

# INTEGRATING THIN-WALL MOLDER'S NEEDS INTO POLYMER MANUFACTURING

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## ABSTRACT

Polyethylene (PE) injection molded rigid containers are widely used for food packaging and promotional drink cups. Molders of these containers have well-defined processing needs and molded part requirements. Likewise, the polymer manufacturer has well-defined manufacturing and analytical methods for characterizing resin properties.

This paper presents a unique method of translating the molder's needs back to polymer melt index and molecular weight distribution. The introduction of an "Isometric Spiral Flow Chart" provides the basis for this new approach. A nomogram for optimizing injection melt temperatures when transitioning from lot-to-lot is also presented. Utilizing this information, injection molders can maximize their production.

## INTRODUCTION

One of the most frustrating problems for resin manufacturers is how to relate injection molding parameters back to manufacturing synthesis conditions and laboratory quality control (QC) measurements. This article describes a unique use of existing QC-measured resin properties to predict relative molding cycle times for high-flow polyethylene (PE) resins. The introduction of the "Isometric Spiral Flow Chart" (figure 4) provides the basis for this new approach. A nomogram for optimizing injection molding melt temperatures when transitioning from lot-to-lot is also presented.

## DISCUSSION

Molders of rigid food packaging containers and promotional drink cups generally have well-defined processing needs and related methods to measure process consistency and molded part performance. Likewise, the polymer manufacturer has well-defined manufacturing and analytical methods for characterizing resin properties and physical properties. How well a resin supplier is able to translate polymer manufacturing measurements back to the molder's process and the end-use applications often determines the degree of success for both the resin supplier and the molder. Table 1 attempts to define these inter-relationships between the molder's processing requirements and the polymer producer's process measurements.

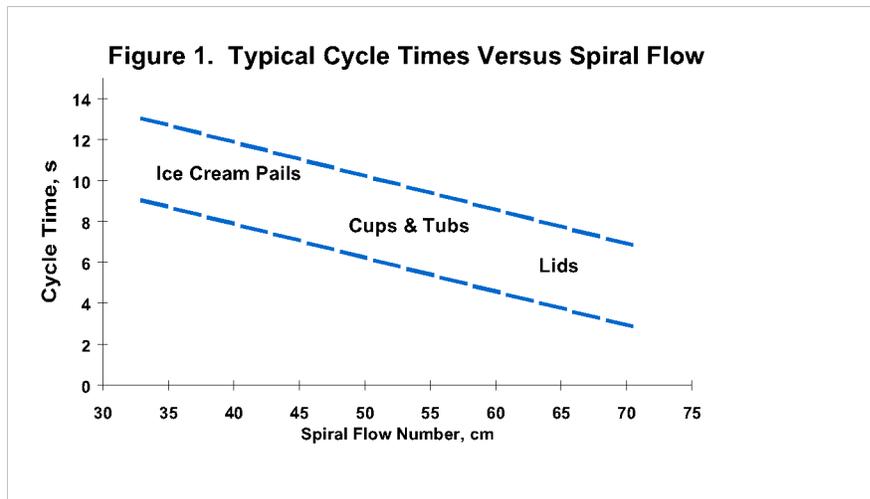
Table 1. Molding Requirements versus Resin Physical Properties

Molder		Polymer Producer	
End-Use Requirements	How Measured	Tech. Service Lab. Measurement	Plant QC-Measurement
Production Rates	Cycle Time	Spiral Flow	MI <sub>2</sub> * and MFR**
Stacking Strength	Topload	Flex Modulus	Density, MI <sub>2</sub> and MFR
Toughness	Drop Impact	Izod Impact - Ambient	Density, MI <sub>2</sub> and MFR
Cold Temp. Impact	Drop Impact	Izod Impact - Freezer	Density, MI <sub>2</sub> and MFR
Dimensional Control	Shrinkage, Lid Fit, Nesting	ASTM Shrinkage	Density, MI <sub>2</sub> and MFR
Warpage	Visual, Printability	Part Deformation	Density, MI <sub>2</sub> and MFR

\* Melt Index (MI<sub>2</sub>)

\*\* Melt Flow Ratio (MI<sub>20</sub>/MI<sub>2</sub>)

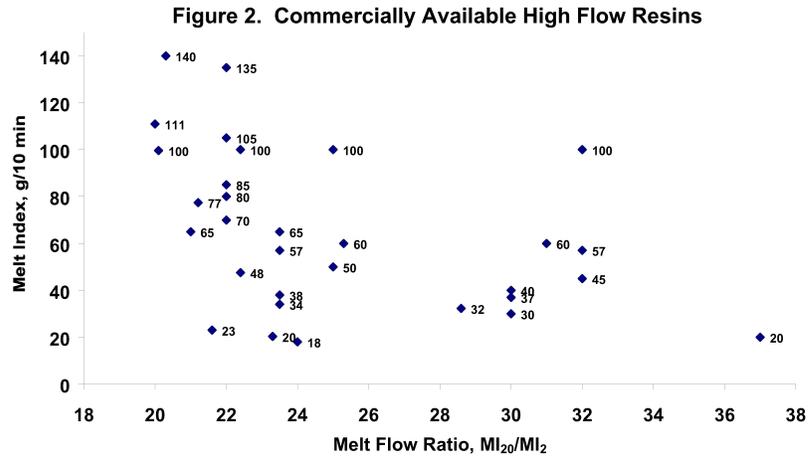
The information in Table 1 shows the injection molder can easily measure some of his needs and the manufacturer can relate those needs through TS (Technical Service) laboratory measurement. In other areas, the customer does not have a well-defined measurement of his needs. The problem is further compounded because even if the customer's measurement can be correlated to a measured TS lab measurement, how does the TS measurement relate to a plant QC measurement? For example, molding cycle time correlates well to TS laboratory spiral flow measurements as illustrated in Figure 1. The LyondellBasell spiral flow number (SFN) is the number of centimeters of flow produced when molten resin at 227°C is injected into a long, spiral-channel insert (half-round 0.635 x 0.157 x 127 cm) at a constant pressure of 6.9 MPa. Estimated shear rate is approximately 10,000 reciprocal



seconds. The equivalent ASTM Method for SFN is D3123.

Now that we have established a relationship between cycle time and SFN, how do polyethylene resin properties influence SFN? Typically a resin manufacturer changes polymerization catalyst systems, modifies reactor configuration or adjusts reactor-operating parameters, such as temperature, ethylene and hydrogen concentrations, to vary molecular weight (MW) and molecular weight distribution (MWD). Melt index, MI<sub>2</sub>, is measured in the QC lab and is used as an indication of resin molecular weight. It is defined as the number of grams of polymer extruded in ten minutes as measured by ASTM Method D1238. The higher the melt index, the lower the molecular weight and melt viscosity which means the resin processes more easily. Melt flow ratio (MFR or MI<sub>20</sub>/MI<sub>2</sub>) is a calculated QC lab number, which is used as an indication of MWD. It is calculated by dividing a melt index measured at a high shear rate (MI<sub>20</sub>) by a melt index measured at a low shear rate (MI<sub>2</sub>). A low

MFR indicates a narrow MWD; conversely a larger number indicates a broad MWD polymer. In general, a broader MWD resin flows easier than a narrow MWD resin at a given melt index. This article defines high-flow polyethylene resins as those resins with melt indices above 20 and MFRs between 20 and 40. Figure 2 plots commercially available high-flow resins as functions of melt index and MFR. Individual resins are identified by their MI<sub>2</sub>.



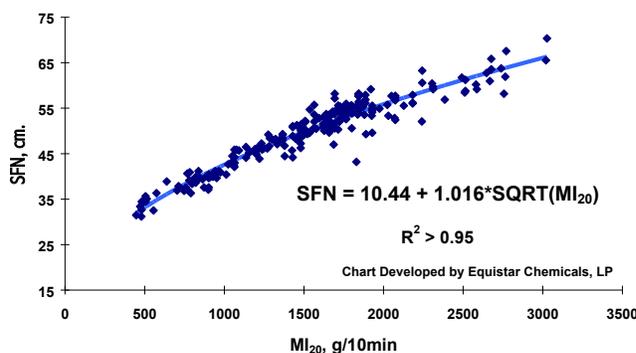
Regression of LyondellBasell laboratory spiral flow data for the resins shown in Figure 2 resulted in the correlation shown in Figure 3, which is defined by the following equation:

$$SFN = 10.44 + 1.016 \times \text{Sqrt}(MI_{20}) \quad (1)$$

Remembering that

$$MI_{20} = MI_2 \times MFR \quad (2)$$

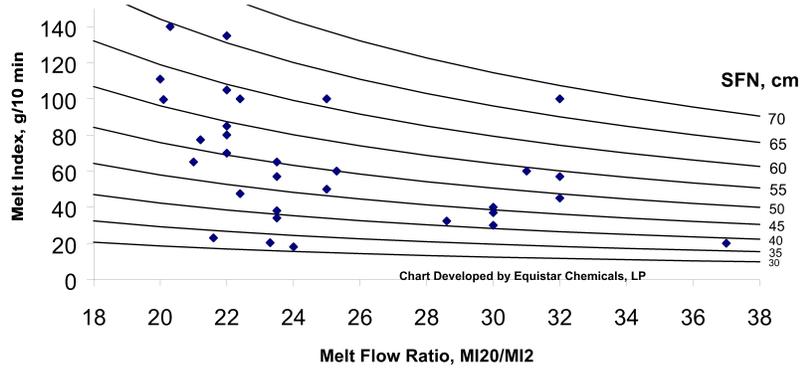
**Figure 3. Spiral Flow Number Versus MI<sub>20</sub> Correlation**



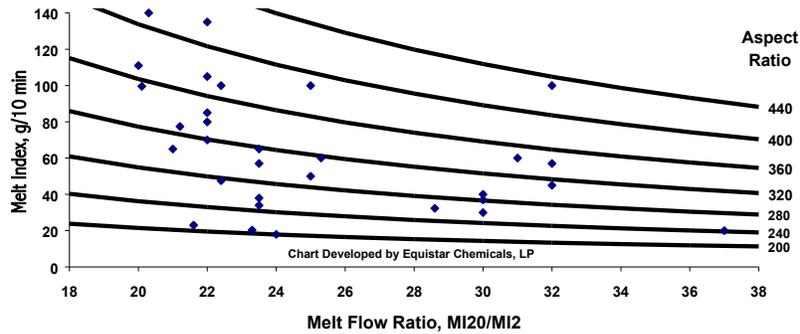
Isometric spiral flow values were superimposed on Figure 2, as shown in Figure 4. With this easy-to-read chart, one can rapidly determine how one resin performs versus another one with regard to cycle time. The effect of melt index and MFR on spiral flow is very graphic. Molders can easily determine which resins satisfy their required cycle times. An equally valuable tool would be a chart that predicts how a given resin fills a particular mold. To accomplish this, the isometric SFN values in Figure 4 were converted into mold aspect ratios as shown in Figure 5. The aspect ratio of a

mold is calculated by dividing the length of melt flow by the average wall thickness of the part. Using Figure 5, the customer and resin manufacturer can easily determine the range of MI<sub>25</sub> and MFRs that will fill a given mold.

**Figure 4. Iso Metric Spiral Flow Chart**



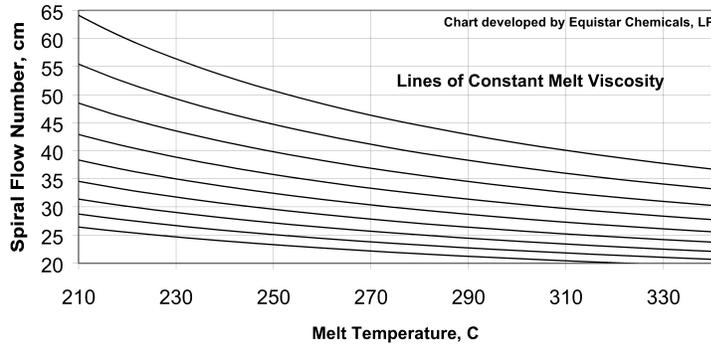
**Figure 5. Iso Metric Aspect Ratio Chart**



Recently, LyondellBasell established spiral flow specifications for all high-flow HDPE resins and began reporting the spiral flow number for each lot on the shipping Certificate of Analysis (COA). The customer can compare the spiral flow of an incoming lot of resin with the spiral flow of the lot on-hand and readily estimate how the new lot will process relative to the lot currently in production. For example, if the lot currently being run has a SFN of 50 cm and the new lot has a SFN of 55 cm, the new lot should process at an approximately 10% faster rate.

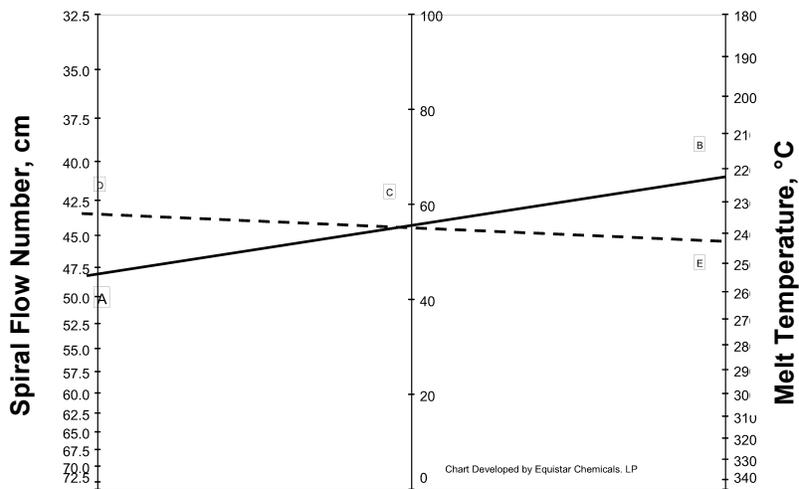
To further aid the customer in adjusting his or her processing conditions, Figure 6, Isometric Melt Viscosity Chart as a function of SFN and melt temperature, was developed from laboratory, capillary rheometer, melt viscosity data. For a given SFN and melt temperature, a point can be located on a constant melt viscosity line. By tracing along this viscosity line to the SFN of the new incoming lot, the required melt temperature to compensate for the difference in SFNs between the two lots can be read. Adjusting the melt temperature to compensate for the difference in SFNs minimizes changes in cycle time.

Figure 6. Melt Viscosity As Function of Spiral Flow and Temperature



To simplify this compensation process, the special nomogram shown in Figure 7 was developed. The left-hand vertical line represents the SFN of a given lot of resin and the right vertical line is the extruder melt temperature used to process the resin. The center vertical line is a Polymer Melt Viscosity Index, which is a relative scale from 0 percent to 100 percent of the melt viscosities used to develop the nomogram. To use the nomogram, the customer draws a straight line between the SFN of the lot currently being run and the extruder melt temperature. This locates a fixed point on the center Melt Viscosity Index. The line is then rotated about this fixed Melt Viscosity Index point to the new incoming resin lot's SFN. The recommended new extruder melt temperature is read from the right side Polymer Melt Temperature Line.

Figure 7. Spiral Flow Temperature Adjustment Nomogram Viscosity Index, %



For example, if a molder was transitioning from a resin with a SFN of 50 cm at a melt temperature of 230°C to a resin with a SFN of 45 cm, the melt temperature required to maintain the same cyclic time would be determined by: 1) drawing a straight line (solid line) between Point A, SFN of 50 cm, and Point B, 230°C melt temperature; 2) locating Point C, 50%, on the Viscosity Index line; 3) extend a straight line (dashed line) from Point D, new SFN of 45 cm, through Point C to Point E, which gives a new melt temperature of 251°C.

## SUMMARY

The use of SFNs to describe the flow properties of a given resin in thin wall injection molds uniquely combines the effect of both the resin's  $MI_2$  and MWD. In addition, superimposing isometric SFNs and Aspect Ratios onto resin product maps graphically depicts how one resin will perform in a given mold versus another resin. Furthermore, the thin wall molder can minimize transition losses between resin lots and between resin grades by using the Isometric Melt Viscosity Chart or the associated Nomogram to adjust injection melt temperatures.

## ACKNOWLEDGMENTS

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### Key Word/Phrase Index

1. Isometric Spiral Flow
2. Thin-wall Molding Cycle Time
3. Temperature Correction for Spiral Flow Changes



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