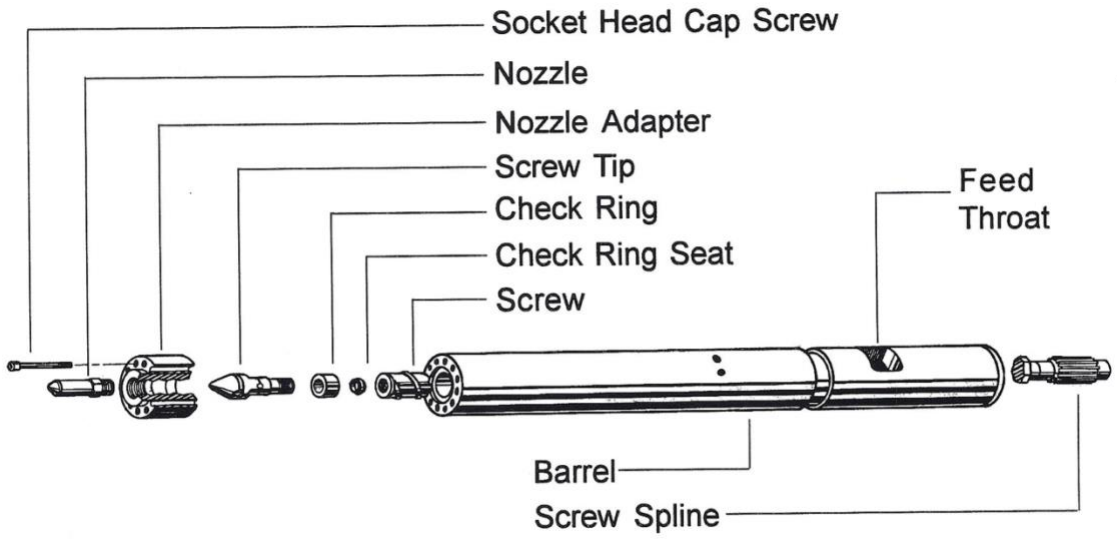

Figure 6 - Screw and Barrel Assembly

It is important that the radius of the nozzle properly matches the internal radius of the sprue bushing (Figure 7) or leaking may occur. Nozzles usually come with either a 1/2 inch or 3/4 inch tip radius.

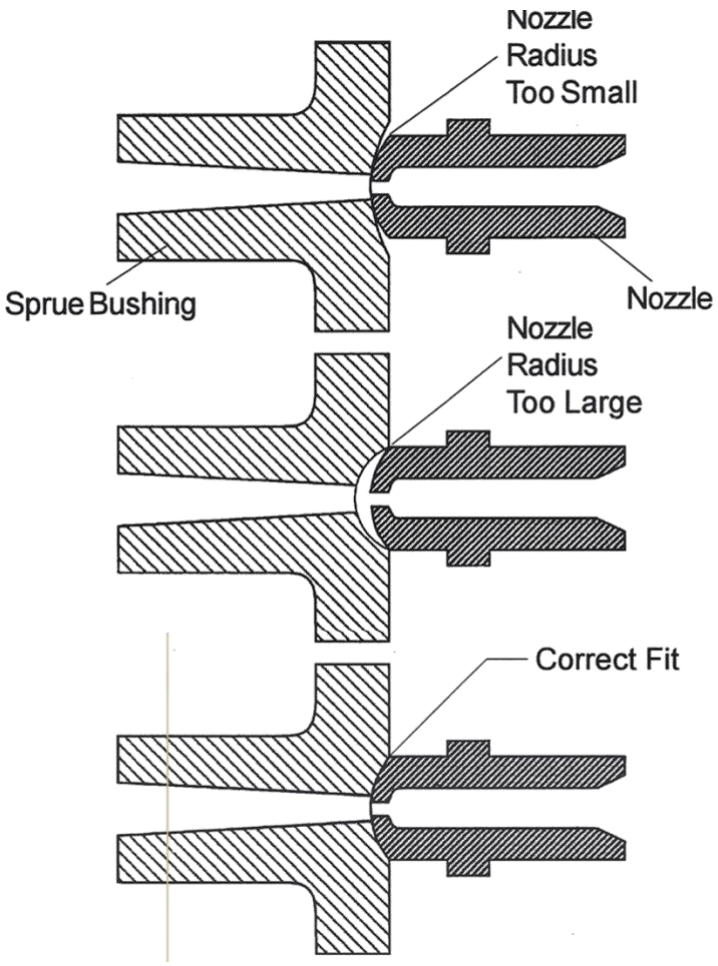

Figure 7 - Nozzle and Sprue Bushing Match

The diameter of the hole (orifice) in the nozzle may vary from machine to machine. Common orifice sizes range from 1/16 inch to 3/8 inch in diameter in 1/64 inch increments. The nozzle orifice needs to be equal to, or slightly smaller than, the opening in the sprue bushing, which is the point where the plastic enters the mold (Figure 8).

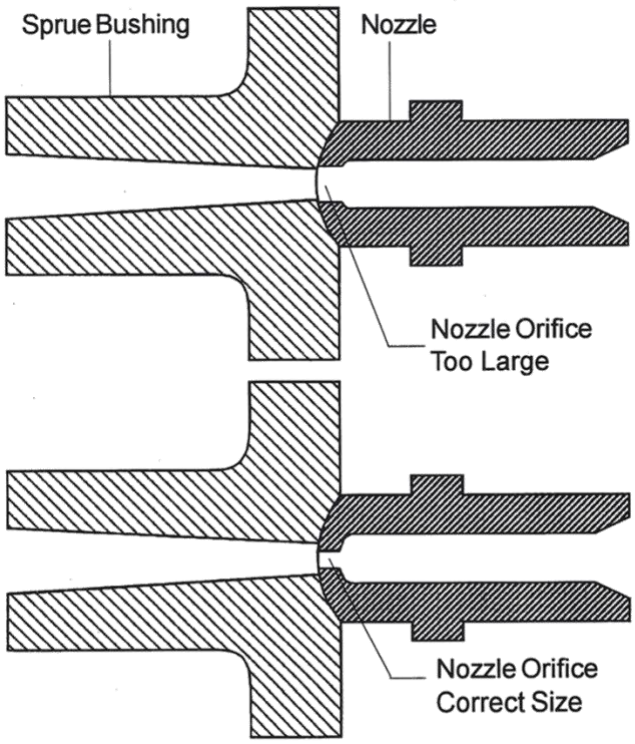

Figure 8 - Nozzle Orifice Size

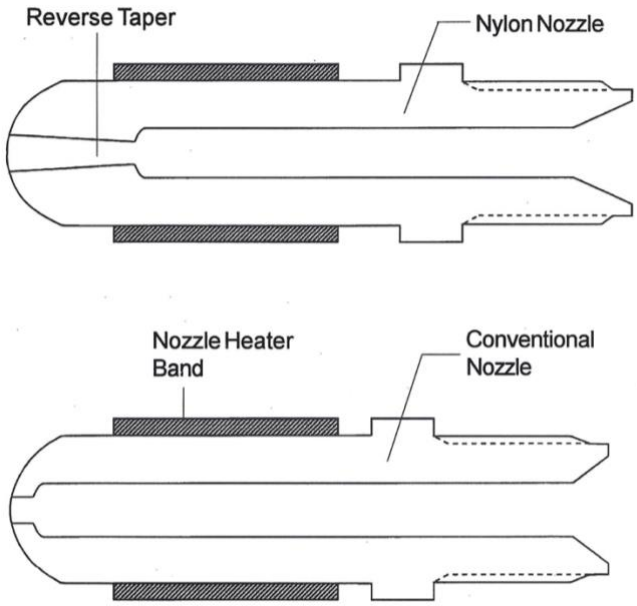

Figure 9 - Specialty Nozzles

In addition to the standard design, special nozzles are available for processing nylon. The nylon nozzle has a reverse taper design as shown in Figure 9.

Different types of spring loaded shut-off nozzles (Figures 10 and 11) can be used to keep molten plastic from drooling out of the orifice. However, this type of nozzle requires more frequent maintenance to keep it working properly.

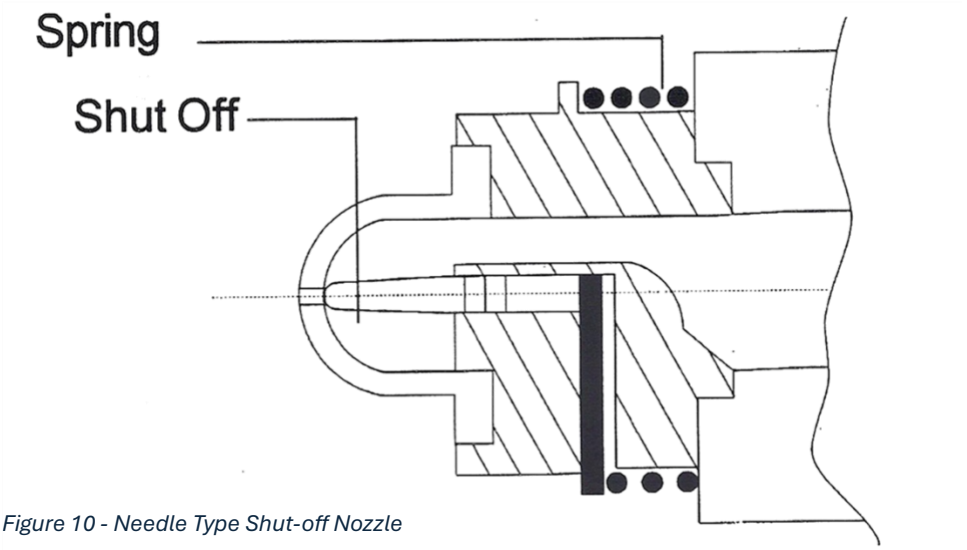

Figure 10 - Needle Type Shut-off Nozzle

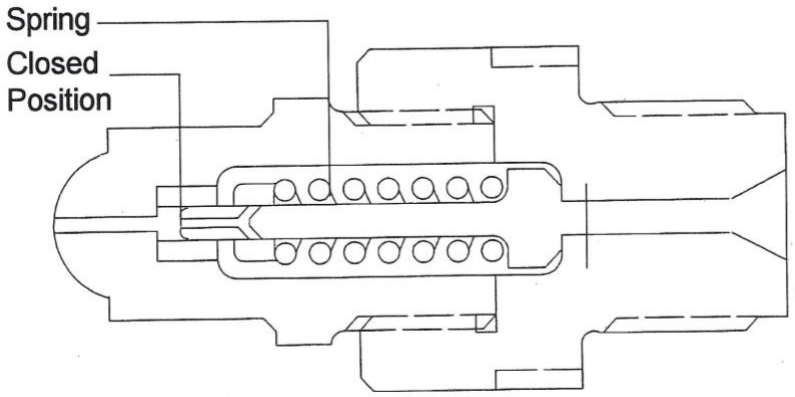

Figure 11 - Piston Type Shut-off Nozzle

Exercise Two

Locate several nozzles in a tool chest or work bench and categorize them according to size and type. Often the size is stamped on the outside of the nozzle. Pin and radius gauges can usually be found in the tool room or machine shop.

Nozzle Number	Orifice Diameter	Nozzle Radius	Nozzle Style or Shape

Instructor Date

Objective Two

Screw Terminology and Functions

Figure 12 shows the basic parts of the screw. The plastic pellets first drop into the feed section of the screw where the flights are the deepest. As the screw rotates, the pellets are pushed down the flights where they are heated by the barrel and begin to melt.

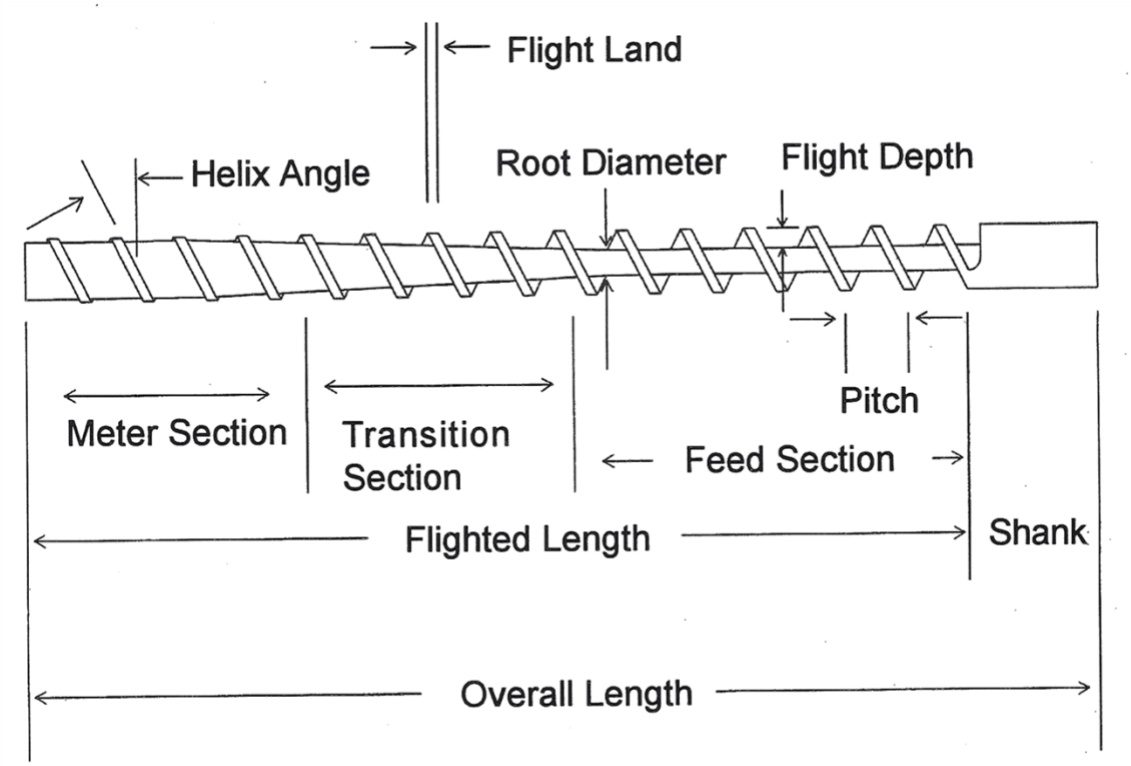

Figure 12 - Plasticizing Screw Terminology

In the transition section, the screw is tapered and plastic is compressed as it is pumped forward. The plastic is squeezed and pressed against the barrel wall. This action is called

shearing, and causes the plastic to heat up because of the friction within the pellets. This "shear heat" that develops accounts for about half of the heat input needed to melt the plastic. The remainder comes from the barrel heaters.

The metering section is the shallow section of the screw where the plastic is held close to the barrel walls. The purpose of the metering section is to stabilize the melt completely before it is injected into the mold.

Screw Functions

The rotating action of the screw does several important things in the injection molding process. As described in the previous section, the shearing effect greatly improves the melting action. This same shearing action also mixes the plastic, and this is especially important when colorants are added to the plastic. The rotating action of the screw is also responsible for pumping the plastic forward into the front of the barrel.

The forward movement (reciprocating action) of the screw injects the plastic into the mold. This same forward motion holds the plastic in the cavity as it cools.

Figure 13 shows the different positions and movements that the screw must complete during the operation of the machine. In position 1 the screw moves forward without rotating to inject the plastic. In position 2 the screw bottoms out and stops near the front of the barrel when the cavity is

full. Position 3 shows the screw in its rotating mode, pumping plastic forward as it backs down the barrel.

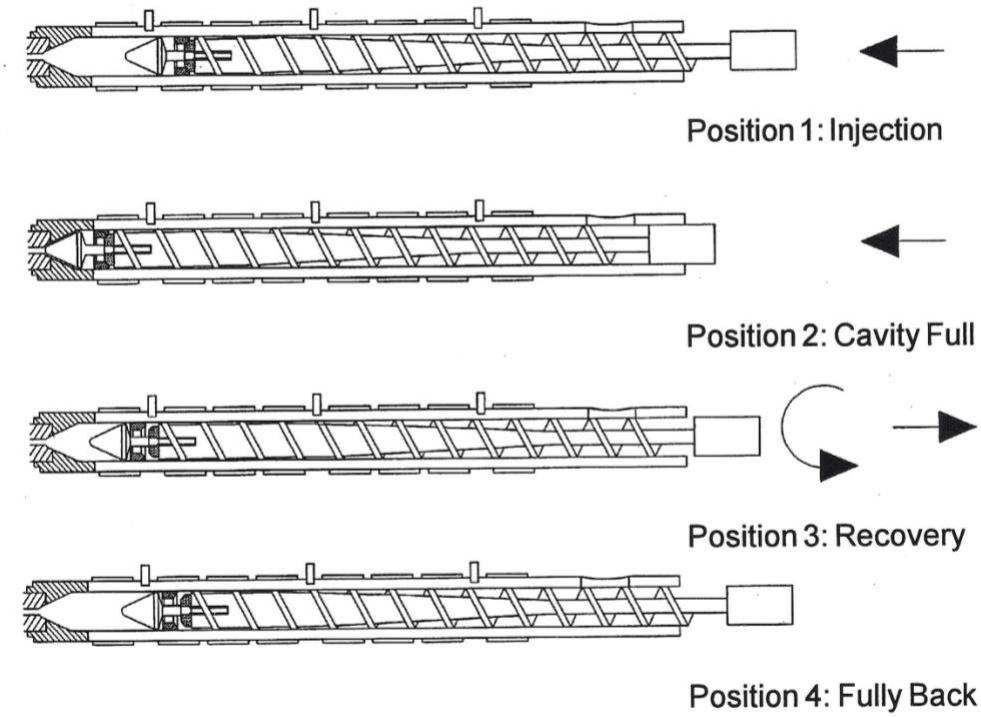

Figure 13 - Screw Movements

This backward action is referred to as screw recovery. In position 4 the screw has stopped rotating and is all the way back in the barrel ready for the next injection stroke.

As the screw rotates back to the injection position, the hydraulic oil behind the injection piston is forced out through the back pressure valve. When this valve is in a more closed position the screw will have to work harder to push the oil through the valve. This causes the screw to move backwards (recover) more slowly than if the valve is open. Figure 14 illustrates the path of the oil during screw recovery.

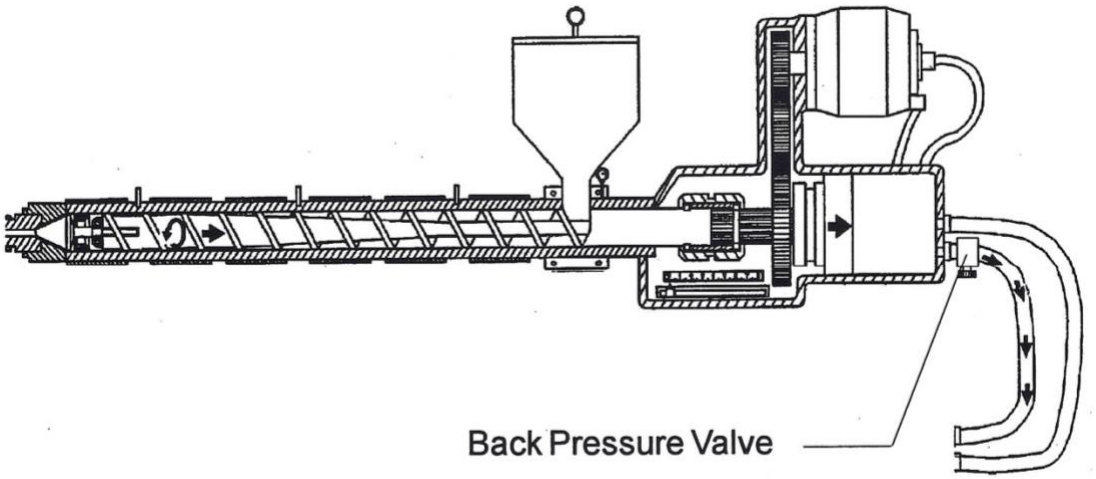

Figure 14 - Creating Back Pressure During Screw Rotation

Exercise Three

Locate a stop watch or wrist watch with a second hand. On several different machines that are running, check the screw recovery times. Suggest some reasons why they are different.

Machine Number	Recovery Time	Why are they different?

Instructor Date

Objective Three

Temperature Control

Barrel Heating

The barrel is heated by the electric heater bands wrapped around the outside of the barrel. They are usually grouped into three or four separate zones along the length of the barrel (Figure 15). Each zone has its own thermocouple and temperature controller to control the barrel temperature very accurately.

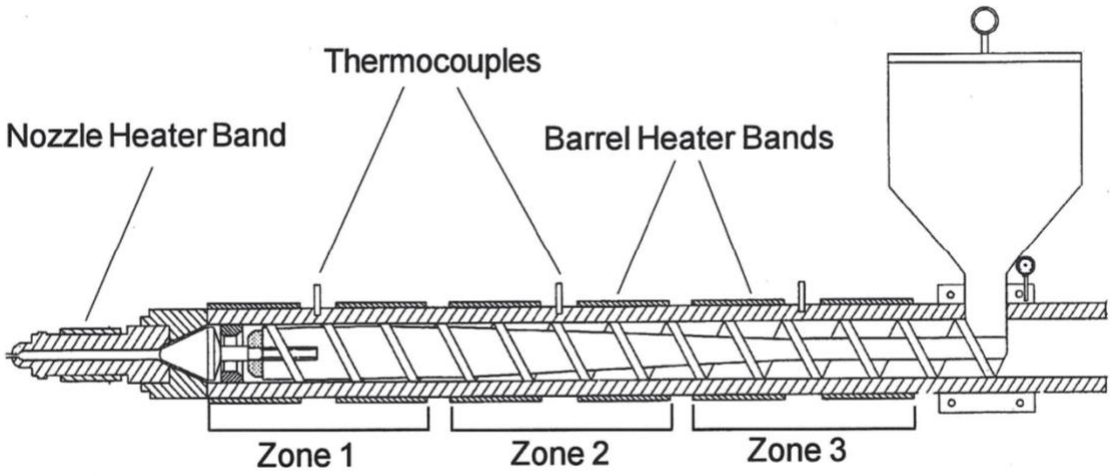

Figure 15- Barrel Heating

Nozzle Heating

The nozzle has its own heater band and temperature controller. Since the nozzle seats against the much colder mold, it is important that the heater band is as close to the tip

as possible. This heater helps keep the nozzle hot and prevents the plastic from solidifying in the nozzle.

A common maintenance problem is that the nozzle heater bands, power cords, and thermocouple wires often get coated with molten plastic. This can shorten their life, or cause them to short out. Another common problem in this area of the machine is that the bolts holding on the heater bands become loose. This greatly reduces the amount of heat that is conducted into the nozzle and can cause the plastic to solidify and plug the nozzle. A responsible operator or technician should monitor this area of the machine frequently.

Feed Throat Cooling

The feed throat is cooled by an internal water jacket (Figure 16) using a flow control valve. The flow control valve can be adjusted to increase or decrease the amount of cooling water that flows through the jacket. Many machines have a thermometer inserted into the feed throat that allows for more accurate temperature control.

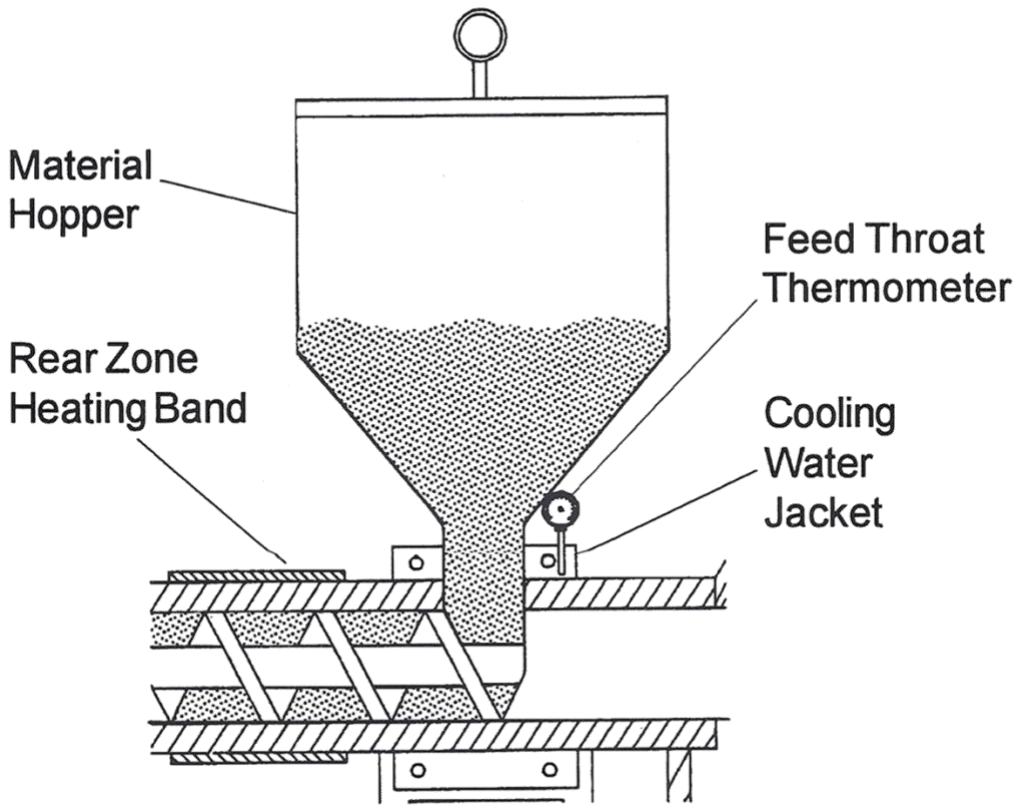

Figure 16 - Feed Throat Cooling Jacket

Exercise Four

Find several different machines in the shop that are not running. Note the condition of their nozzle heater bands and connecting wires.

Machine Number	Nozzle Heater Condition (good/bad)	Needs Repair (yes/no)

Instructor Date

Self-Test

1. What are the two modes of operation of the screw?
   a. _____
   b. _____
2. What part keeps the plastic from pushing back down the flights of the screw during injection?
   a. Spring loaded nozzle
   b. Sprue bushing
   c. Screw tip
   d. Non-return valve
3. Should the nozzle or the sprue busing have the larger internal opening diameter?
   a. Nozzle
   b. Sprue bushing
4. One way to keep the plastic from drooling out of the nozzle is to use a:
   a. Spring loaded nozzle
   b. Two piece nozzle
   c. Nozzle with a small orifice

5. List the three things that the screw does to the plastic.
    a. _____
    b. _____
    c. _____
6. During the screw recovery phase, the screw is rotating and moving:
    a. Forward
    b. Backward
7. When the screw is rotating, which position is the non-return valve ring in?
    a. Forward
    b. Rearward
8. How many heating zones are usually on a machine barrel?
    a. 1
    b. 3
    c. 5
    d. 7

9. The nozzle has the potential to lose a great deal of heat because:
    a. It sticks out of the end of the barrel
    b. It is in contact with the mold
    c. It has no heater band of its own

Glossary

Back Pressure - the pressure generated on the plastic as the screw rotates and pumps the plastic into the front of the barrel.

Feed Throat - the opening in the back of the barrel where the plastic enters.

Injection End - the end of the molding machine that contains the plastic injection cylinder.

Metering Section - the front end of the screw where the flight depth is constant.

Non-Return Valve - the valve assembly on the screw tip that keeps plastic from returning back down the screw flights during injection.

Plasticizing - to mix and melt plastic. This function is taken care of by the screw.

Reciprocating Screw - the term used to describe both the back and forth movement and the rotating action of the feed screw.

Screw Recovery - the backward motion of the screw as it rotates and pushes plastic forward in the barrel.

Shear Heat - heat generated by the mixing action of the screw on the plastic.

Sprue Bushing - the mold component that the nozzle seats against that is the point where plastic enters the mold.

Thermocouple - a temperature sensing device used to control barrel heat.

Transition Section - the middle zone of the screw where material compression takes place.