An Empirical Study of Various Non-Return Valves Available to the Injection Molding Industry Today

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Introduction

There are many different types of non-return valves available to the injection molder today. The most common designs are the Sliding Ring Valve (Figure 1), the Ball Check Valve, either side or front discharge (Figure 2), and the Poppet Type, of which there are several different styles.

Of course, one would like to design the valve to operate efficiently and precisely with all resins, but this is not the case. Sliding ring valves are used primarily with high viscosity, shear-sensitive materials. Ball check valve designs are used primarily with low viscosity, shear-forgiving materials. The poppet valve is the least popular with limited application.

There are many variables that play a role in the operation of the non-return valve. A few of these are viscosity of the resin, shear sensitivity of the resin, quality of the melt, the amount of back pressure used, the amount of screw decompression used during the cycle, plasticating cylinder size and injection speed rate.

Unfortunately, with the past technology, a problem occurs when scheduling warrants that a high viscosity of polycarbonate resin be used one day and high melt flow, low viscosity nylon the next. This type of change occurs regularly in typical custom molding facilities and the valves that are used are not general purpose enough to allow for consistent shot sizes.

With the call for higher quality dimensional plastic components, the injection molding machinery manufacturers have improved the electronic and hydraulic mechanisms. Therefore, research and improvements in the function of the non-return valve have been needed.

In the last couple of years, there have been advancements in the design of the non-return valve. One could theoretically analyze the "new designs" if he were versed in the physics involved in the process or he could undertake a comprehensive empirical trial. In order to completely evaluate the designs, an exhaustive effort would have to be made, utilizing many different resins, applications and machine sizes.

For this paper, we have analyzed the designs of the old standard sliding ring and ball check valves along with a new style of positive shut-off poppet valve, the Auto-Shut valve (Figure 3). All three valves were tested using a wide range of various resins, but we were unable to display the results over a variety of plasticating cylinder sizes. Nonetheless, the data is comprehensive and quite revealing, showing that there are alternatives to the old technology.

Statement of Theory

A description of the injection molding process and the role of the non-return valve is as follows. As the plasticating screw rotates, a number of functions are occurring simultaneously; pellets are being fed into the entrance of the screw and gently plasticated into a molten resin which is conveyed forward through the flights and extruded through the non-return valve. In order for the feedscrew to reciprocate backwards, pressure has to be built to exceed the mass of the drive unit and the hydraulic back pressure setting of the machine. The amount of pressure needed is dependent upon the sum of the above two components. At some point along the screw axis a peak pressure occurs, which is determined by the viscosity of the resin, the screw geometry and the mass of the equipment. Nonetheless, the pressure is upstream of the non-return valve and applies a positive pressure to the rear facing components, which has a tendency to keep the non-return valve in an open position. Of course, if melt decompression is used, the pressure profile is changed and is dependent upon the viscosity of the resin and the linear travel of the screw.

During the next portion of the cycle, the injection phase, the screw moves forward. In the case of the sliding ring non-return valve, the ring has a tendency to be static relative to the forward movement of the screw due to the friction between the outside diameter of the ring and the inside diameter of the barrel cylinder, as well as the friction of the flow of the melt. In the case of a ball check or poppet valve design, the ball or poppet is forced toward the seat as a result of the flow of the molten resin. Of course, once the components have seated they have to remain seated for the valve to hold pressure and work properly. The problem that occurs with these types of designs is that in order to close the valve, the screw must actually move forward to facilitate the shut off.

It has been recognized that a positive shutoff design is needed to eliminate the inconsistencies of the standard art. A valve that can be engaged or seated independently of the motion of the screw would be most desirable. One such design has been included in this paper. With this design, the poppet is seated as a result of spring pressure that has been applied.

Description of Equipment and Process

Injection Press

The equipment used for these trials to complete this empirical study consisted of a 200 ton/20 ounce Natco injection press. The injection unit was equipped with a modified screw and barrel which had the standard 57.2mm (2.25") cylinder bore but had the length increased to a 20:1 L/D.

Screw

The screw that was used for all of the trials was a general purpose design having the configuration listed below:

Feed:	8.8mm/568mm	(.347"/22.35")
Transition:	284mm	(11.175")
Metering:	3.43mm/284mm	(.135"/11.175")
Lead:	57.2mm	(2.25")
Flight Width:	6.35mm	(.25")

Compression Ratio: 2.57:1

Valves

All of the tests were done using the general purpose screw and evaluating the three different non-return valves; Front Discharge Ball Valve, Sliding Ring Valve and a Positive Shut-Off Valve. (See Figures 1, 2 & 3)

Resins

A wide range of materials were tested for this evaluation in order to evaluate the effects of melt viscosity versus the repeatability of the non-return valves. The resins tested consisted of 5 MI Polycarbonate, 60 MI Polycarbonate, 5.5 MFR ABS, Cellulose Acetate Propionate (CAP) and Nylon 6/6.

Resin Preparation

Each material was dried per the manufacturers' recommended drying time and temperature using a Conair desiccant dryer. The following times and temperatures were used to insure the proper preparation of the resin before processing:

Resin	Time	Temperature
PC (5 MI)	4 hrs.	115°C (215°F)
PC (60 MI)	4 hrs.	130°C (240°F)
ABS	2 hrs.	93°C (180°F)
CAP	4 hrs.	86°C (170°F)
Nylon	6 hrs.	83°C (165°F)

Temperature Profiles

All of the resins that were tested were processed on the same screw with the only variation being the temperature profile. The zone temperature profiles used for each resin were predetermined from the temperatures recommended by the resin manufacturers. They were then slightly modified to achieve the melt temperature approved by the resin manufacturer.

The zone temperature profiles used are shown below:

Resin	Zone 1	Zone 2	Zone 3	Nozzle
PC (5 MI)	270 (465)	289 (495)	302 (515)	216 (420)
PC (60 MI)	258 (445)	277 (475)	289 (495)	293 (500)
ABS	230 (400)	255 (440)	280 (480)	293 (500)
CAP	234 (390)	230 (400)	236 (410)	227 (395)
PA - 66	299 (510)	293 (500)	286 (490)	286 (490)

Molds

The mold used was a ASTM standard which consisted of two tensile bars, two color dispersion discs and two Izod notch bars. This mold was used throughout the entire test in order that test consistency could be maintained. The mold required a shot size of 72 cubic millimeters of polymer. This shot included not only the test specimens but also the sprue along with the gate and runner system.

Weighing Equipment

All samples were weighed using a Fisher digital gram scale and were weighed just as they were removed from the molds with the sprue and runner system intact. This method was used to insure a consistency in part weight.

Data Collection

A software package, "Quattro Pro", was used to evaluate the shot consistency of each of the trials. With this Lotus-type program, we were able to compare the standard deviations of each trial.

Application of Equipment and Process

Each of the non-return valves were tested using the minimum injection pressures required to properly fill the molds and using minimal back pressure.

All of the resins were processed at 100 r.p.m. so that the shear rate being applied to each resin would be the same.

Each valve was tested by producing 250 samples on each of the five resins; 125 samples were taken with decompression and 125 samples without decompression. The first 50 samples of the 125 samples were used to stabilize the process upon start-up and between changeovers. The stabilization was evident where the date was graphed, therefore disregard in order that a fair comparison could be made.

After each sample was removed from the mold, it was placed on the digital scale and weighed. The data was then logged into the spreadsheet program.

Presentation of Data and Results

After all of the data was logged into the spreadsheet, it was evaluated for maximum weight, minimum weight, average weight and standard deviation. All of the tests were graphed in sets, comparing the part weight variation of each resin. The graphs were done comparing each valve to the other. A sample of these graphs can be seen in Figures 4 and 5. After the graphs were compared, the data was evaluated for the standard deviation comparison of the valves. The comparison of this data made it very evident that the positive shut-off valve had the best overall repeatability.

The following data are the results of the standard deviations that were found:

Samples With Decompression

Resin	STANDARD DEVIATION Ball Check	Ring Check	Positive Shut-Off
PC (5 MI)	.239	.498	.147
PC (60 MI)	.284	.162	.179
ABS	.291	.214	.070
CAP	.366	.379	.164
Nylon	.145	.197	.069
Average	.265	.290	.126

(See Figure 6)

Samples Without Decompression

Resin	STANDARD DEVIATION Ball Check	Ring Check	Positive Shut-Off
PC (5 MI)	.201	.392	.213
PC (60 MI)	.272	.177	.162
ABS	.216	.200	.108
CAP	.295	.383	.203
Nylon	.382	.280	.147
Average	.273	.286	.167

(See Figure 7)

Interpretation of Data

After evaluating all of the standard deviations, it was evident that the positive shut-off non-return valve was able to produce parts which had more consistent part weight 230% of the time when using decompression compared to the worst case of either the sliding ring type or ball check during the cycle. The positive shut-off was also 156% better than the sliding ring and ball check when not using decompression during the cycle.

If the improved performance of the positive shut-off non-return valve is evaluated in terms of dollars saved due to the ability of this value to reduce the variation in part weight, a monumental savings can be achieved. The following example will show that savings.

Example

Assume a part is manufactured of ABS (5.5 MI), has an average weight of 74.95 grams and used a 30-second total cycle time. In using a Ball Check Non-Return Valve, the part weight variation is 1.29 grams versus that Positive Shut-Off Non-Return Valve which has a part weight variation of .34 grams. There is a difference of .95 grams in the comparison of part weight variation. Based on 6000 hours annual production time and a price of $.0029 per gram ($1.30 per lb.), the following savings could be obtained.

(3600 sec/hr.) / (30 sec/cycle) x 6000 hr. = 720,000 parts/yr.

(720,000 parts/yr.) x (.95 gm/part) x ($.0029/gm) = $1,983.60/yr. savings

This comparison is an example showing the savings based on the reduction of material used and does not take into account the savings that can be obtained based on the reduction of parts that are out of specification.

Conclusion

The results of these tests show that there are components available to the injection molding industry that can reduce part weight variation which, in turn, will result in more profit to a company. With the importance that is being placed on product quality today, it is necessary for a company to be able to produce parts that will satisfy the customer's specifications and still produce a profit for the manufacturer. Therefore, it is possible for a manufacturer to improve their product without a large capital expenditure and be able to improve the function of their existing equipment with typical maintenance expenditures.

Nomenclature

gm = grams
mm = millimeter
F = Fahrenheit
C = Centigrade

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The Auto-Shut non-return valve is a patented design of Spirex Corporation, Youngstown, Ohio, Patent #5,164,207.

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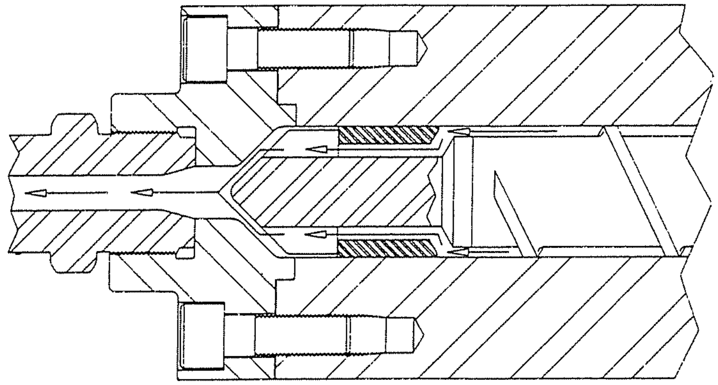

Figure 1

Sliding Ring Valve

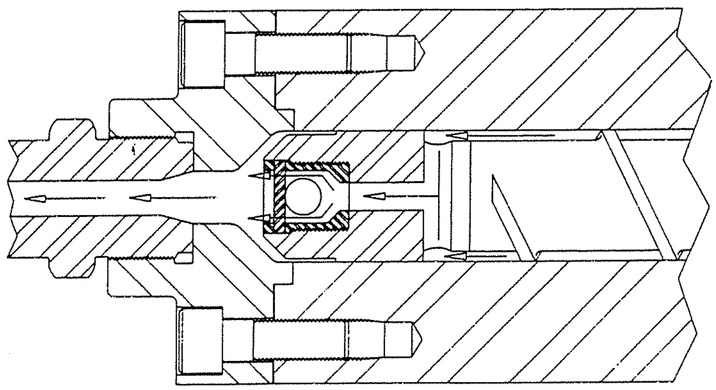

Figure 2

Ball Check Valve

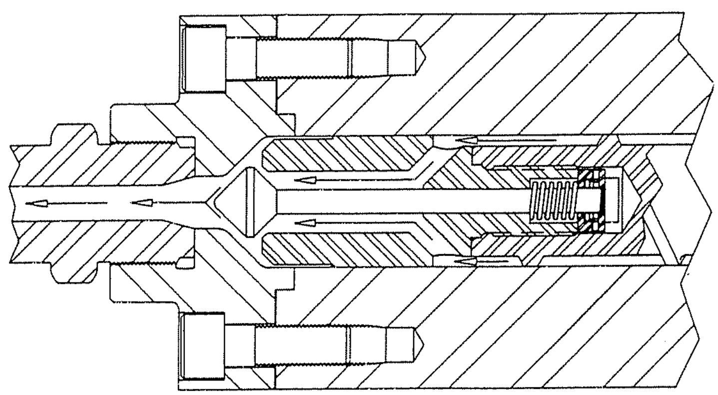

Figure 3

Positive Shut-Off Valve

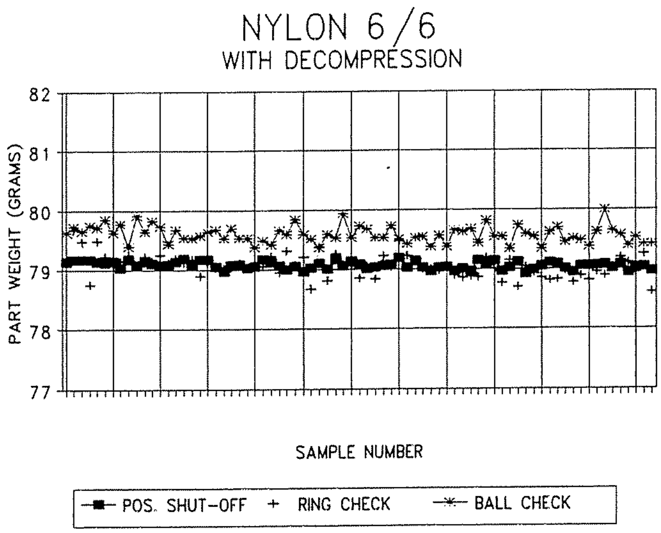

Figure 4

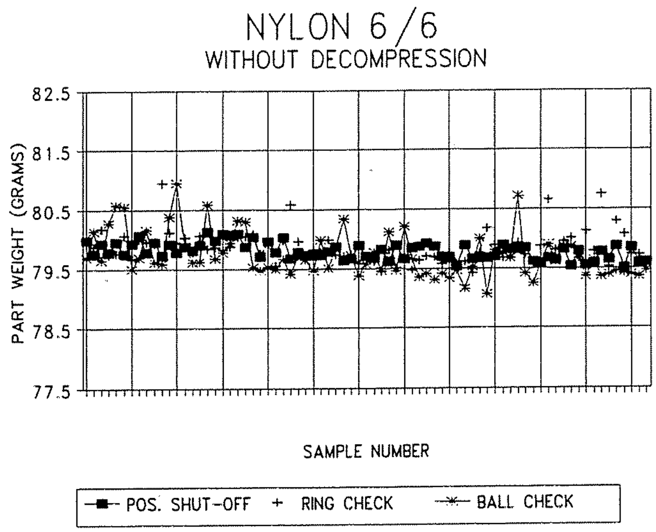

Figure 5

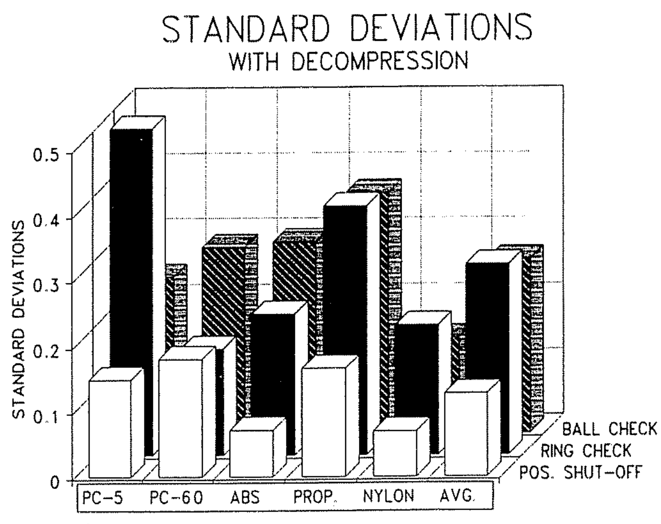

Figure 6

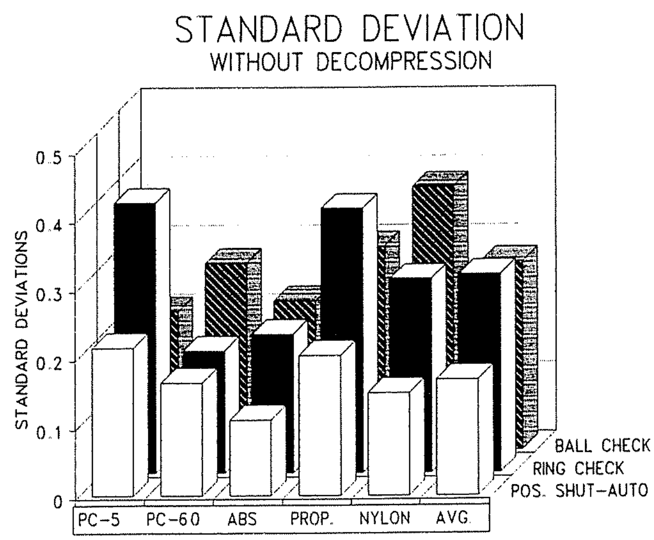

Figure 7

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