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Optimizing and Streamlining Channel Geometry In Multilayer Blown Film Dies

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Introduction

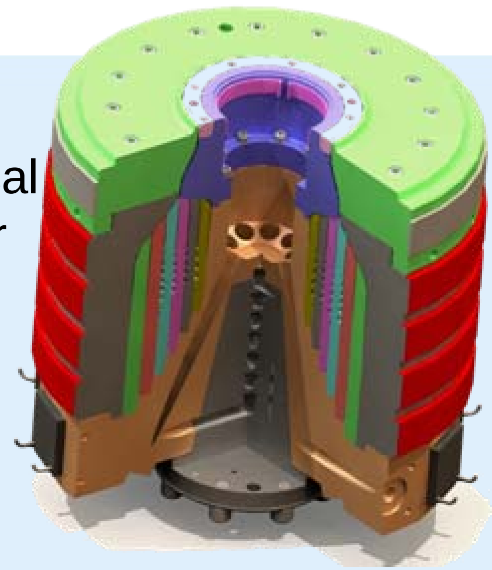
- Today we will look at polymer flow channels and design geometries used in multilayer blown film dies. The geometries, although simple, can be optimized to render a die design with low polymer residence time and low residence time distribution (RTD).
- The benefits to the processor are quicker purge times, faster product changes, and improved product quality.

The Basics

Basic Die Designs

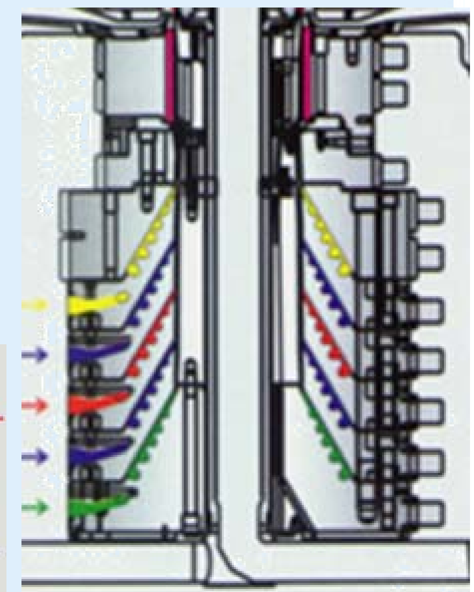
1. Concentric mandrel

   spiral mandrels are cylindrical in shape and assemble over one another securing to a common component



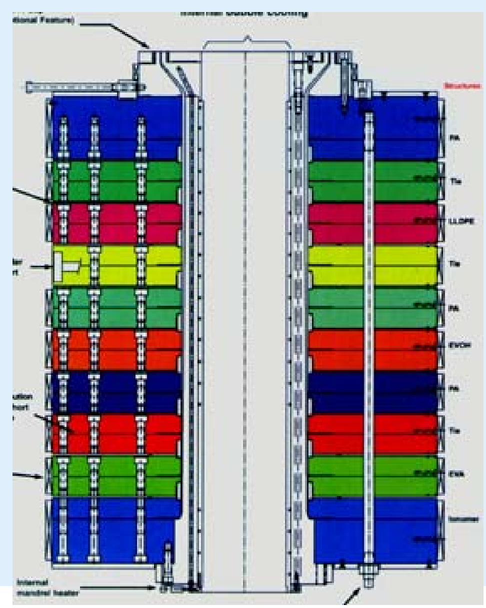
2. Conical stacked mandrel

   conical-shaped mandrels stack on or over one another



3. Modular plate design

   mandrels are split 2-pc modules which, like the conical design, stack on one another.



Die Design Basics

- The basic function of any blown film die is to take one or more melt streams entering the die and distribute them to a single concentric annular melt stream as uniformly as possible at the die exit.

- Effective design optimizes 3 basic channel geometries:
  - a single round hole,
  - multiple round holes and
  - annular gaps/channels

resulting in reduced purge times, faster product change-overs, and reduced down time.

Effect of Geometry – LLDPE & EVOH

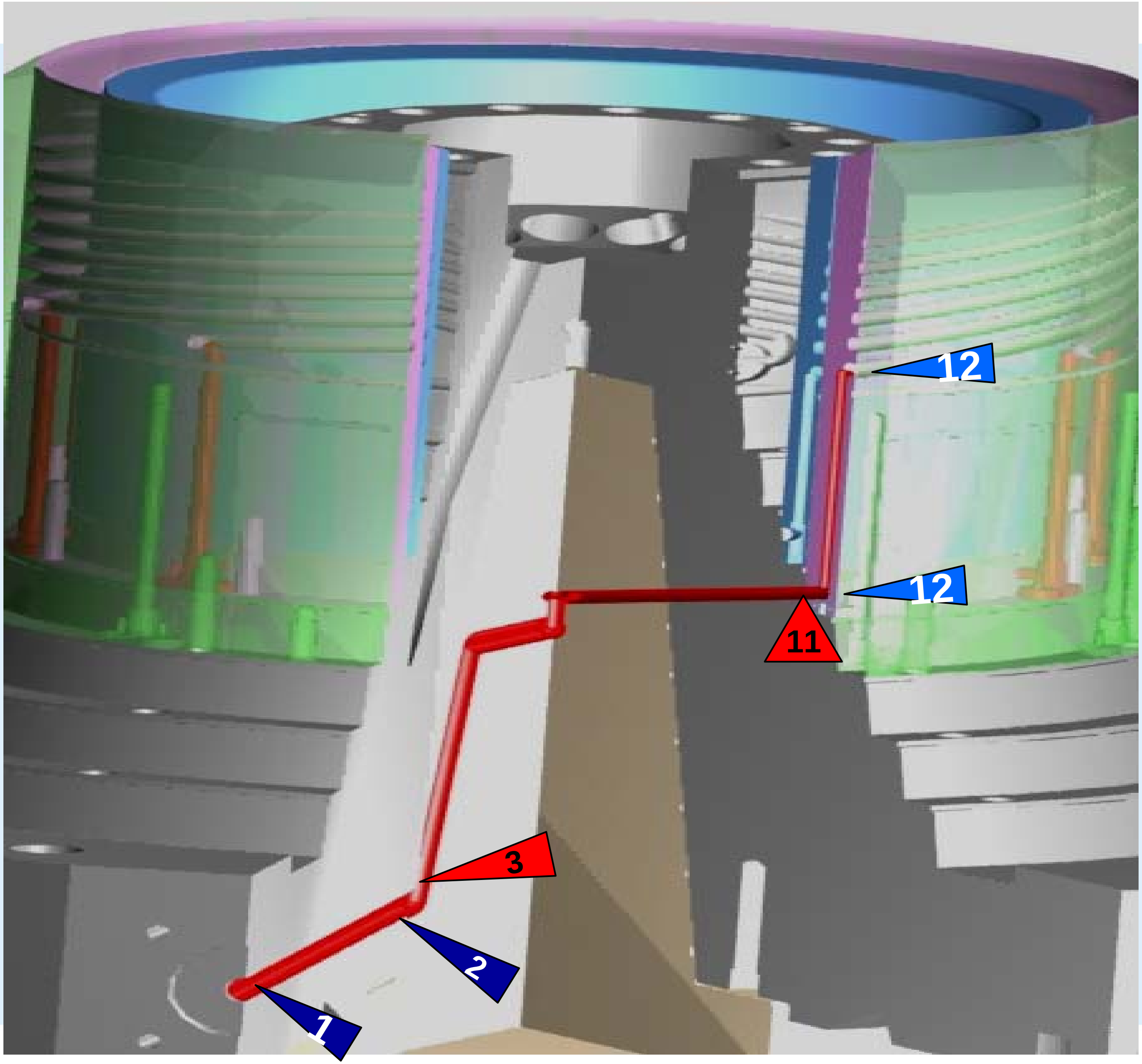
Die Channel Geometry	Material	Rate (PPH)	Hole Ø (in)	No. of Holes	Shear Rate (1/sec)	Bulk Avg Residence Time (sec)	Pressure Gradient (PSI/in)
Hole	1MI C8 LL	250	1.25	1	15.6	0.5	22
Multiple Holes	1MI C8 LL	250	0.79	4	15.5	0.8 1.6X	35
Multiple Holes	1MI C8 LL	250	0.625	8	15.6	1 2.0X	44
Hole	38M % EVOH	50	0.65	1	15.7	0.8	15
Multiple Holes	38M % EVOH	50	0.41	4	15.7	1.3	24
Multiple Holes	38M % EVOH	50	0.325	8	15.7	1.6	30
			Channel OD (in)	**Channel Gap (in)**			
Annular Gap	1MI C8 LL	250	12	0.180	15.8	2.7 5.4X	77 3.5X
Annular Gap	38M % EVOH	50	12	0.065	15.7	6.3	71

Single hole if the fastest way to move polymer melt

Designing for Maximum Streamline

Effective Use of Geometry

Flow Channels – Core Layer Concentric Mandrel Die

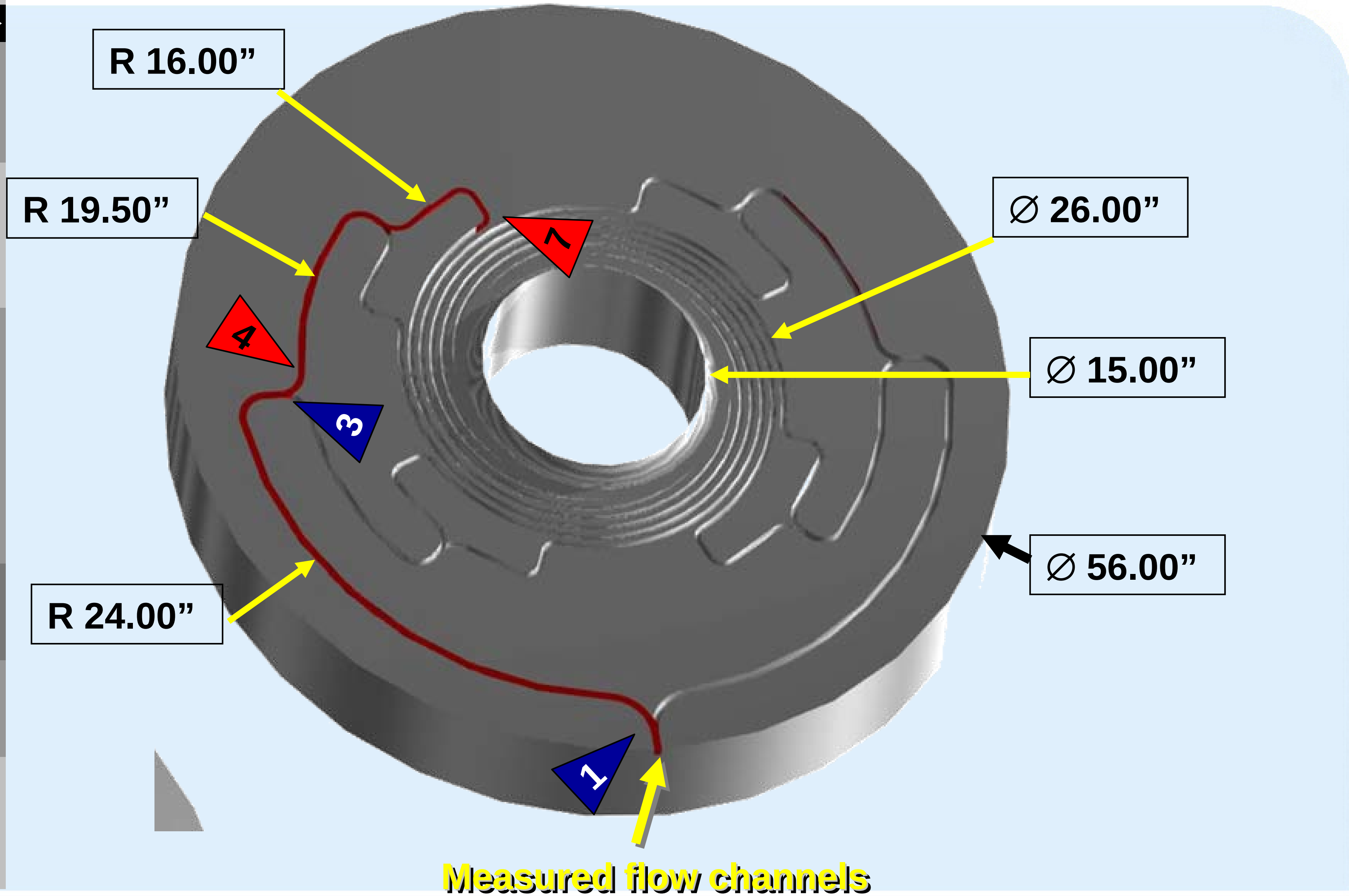


Lengths/Pressure Drops –
Core Layer Concentric Mandrel Die

Pre-Spiral

Leg#	*Description*	*Hole Dia. (IN)*	*#Holes*	***Press Drop (PSI)***	***Length (IN)***
1	**ASM**	**0.813**	**1**	**155**	**16.1**
2	**Taper Feed block**	**0.813**	**1**	**8**	**.8**
3	Taper Block J -layer	0.813	1	**18**	**1.8**
4	Taper Block H -layer	0.813	1	**18**	**1.8**
5	Taper Block G -layer	0.813	1	**18**	**1.8**
6	Taper Block F -layer	0.813	1	**18**	**1.8**
7	Taper Block E -layer	0.813	1	**18**	**1.8**
8	Taper Block E -layer	0.813	1	**30**	**3.1**
9	Taper Block E -layer	0.813	1	**6**	**.6**
10	Taper Block D -layer	0.813	1	**3**	**.3**
11	Radial Feed Holes	0.375	10	**181**	**8.5**
12	Radial Vertical Feeds	0.375	10	**100**	**4.7**
			TOTALS	**573**	**43.1**

Flow Channels – Core Layer Modular Stack Die

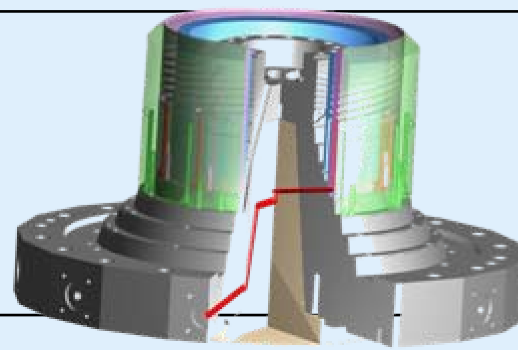


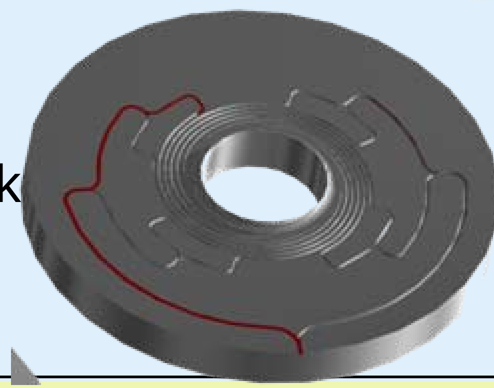
Lengths/Pressure Drops – Core Layer Modular Stack Die

Pre-Spiral					
Leg#	***Description***	***Hole Dia***	***#Holes***	***Press Drop (PSI)***	***Length (IN)***
1	Straight Leg	0.813	1	**12**	**1.2**
2	90° flow split circumferential flow	0.625	2	**548**	**40.4**
3	90° flow split radial Flow	0.625	2	**14**	**1.0**
4	45° flow split circumferential flow	0.50	4	**287**	**17.2**
5	45° flow split radial Flow	0.50	4	**8**	**0.5**
6	22.5° flow split circumferential flow	0.41	8	**145**	**7.7**
7	22.5° flow split radial Flow	0.41	8	**43**	**2.3**
			TOTALS	**1057**	**70.3**

Comparison

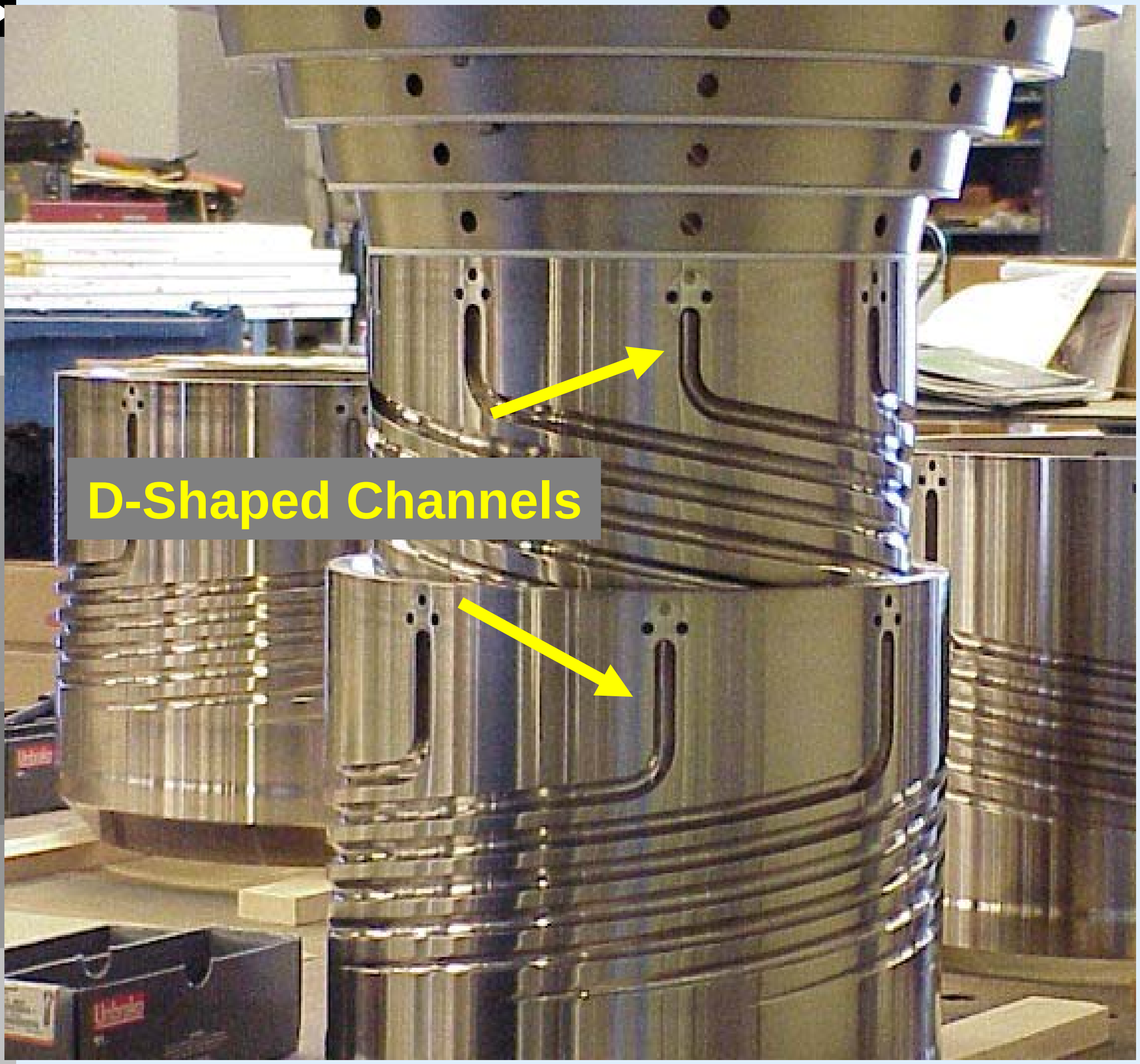
Total Pre-Spiral Length – die entry to spiral start	*Pressure Drop (PSI)*	*Length (in)*
Concentric Mandrel	573	43.1
Modular Stack	1057	70.3
Percent Increase, Stack > Concentric	**84.6%**	**63.1%**





D-Shaped Channel vs Encapsulated Feed Hole

D-Shaped Channels

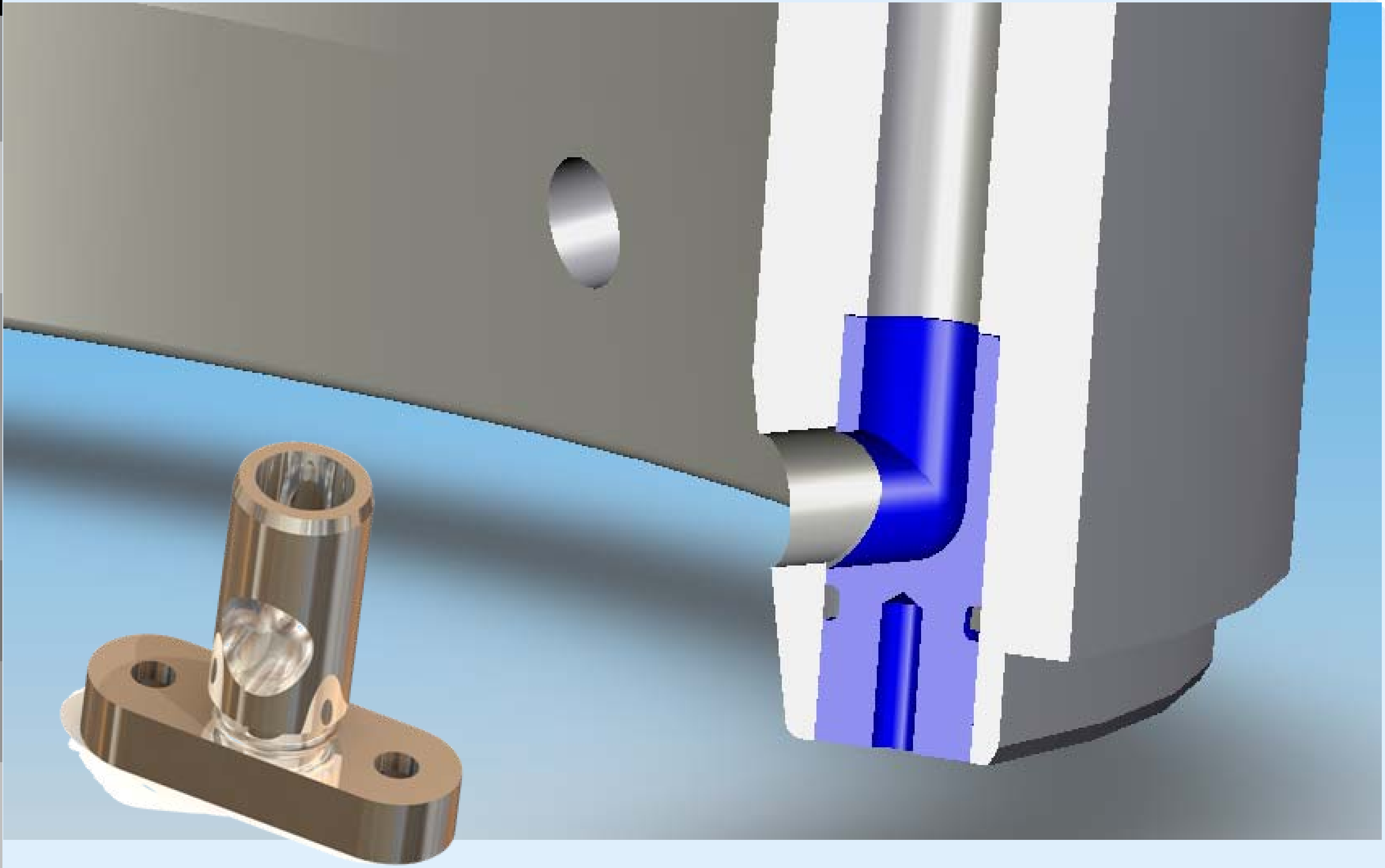


- Standard path to feed melt to spirals
- Can be slow to purge
- Can be a source of flow lines in the film

Encapsulated Feed Channels

- Encapsulated feed holes are naturally round, resulting in;
  - Faster purging and reduced die cleaning frequency
  - Reduced flow lines in film
- Easily removable inserts at melt flow transition

Section View- Encapsulation



Advantages of Fully Encapsulated Mandrel

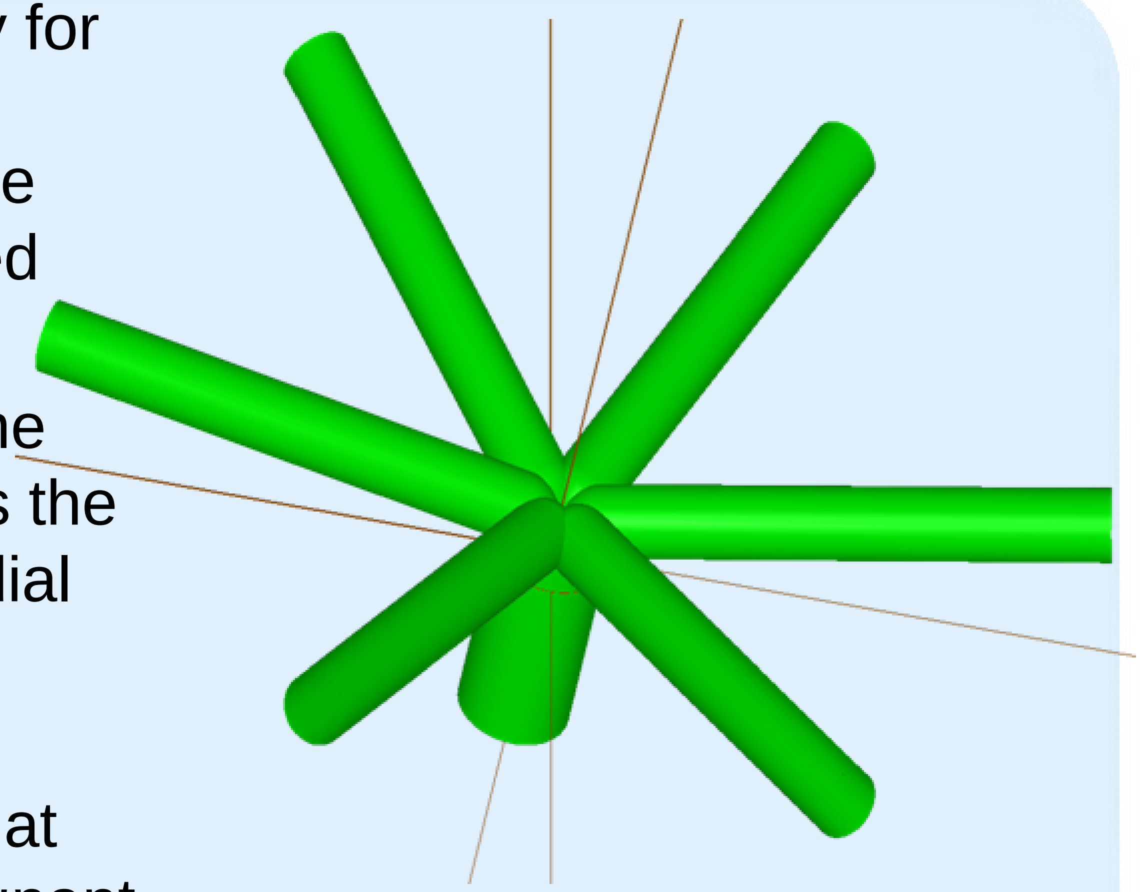
- Reduction of material exchange into assembly clearance area
- Elimination of “D” shaped vertical channel
- Simplified machining and polishing in assembly clearance area
- Significant improvement in purge / material transition times
- EVOH to Nylon in 40 min @ 90 lb/h for that layer

Bulk Average Residence Time & RTD

- Bulk average residence time = total channel volume (in^3 or m^3) divided by the flow rate (volume/sec) with the result in seconds
- RTD or Residence Time Distribution = the time difference between the fastest and slowest moving particles. We are normally concerned about the difference between the average and the slowest since the slowest moving particles are prone to degradation and long purge times.
- Affected by channel geometry, variations in surface finish, and plating.

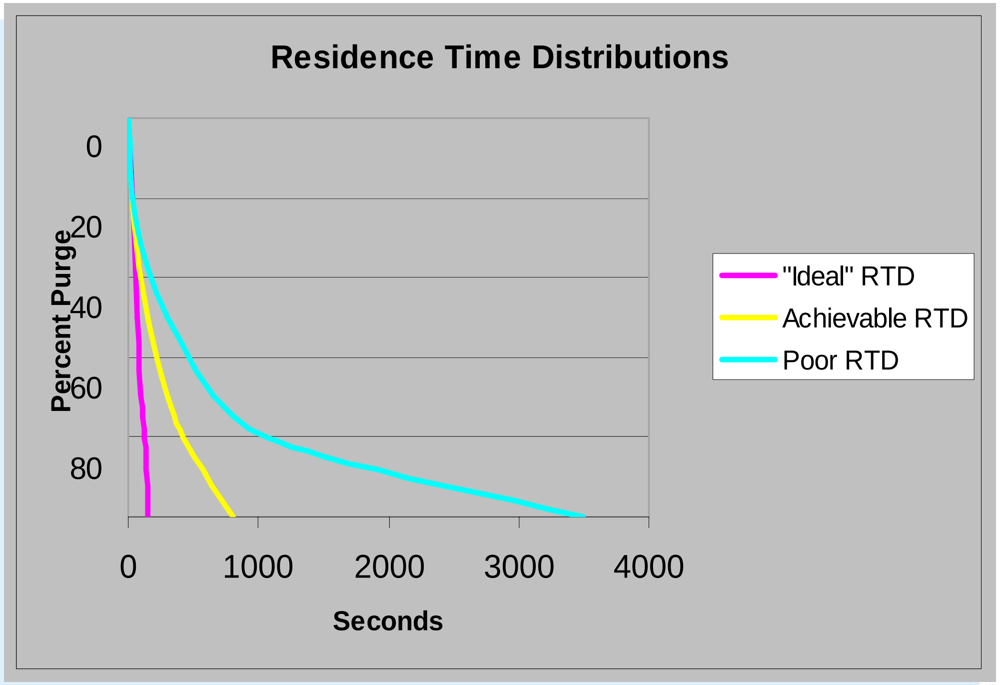
Optimized Flow Transition

- Optimized geometry for a center-fed flow splitting from a single hole to (6) radial feed holes.
- The shear rate of the center hole matches the shear rate in the radial holes.
- This is a very fast purging geometry that doesn’t support stagnant flow.



RTD

- RTD can be calculated but is more accurate when developed empirically.
- ‘Ideal’ curve is actually the polymer residence time calculation, V/Q.
- ‘Ideal’ doesn’t account for flawed geometry or bad surface finish.
- ‘Achievable’ distribution is possible with optimized geometry and polished flow surfaces with non-porous auto-catalytic coatings, like electroless nickel.
- ‘Poor’ RTD will result when geometry is not optimized and finish and/or fit is bad.



Conclusion

- It has been noted here that time spent optimizing simple geometries while designing multi-layer blown film dies can have large paybacks for the end user in terms of faster purge times, easier product changes, and improved film quality.

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Thank You

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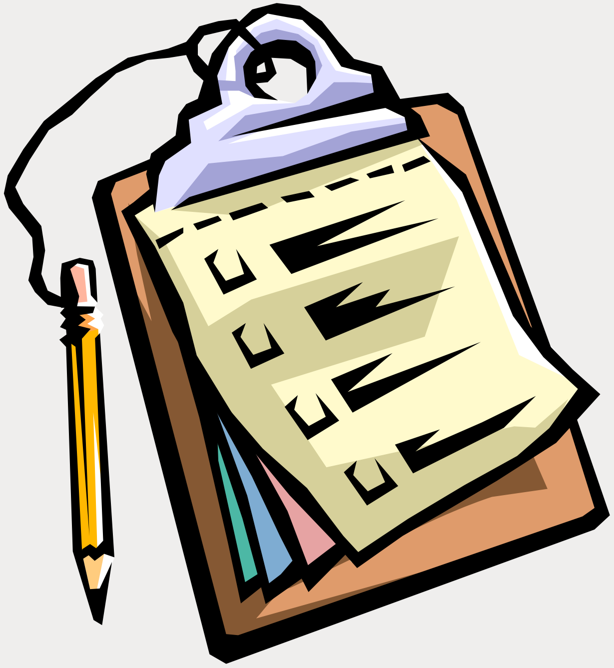

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