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

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

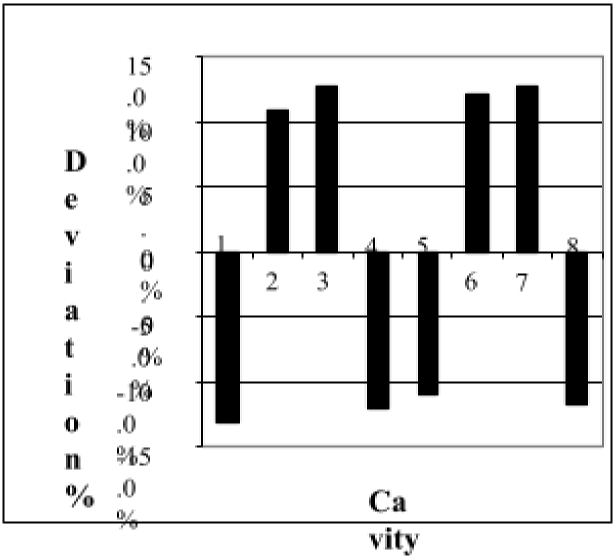
$$Vd_i = \left[ \frac{W_i}{\left(\frac{W_T}{\#cavities}\right)} - 1 \right] 100\%, \text{ i = 1 to \# of cavities}$$

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 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 water flow and cavity temperature, 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 limit pressure 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.

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

   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.

# X. Determining Hold Stage Parameters

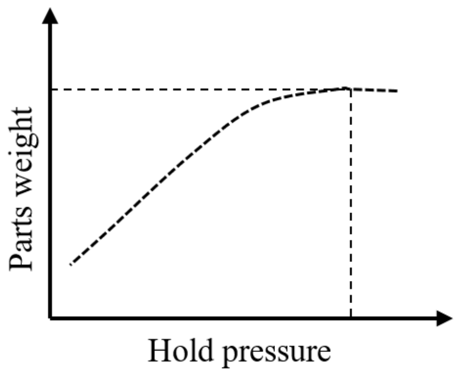
- **Laboratory I - Determining Hold Pressure**
- **Laboratory II - Determining Hold Time**
- **Hold Stage for Molds with Hot Runners and Gate Valves**

Again, remember that before continuing with these ***Universal Molding***$^{TM}$ labs:

- 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.
- The fill balance should have been verified and adjusted.

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

The hold pressure is determined, increasing the hydraulic or melt hold pressure, until the cavities are completely full or have reached the desired weight.

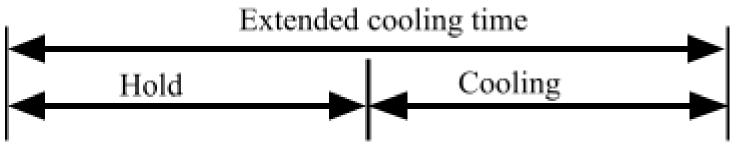



*X-1. Graph of the effect of hold pressure on the weight of the parts*

## Laboratory I - Determining Hold Pressure

1. Set the hold time to a value greater than required. For example, consider half the extended cooling time that was used in previous labs. The goal is to ensure gate freeze; hold time will be optimized later.

2. Write down a cooling time equal to the difference between extended cooling time and hold time. Note that the sum between hold time and cooling time will be equal to extended cooling time.




*X-2. Extended cooling time*

For example, in a laboratory where the extended cooling time is equal to 12 seconds, half of the extended cooling time was used in order to guarantee gate freeze. The results are the following:

Hold time = 6 seconds
and
Cooling time = 6 seconds

Important, always guarantee that cooling time is longer than recovery time. It was explained in previous chapters that, when cooling time expires, permission to open the mold will only be allowed if recovery has finished. In other words, the mold will be closed until the recovery is complete, regardless of whether cooling time has finished. Consequently, cooling time will be extended and, depending on the machine, you may not realize this is happening.

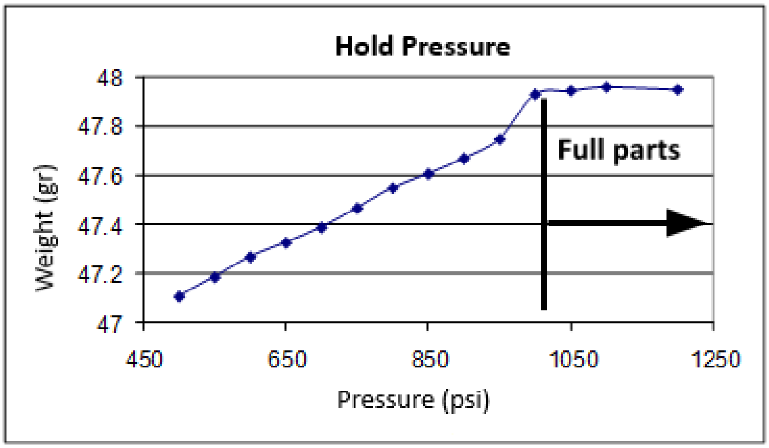
3. Perform a weight study of the parts at different hold pressures. Start the experiment with a lower pressure than required. For example, start with 10% of the injection pressure acquired at the time of transfer; then increase the pressure until you get completely full parts or the desired weight. Take two or three samples per pressure and calculate the average of the weight of the parts. Tabulate the data and plot the

weight of parts against hold pressure. Weigh only the molded parts; do not include the runner.

| Pressure (psi) | Average weight (gr) |
|---|---|
| 500 | 47.11 |
| 550 | 47.19 |
| 600 | 47.27 |
| 650 | 47.33 |
| 700 | 47.39 |
| 750 | 47.47 |
| 800 | 47.55 |
| 850 | 47.61 |
| 900 | 47.67 |
| 950 | 47.75 |
| 1000 | 47.93 |
| 1050 | 47.95 |
| 1100 | 47.96 |
| 1200 | 47.95 |

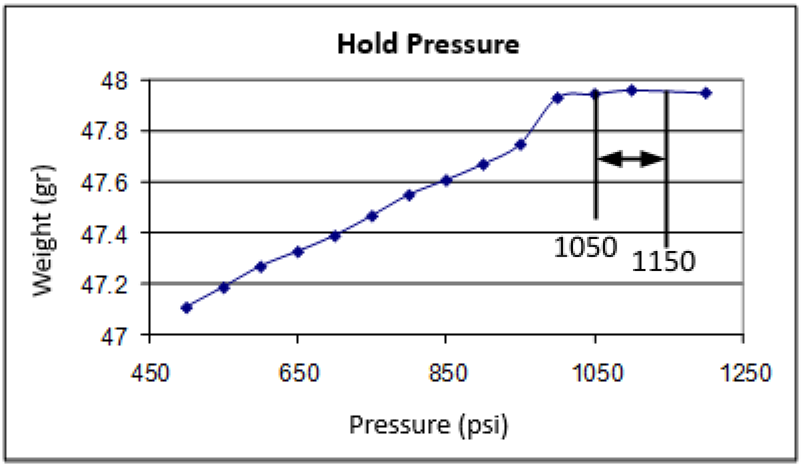
*X-3. Table of the effect of hold pressure on the weight of the parts*

In the graph below, we see that the pressure stopped contributing to the weight of the parts after 1000 psi of hold pressure.



*X-4. Graph of the effect of hold pressure on the weight of the parts*

4. Select a pressure where the weight is relatively constant. This example used a minimum hold pressure of 1050 hydraulic psi, a machine parameter. The norm would be to select a pressure range, for example from 1050 to 1150 psi.




*X-5. Graph indicating hold pressure range*

5. Once you select your hold pressure range, convert to Universal parameters.

In this example the injection unit used had an intensification ratio of 12.2, and its corresponding Universal parameters are:

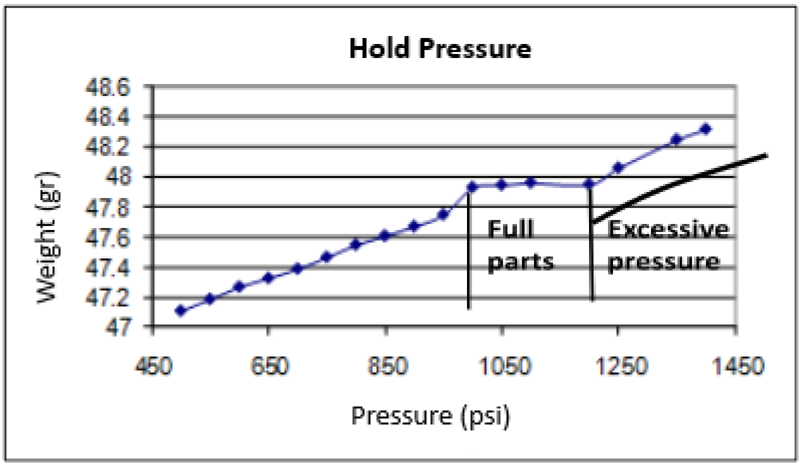
Universal hold pressure = Hydraulic pressure x $R_i$
Minimum pressure = 1050 psi x 12.2 = **12810 psi**
Maximum pressure = 1150 psi x 12.2 = **14030 psi**
Average pressure = 1100 psi x 12.2 = **13420 psi**

Notes:

- Although the objective is dimensions and not weight, for now you must work with the weight of the cavities. After unmolding, the parts will undergo multiple changes in dimensions due to shrinkage.

- Only weigh the molded parts, not the runner.

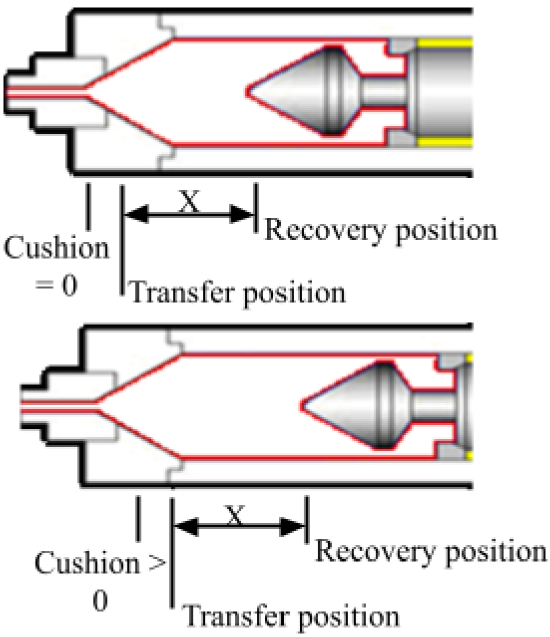
- Avoid opening the mold or forcing melt to sneak into unwanted spaces as a result of excessive pressure. An easy way to find out if the pressure is excessive is by looking at the graph of pressure versus weight of the parts.




*X-6. Graph indicating excessive hold pressure*

In the graph, after 1200 psi a new tendency was started, indicating that the mold is opening, or plastic is oozing.

- The cushion must be greater than zero. If it reaches zero, injection volume will have to be increased. Assuming there are no defects in the injection unit, such as a leaky check ring, increase the recovery position and transfer position by the same amount until the final position (after hold) is greater than zero.




*X-7. Correction when cushion is zero*

If the cushion becomes zero as a result of a defective injection unit, such as a leaky check ring, talk to the maintenance department to have the defect repaired.

Always ensure that the cooling time is longer than the recovery time.

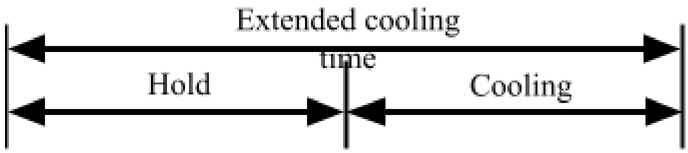
## Laboratory II - Determining Hold Time

Hold time is determined by the gate freeze test. While the gates are liquid, hold pressure keeps the melt in the cavity. Once the gates freeze, the melt cannot escape even when hold pressure is removed.

1. Adjust to the previously determined hold pressure.
2. Without changing the hold pressure found, decrease the hold time in intervals until the weight of the parts begins to decrease due to soft

gates, which are unable to keep the compressed melt inside the cavities.

In order to maintain a constant total cycle, the sum of cooling time and hold time must be kept constant. For each interval that is subtracted from hold time, the same amount should be added to cooling time.




*X-8. Extended cooling time*

3. Tabulate the times with their corresponding total weights of the parts and make a chart of the weight of the parts against hold time.

| **Hold time (s)** | **Average weight (gr)** | **Cooling time (s)** |
|---|---|---|
| 5.00 | 47.949 | 23.00 |
| 4.75 | 47.949 | 23.25 |
| 4.50 | 47.949 | 23.50 |
| 4.25 | 47.947 | 23.75 |
| 4.00 | 47.945 | 24.00 |
| 3.75 | 47.940 | 24.25 |
| 3.50 | 47.935 | 24.50 |
| 3.25 | 47.931 | 24.75 |
| 3.00 | 47.927 | 25.00 |
| 2.75 | 47.901 | 25.25 |
| 2.50 | 47.875 | 25.50 |
| 2.25 | 47.845 | 25.75 |
| 2.00 | 47.815 | 26.00 |
| 1.75 | 23.908 | 26.25 |

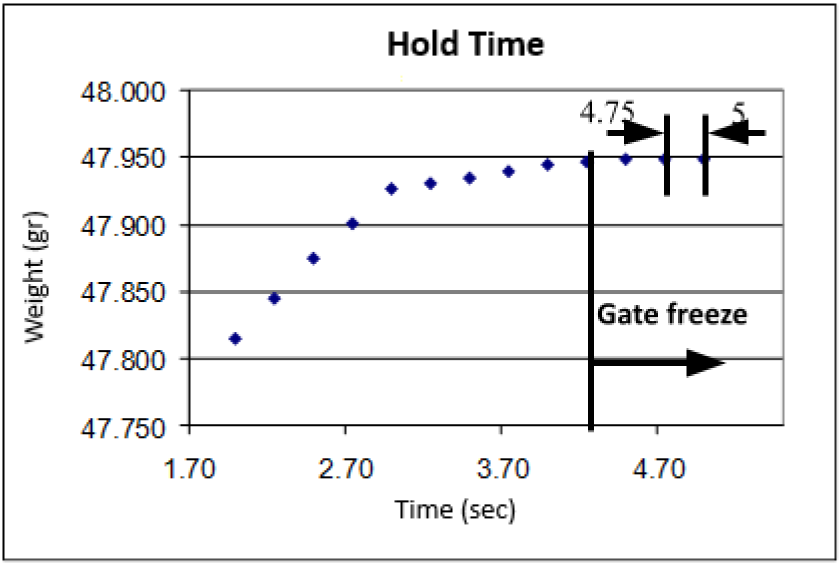
*X-9. Table of the weight of the parts and their respective hold and cooling times*

Although the cooling time column is not graphed, include it. It will help you when entering the times during the experiment.

Notes:

- For each hold time setting, take two to three samples and average the total weight of the parts.
- Only take the weight of the molded parts without the runner.
- Always ensure that the cooling time is longer than the recovery time.

4. On the graph, find the time where the weight of the parts begins to decrease. It is clearly shown that hold times longer than 4.5 seconds will be required to ensure gate freeze.




*X-10. Graph of the effect of hold time on the weight of the parts*

The hold time range selected in this example is 4.75 to 5 seconds.

**Summary of parameters**

Once the hold parameter determination is complete, summarize them:

- determined hold time and its operational range

- determined hold pressure (Universal and machine parameter) and its operational range
- remaining extended cooling time
- volume position or recovery position
- cushion or final position of the screw after hold and its operational range.

Finally, verify that the machine control has been programmed with the determined hold parameters.

## Hold Stage for Molds with Hot Runners and Gate Valves

With molds that include hot runners, the procedure is similar; we will have to guarantee gate freeze.

Now, if the mold also includes gate valves, those will do the function of gate freeze. These are programmed so that valve closure occurs when the adjusted hold time is met. In addition to creating a good finish at the injection site, these valves reduce hold time, since you don't have to wait for gate freeze.

Notes:

- If the valves close prematurely you will probably end up with incomplete parts.
- If the valves close too late, they may encounter hardened material in the valve seat, which could damage the gates in the cavities. Consequently, this defect would be reflected at the injection point of the parts.

During the hold stage, we guarantee measurements that are a function of mass. Do not attempt to correct thermal measurements in the hold laboratory.

| **Amorphous** | **Semi-crystalline** |
| --- | --- |
| Problems with over-packing due to low shrinkage | Problems of incomplete pack due to high shrinkage |
| Problems with flash | Sink marks |
| Breaks during demolding | Easy demolding |

| | |
|---|---|
| The transition from softened melt to solid is gradual | The transition from liquid melt to solid is sudden |

*X-11. Mechanical characteristics of materials which should be considered during hold*