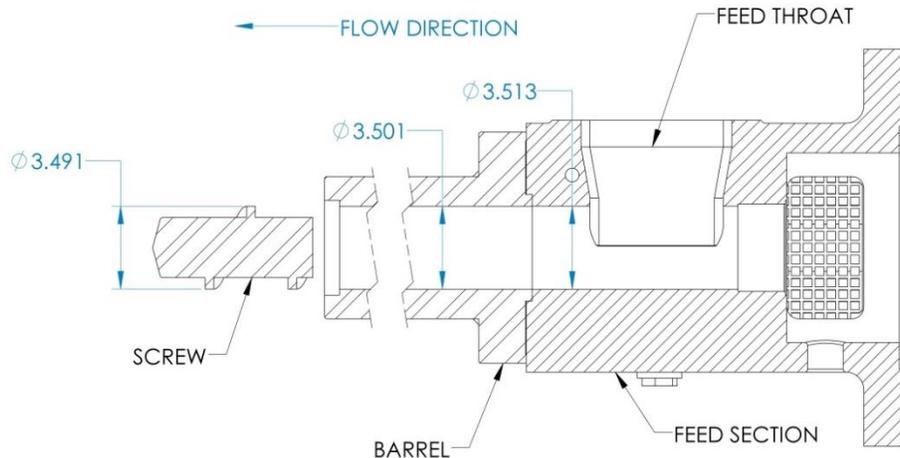


## Cast vs. integral feed section: 7 factors to consider when deciding

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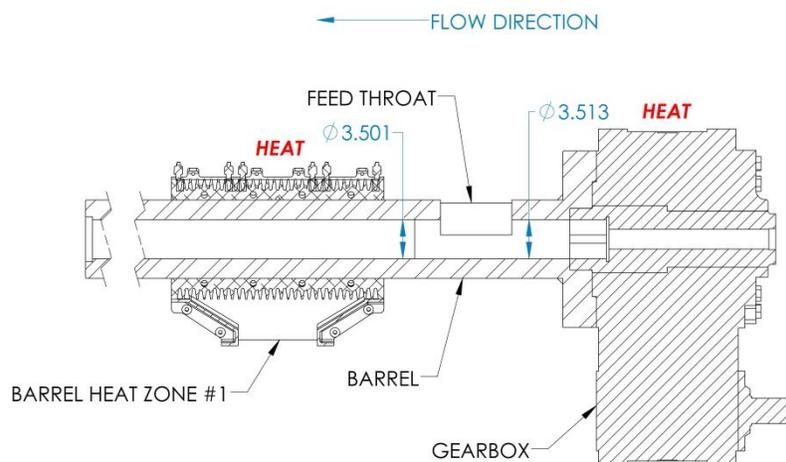
Feed section design plays an important role in the extrusion process and should be carefully considered when specifying a new extruder.

The vast majority of single screw extruders operating in North America (in the thousands) include a cast feed section with cooling passages that are molded directly into the casting in close proximity to the feed throat. As indicated on [Figure 1](#), the feed casting is bolted to the upstream side of the barrel and it acts as a thermal barrier to prevent bridging (early melting) of the polymer on the feed throat walls, melt blocks in the feed section of the screw, and also minimizes heat transfer from the barrel to the gear reducer.



**Figure 1: 3.5-inch Screw, Barrel and Cast Feed Section**

An alternate design offered by some extruder manufacturers is a single piece barrel with integral feed port. In this design, a longer barrel is used and the feed port is machined directly into the barrel cylinder and liner as shown on [Figure 2](#).



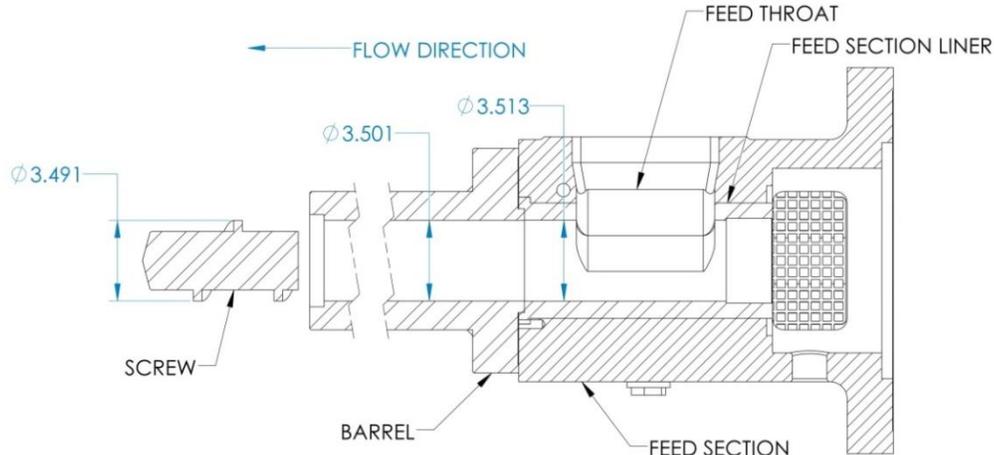
**Figure 2: 3.5-inch Barrel with Integral Feed Throat Bolted Directly to Gear Reducer**

Studies have indicated the potential for an increase in output rate when processing certain polyolefin polymers with this second approach. Tim Womer, et al, 2007 studied the differences in output rate of 100% PP regrind (2.0 MI) and 100% HDPE regrind (0.3 MI) on a 3.5" 24D extruder with a barrel with integral feed port and a water-cooled cast iron feed section. Each test included five different screw speeds and the integral feed throat configuration produced more output at every screw speed compared to the standard barrel with water cooled cast feed section. For instance there was an increase in output rate of 5.25% for PP and 3.93% for HDPE when running at 75 rpm screw speed.

Due to the increased output rate, the motor amp draw and melt temperature also increased with the integral configuration compared to the water-cooled cast feed section. The increase in solids conveying and output rate is attributed to the heat migration from using an integral barrel-feed port barrel configuration that increases the coefficient of friction between the pellet and the barrel wall in the feed section of the screw. The extra heat input to feed zone moves the onset of initial melting back toward the hopper, which is beneficial for certain polymers.

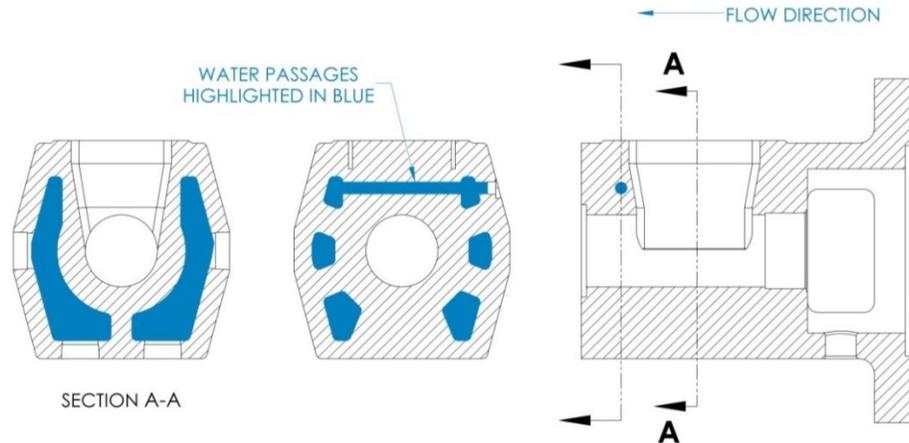
Although increased output rates for PP and HDPE may be attractive, there are several risks and downsides when considering the purchase of an extruder with an integral barrel/feed throat, especially when a processor has multiple extruders with the more common water-cooled cast iron feed section. Here are the key considerations:

1. An optional removable and replaceable feed section liner as shown on [Figure 3](#) protects against accidental damage or long term wear. With the integral barrel/feed throat design, you have to swap out the entire barrel when you want to change feed throat geometries or replace a damaged feed throat.



**Figure 3: 3.5-inch Screw, Barrel and Cast Feed Section with Replaceable Feed Liner**

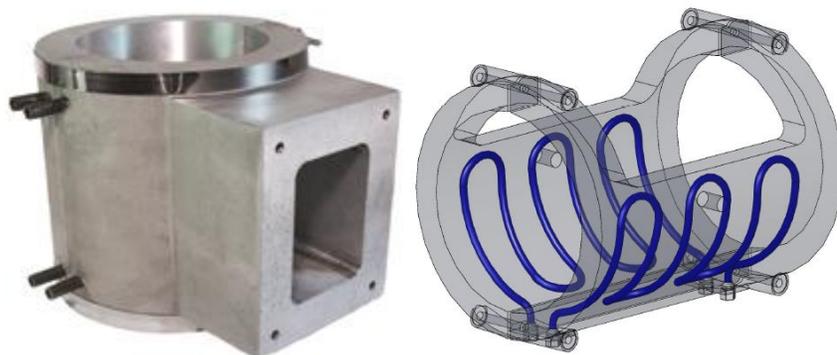
2. The cast feed section is cored for full-surround water cooling as shown on [Figure 4](#) that surrounds the feedscrew to prevent premature melting of the polymer flowing from the hopper. The outside temperature of the casting is typically 90° - 120 °F or "warm to the touch". The issue with integral barrel/feed throat is that the barrel acts as a big heat pipe and heat flows into the feed throat zone. It is harder to effectively control the feed throat temperature without being affected by barrel zone #1. The separate cast feed section provides a thermal barrier that results in greatly reduced thermal conduction from barrel zone #1.



**Figure 4: 3.5-inch Cast Feed Section with “Full Surround” Internal Cooling Passages**

With an integral barrel, the area of conduction is much larger necessitating much more cooling for the feed throat. From a screw design and extruder performance standpoint it would be better to have a separate feed section with a good thermal barrier to control the amount of heat transfer into the feed throat. Excessive heat in the feed throat can cause bridging problems where the pellets travelling down the throat will start to prematurely melt and clump up. Low melting point polymers are most susceptible to sticking to the wall of the feed throat. As the pellets build up on the feed throat walls, material flow is restricted or blocked as it enters into the extruder and gradually there is a decrease in output rate. Cooling of the feed throat is very important to prevent bridging. Removing the partially melted clump of material blocking a feed throat can be difficult, dangerous, and can result in significant downtime.

3. It is harder to machine efficient cooling channels in the feed housing. Typically an aluminum water jacket with cast-in cooling tubes would be used with the integral barrel/feed throat like shown on [Figure 5](#) that cools the outside surface of the barrel compared to more efficient internal cooling passages within a cast feed section. Air cooling the feed section with a blower would be considerably less efficient and mostly inadequate, especially as the extruder size increases. The larger the extruder size, the greater the mass of the barrel, and the thicker the barrel wall, so the heat removal requirement is increased. Air only has a gentle effect on the barrel; water cooling is instant for fast heat removal and therefore water cooling is the most effective method to cool the feed throat. Air cooling would also be dependent upon the ambient temperature with summer or winter room temperature differentials.



**Figure 5: Aluminum Water Jackets with Cast-in Cooling Tubes**

4. Increased potential for melt block problems in the feed section due to higher feed zone temperatures. A melt block is when output rate and motor amps fall due to a loss in solids conveying from polymer sticking to the screw root in the feed zone. A melt block usually happens when the extruder is stopped even for a few minutes with the screw full of polymer. The screw surface under the hopper becomes hot during a screw stoppage. Polymer stuck on the screw root will rotate with the screw, reducing the screw channel area, resulting in flow surging and a loss in output rate. Even small traces of polymer stuck to the screw root can cause flow surging issues. The fix to a melt block problem often requires pulling the screw for a full clean out. In small extruders the screw can be pulled and cleaned within a few hours. However, pulling and cleaning a large screw by hand may take half a day or longer. Because the integral barrel/feed throat design does not include a thermal barrier (cooling break) you must have constant water flow to the feed throat area, especially during a stoppage.
5. As mentioned previously, the cast feed section minimizes heat transfer from the “hot” barrel to the extruder gear reducer. The barrel/screw and gear reducer both generate heat and the cast feed section acts as a heat sink and absorbs heat between the two devices, as shown on [Figure 2](#). The normal operating temperature of common extruder gear reducers is 130° to 160°F and depends on the gearboxes heat dissipation. Without the thermal barrier of a cast feed section between the barrel and the gear reducer, as in the integral barrel/feed throat design, heat will migrate to the extruder gear reducer. Excessive heat around the output shaft area of the gear reducer may result in premature failure of the output shaft radial seal ring. In addition, the use of an integral barrel/feed throat bolted directly to the gear reducer may necessitate the need for a cooling coil to be added to the gear reducer when it would otherwise not be needed with a cast feed section bolted to the gear reducer.
6. If a processor has several extruders with traditional water-cooled cast iron feed sections running certain polymers and they decide to change to an extruder with an integral barrel/feed throat to run the same polymers then they would likely have to modify their barrel temperature profiles to compensate for the higher melt temperatures associated with the integral barrel/feed throat.
7. The extra heat input into feed zone with the integral barrel/feed throat moves the onset of initial melting back toward the hopper. Similarly, pre-heating feed stock results in faster melting because a substantial amount of heat is conducted into the polymer in the hopper. Using an integral barrel/feed throat in conjunction with the pre-heated feed stock has shown to cause entrapped air issues while running preheated amorphous PET (A-PET) pellets mixed with a high percentage of preheated recycled A-PET thin flake. Feed stocks can contain up to 70% air by volume and air is also between the pellets. The air is squeezed out and flows backwards into the hopper from the feed throat as the pellets are compacted into a solid bed along the screw prior to melting. The issue is that the thin regrind flake will melt too quickly in the feed zone before compaction is complete blocking the air from flowing backward to the hopper resulting in entrapped air in the melt and defects in the final product. The early melting phenomenon seen in pre-heating flake with an integral barrel/feed throat design would likely not occur with a separate water-cooled cast feed throat.

## **Are screws interchangeable between extruders with a cast feed section and an integral barrel/feed throat?**

Even if the main flight OD, screw shank and the overall length of the screws are the same, the concept of screw “interchangeability” between the two extruder designs cannot be fulfilled in the context of mechanical design and screw process performance.

The clearance between the screw and the barrel and feed section is a very important factor in extruder design. The vast majority of extruders in operation are designed with a feed screw with full diameter throughout the flighted length and a cast iron feed section that has a slightly larger bore ID compared to the barrel bore ID as indicated on [Figure 1](#). When the screw and barrel increase in temperature, both the screw and barrel will increase in diameter due to thermal expansion. The clearance between the screw and the barrel and feed section will reduce with increasing temperature. In a running extruder, the screw, barrel and feed section are not at the same temperatures. A large amount of viscous heat is generated as the melt is sheared by screw rotation. When viscous heating is significant, the screw temperature will likely to be higher than the barrel temperature and the largest difference in temperature will be between the screw and the feed throat.

The feed throat is typically water cooled in the 90° - 120 °F range and the screw temperature in the feed section will be much higher because the high temperatures in the compression and metering section will raise the temperature of the screw in the feed section due to thermal conduction. If the feed bore ID and the barrel ID are the same as in an integral barrel/feed throat design, then as the screw heats up it will expand against the “cold” feed section bore that doesn’t expand and binding and galling will likely occur. That is why the cast iron feed section has a slightly larger bore ID compared to the barrel bore ID or alternatively the screw flights in the feed section are undercut. The higher screw temperature will cause the screw to expand much more than the feed throat and the barrel, and therefore there is less chance for catastrophic failures from the screw locking up in the feed section.

The only way to solve this with the integral barrel/feed throat design is to grind a relief into the inlay of the barrel in the feed area ([Figure 2](#)) or undercut the screw to increase the flight clearance. Grinding a relief in the barrel inlay is not a common practice in the industry and it is likely that in the future the relief will be mistaken for feed wear. Undercutting the screw in the feed will have an adverse effect on screw performance if the screw is used with an extruder with a common oversized feed bore ID because the clearance between the screw flight OD and the feed bore ID will be large enough to allow small feed stock particles such as powder, additives and “fines” to pass over the top of the flights, reducing the ability to solids convey resin out of the feed section. Even worse, if the standard screw that does not include an undercut in the feed area were to be used in the extruder with an integral barrel/feed without a relief in the feed, the screw would almost certainly bind and catastrophically lock up in the feed section.

## **Does an integral feed throat improve alignment?**

Extruder manufacturers that offer the integral barrel/feed throat design claim that the design offers improved alignment between the barrel and gearbox. Barrel and feed section misalignment can cause problems; however, of the thousands of extruders in operation around the world that include a cast iron feed section, I have not seen any issues with the screw becoming stuck in an extruder barrel due to misalignment. It is important to remember that the screw is supported and centered in the barrel hydraulically by the internal pressure of the polymer in the screw channels.

## **Conclusion**

Efficient and uniform water cooling of the feed throat is important for many polymers to insure feeding consistency and to reduce the chances of feed bridging. The integral barrel/feed throat design is rife with unknowns and potential risks especially in larger extruders where it is more difficult to control the temperature of the integral barrel throat section. The integral barrel/feed throat design is a low cost approach to extruder design that may result in high output rates but not necessarily improve the quality of extrusion. Extensive lab experiments would need to be completed to demonstrate the effectiveness through a range of extruder sizes and with a wide variety of polymers and feedstocks including powders and recycled material.

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