# IX. Verifying Fill Balance

- **Effect of Injection Time on Fill Balance**
- **Laboratory - Fill Balance**
- **Thermal Imbalance**
- **Unbalanced Fill in Molds with Cold Runners**

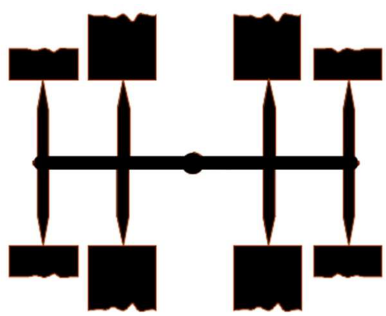
Again, before proceeding with this ***Universal Molding™*** laboratory remember that:

- Auxiliary equipment should be properly installed and correctly operating.
- Temperatures should already be reached.
- Barrel adjustments should have been programmed.
- The required clamping force should have been set.
- The press openings, their movement, speeds, and mold protection should have been carefully and precisely adjusted.
- Extended cooling time should have been set, in order to prevent it from interfering in the determination of other parameters.
- The ideal injection speed should have been determined, adjusted and should be filling about 95% of the required fill for the mold.
- The injection pressure limit should have been determined and adjusted.
- The hold stage should stay off.

**Important --** only qualified personnel who have read the operational manuals of the equipment and understand the functionality of the equipment should operate and/or adjust them.

Multi-cavity molds increase productivity. However, their fabrication, as well as their operation, is complicated; the melt's flow path must be balanced, and cooling is more elaborate.

Imagine a multi-cavity mold with distinct fill times for each cavity, or with some cavities that fill before others.

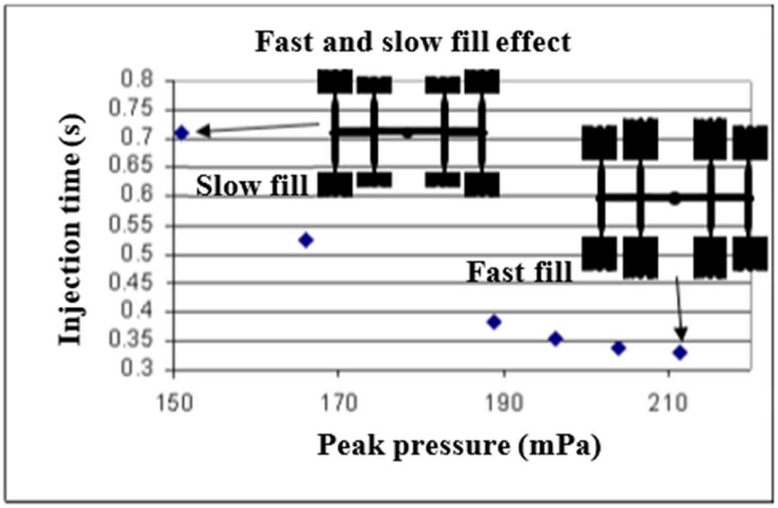


*IX-1. Multi-cavity mold with unbalanced fill*

This situation defeats the objective of maintaining constant flow and viscosity per cavity; it is like accepting the molding of distinct parts for each cavity.

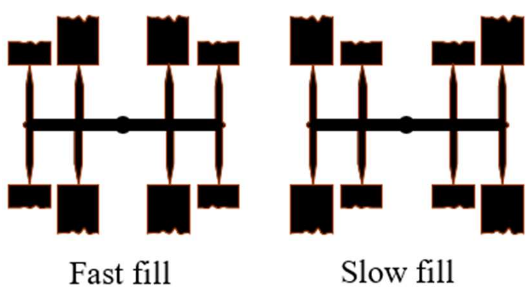
## Effect of Injection Time on Fill Balance

The "Determining Injection Speed" chapter mentioned the multiple effects of injection time on fill. In the injection stage, the volume of melt in the parts increases with an increase in injection speed. Look at the illustration.



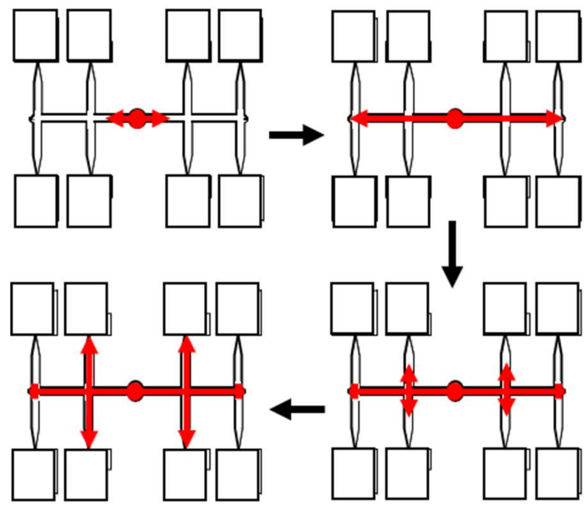

*IX-2. Graph of the effect of injection speed on the fill of incomplete parts*

In addition, it can be noted that with a fast fill, the interior cavities will be filled sooner than the exterior ones.




*IX-3. Fast and slow fill*

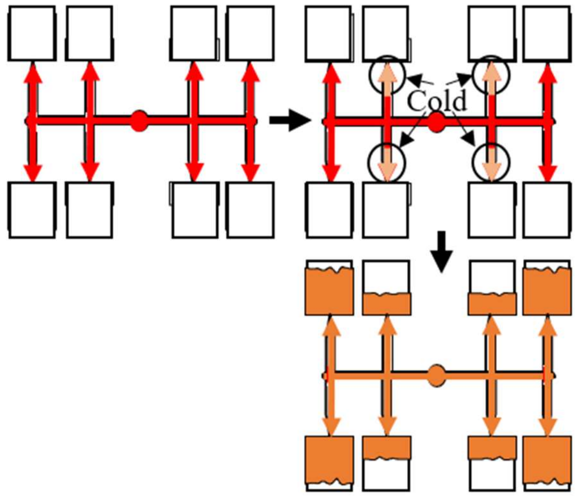
Let's see why; during the start of fill, the flow is divided between both sides of the sprue. Melt flow will always prefer the least restriction, so it will continue in a straight line and not turn into the first intersections where the runner branches out. Once it reaches the end of the main branch and is forced to turn, it prefers filling the previous intersection, since the melt pressure will be greater at that intersection.



*IX-4. Example of flow sequence of the runner*

Now, once the melt reaches the first gates, it encounters the restriction of those narrow openings. Then, the melt will prefer to continue flowing through the runner, since it is the path of least restriction, until it encounters the same difficulty, the restriction of small gates at the end.

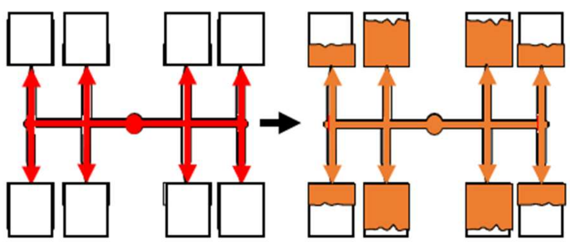
Let's assume the fill is slow. The melt in these outer gates is still hot and has less viscosity than the melt in the inner gates, as it has been in contact with the cold metal for longer.




*IX-5. Example of slow fill*

Consequently, the exterior cavities will be filled first. During injection, the melt in contact with the cold metal is the first to harden, and the thickness of this hardened layer will depend on the amount of time the melt is in contact with that cold metal. When the injection is slow, the hardened layer is thicker and, as a result, the melt path is narrower.

Now let's do the same exercise, but this time do it assuming the flow is fast. Initially the runner will fill in the same manner as before. The difference is that the time that the melt sits in the first runners is less.



*IX-6. Example of fast fill*

Consequently. its viscosity will stay low and the melt will prefer to fill the interior cavities, since the required pressure will be less.

Injection time has a lot to do with the flow balance, which is why the injection speed must be determined and adjusted before carrying out a study of flow balance.

Other situations caused by imbalance:

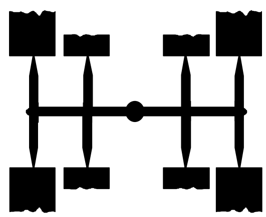
1. Jamming or difficulty in ejection:
   - Some cavities may cause parts to get stuck or exhibit ejection difficulties. These cavities probably fill first.
   - On the other hand, parts that detach on their own (with minimal or no effort from ejectors) are probably the last to fill.
2. Flash formation:
   - Cavities that frequently show flash (excess material) are most likely the ones that fill first.
3. Higher part weight:
   - Parts with greater weight also have a probability of filling first.

Understanding these scenarios is essential, as they can impact the overall molding process.

## Laboratory - Fill Balance

This section will present the procedure for verifying flow imbalance:

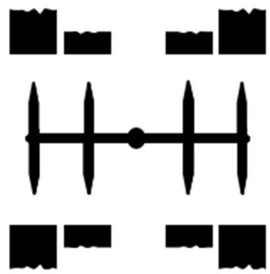
1. Adjust the injection unit to produce incomplete parts and make sure that hold is still turned off.



*IX-7. Example of incomplete fill*

This experiment is carried out with incomplete fill so that we can evaluate the fill of each individual cavity. If one or more cavity completely fills, it would be impossible to determine the fill balance. Try to achieve a fill of 80%, then verify that each cavity is incomplete; if any is not, reduce the recovery volume even more and reverify.

2. If the parts are attached to the runner, separate them.



*IX-8. Parts separated from the runner*

3. Weigh the parts separately and identify them with $W_i$ ($i$ = 1 to # of cavities). Add all the $W_i$ weights and call this $W_T$.

$$W_T = \sum_{\#\,cav.}^{1} W_i$$

4. Determine the volume deviation for each cavity, $Vd_i$.

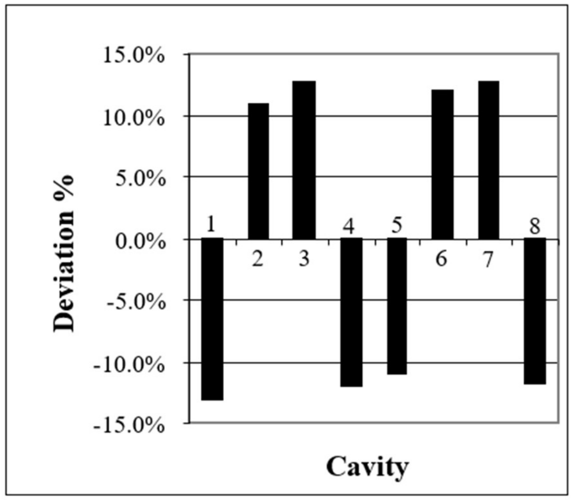
$$Vd_i = \left[\frac{W_i}{\left({}^{W_T}/_{\#cavities}\right)} - 1\right] 100\%,\ i = 1 \text{ to \# of cavities}$$

If the determined percentage is zero, the flow is ideal; if it is positive, the flow is higher than ideal; if it is negative it is lower than ideal. You should normally try to maintain this percentage to within $\pm$10%. Verify the deviation that is permitted by your company. Example:

| Cavity | Sample 1 | Sample 2 | Average | Deviation |
|---|---|---|---|---|
| 1 | 3.42 | 3.42 | 3.42 | *-13.1%* |
| 2 | 4.36 | 4.37 | 4.365 | *10.9%* |
| 3 | 4.42 | 4.44 | 4.43 | *12.5%* |
| 4 | 3.46 | 3.47 | 3.465 | *-12.0%* |
| 5 | 3.5 | 3.5 | 3.5 | *-11.1%* |
| 6 | 4.4 | 4.41 | 4.405 | *11.9%* |
| 7 | 4.43 | 4.44 | 4.435 | *12.7%* |
| 8 | 3.47 | 3.47 | 3.47 | *-11.8%* |

*IX-9. Table with incomplete cavity weights and corresponding fill deviations*

The data demonstrates a negative deviation in cavities 1, 4, 5, and 8, indicating that they are the last ones to be filled, and a positive deviation for cavities 2, 3, 6, and 7, indicating that they are the first to be filled. Look at the column graph with the results.




*IX-10. Column plot with % of cavity fill deviation*

## Thermal Imbalance

It is good to have and understand the mold cooling water flow diagrams. Cooler cavities tend to harden plastic faster and, consequently, make the flow more viscous.

Some companies use infrared systems to determine their molds' thermal distribution. Remember that the temperature of metal, plastic, and water are usually distinct, although they are still related.

In the case of hot runners, the flow can be corrected by zone, by changing the temperature at the hot drops of the runner system.

For example:

- In the case of a negative $Vd_i$, the temperature of that hot drop should be increased. Be careful not to overheat the plastic in the drops.

- In the opposite case where the $Vd_i$ value is positive, the temperature of the hot drop should be lowered. Be careful not to cause the plastic to solidify in the drops.

It is crucial to understand that when you modify the flow in one zone, the others will also be affected. For this reason, it is recommended to make one change at a time and inject new parts. Additionally, consider starting by cooling the zones of the cavities that fill first, which will yield faster results.

It is important to understand that once the flow of one zone is changed, the other zones will be affected. Therefore, it is recommended making one change at a time and injecting new incomplete parts.

This procedure works with hot runner systems with valve gates. Just make sure the valves remain open during the injection stage.

When the imbalance is such that it cannot be thermally corrected, the correction is made on the tooling.

## Imbalance in Molds with Cold Runners

In the case of cold runners, the correction is not so simple. The imbalance could be a result of the cavity's water flow and temperature by cavity, it could be that the water passages are dirty, or it could be a mold design problem.

For example:

- Cavities with a positive $Vd_i$ value may be receiving less cooling. Possibly there is an obstruction in the water passages.
- Cavities with a negative $Vd_i$ value may be receiving more heat removal. It could be that the water passages are incorrectly connected.

Runners that distribute melt to cavities with a negative $Vd_i$ could be enlarged to facilitate the passage to these cavities. Important! This practice should only be performed by experienced and knowledgeable tooling technicians who know the proper techniques.

## Questions

1) Before verifying the fill balance,
   a. adjust the injection speed to $V_{95}$, the recovery to completely fill the mold, and the fill to a minimum pressure.
   b. adjust the speed to 80% of what's required, the pressure limit to what has been determined, and the fill to an average pressure.
   c. the ideal injection speed and injection pressure limit should be determined and adjusted, and the hold stage should stay off.

2) Choose the correct statement:
   a. Verification of the fill balance is performed with a fill of slightly more than 95% of the mold.
   b. Verification of the fill balance is carried out with an incomplete fill, for example, 20% incomplete.
   c. Verification of the fill balance is performed after the transfer position has been adjusted to a minimum hold.

3) The injection time has a lot to do with the flow balance, which is why the injection speed must be determined and adjusted before doing a study of the flow balance.
   a. True
   b. False

4) In an analysis of flow balance, if the percentage determined by the volume deviation equation is zero, the flow is ideal.

$$(Vd_i = \left[\frac{w_i}{\left({}^{W_T}/_{\#cavities}\right)} - 1\right] 100\%,\ i = 1 \text{ to \# of cavities})$$

   a. True
   b. False

5) In an analysis of flow balance, if the percentage determined by the volume deviation equation is
   a. positive, the flow is above ideal.
   b. negative, the flow is below ideal.
   c. zero, the flow is ideal.
   d. all the above.

6) In an analysis of flow balance, the following was obtained:

| Cavity | Sample 1 | Sample 2 | Average | Deviation |
|---|---|---|---|---|
| 1 | 3.42 | 3.42 | 3.42 | *-13.1%* |
| 2 | 4.36 | 4.37 | 4.365 | *10.9%* |
| 3 | 4.43 | 4.44 | 4.435 | *12.7%* |
| 4 | 3.47 | 3.47 | 3.47 | *-11.8%* |

a. The result shows a negative deviation in cavities 1 and 4, indicating that they are the first to fill.
b. The result shows a positive deviation in cavities 2 and 3, indicating that they are the first to fill.

7) In an analysis of flow balance with hot runners,
a. we can compensate the flow by zone by changing the temperature in the hot drops of the runners.
b. in the case where the volume deviation is negative, the temperature of the hot drop of that cavity should be lowered.
c. in the case where the volume deviation is positive, the temperature of the hot drop of that cavity should be increased.

8) Correcting the flow balance in molds with cold runners is not so simple, since controlling the water flow and its temperatures could be a mold design problem.
a. Runners and gates that distribute the melt to the cavities with a positive volume deviation should be enlarged to facilitate passage to these cavities.
b. Runners that distribute the melt to the cavities with a negative volume deviation may need to be enlarged to facilitate passage to these cavities, carried out only by experienced and technically knowledgeable tooling technicians.