SECTION 2
AIR FLOW AND HEAT TRANSFER

I. TYPES OF HEAT TRANSFER

Heat constantly moves from a warm object to a cold object. Heat moves in three different ways: thorough conduction, through radiation, and through convection. Middleby Marshall conveyor ovens use all three of these paths to cook the product.

- *Conduction* - Heat is transferred through surface contact (such as pizza dough in contact with a pan).
- *Radiation* - Heat is transferred from light-colored objects to dark-colored objects. The darker the color of an object, the greater the amount of heat that it absorbs. The lighter the color of an object, the greater the amount of heat that it reflects. Middleby ovens use light-colored interiors (aluminized or stainless steel, depending on the oven model) to reflect as much heat as possible to the product.
- *Convection* - Heated air will transfer heat to objects with which it comes into contact. Unless the air flow is controlled, hot air will rise and be replaced by cooler air. Middleby Marshall ovens use blowers (one or two large fans, depending on the oven model) to force air through adjustable air fingers onto the product.

The intensity of the heat at the point at which it is sensed is called temperature. The difference in temperature between the food product and the heat source - that is, the pan, oven interior, or heated air, as described above - determines the speed at which the heat flows. The greater the difference in temperature, the faster the heat flows to the product.

In Middleby Marshall conveyor ovens, the heat transfer from conduction is greatly dependent on the customer's product and cooking surface (pans, etc.). Likewise, the heat transfer from radiation is effectively constant, because the color of the oven interior cannot be changed. For these reasons, the best way to optimize heat transfer is by regulating the convection air. This can be done in two ways:

- Adjusting the blowers and blower speed to change the quantity and velocity of air delivered onto the product.
- Adjusting the air finger configuration to change the pattern in which the vertical columns of air are delivered to the product.

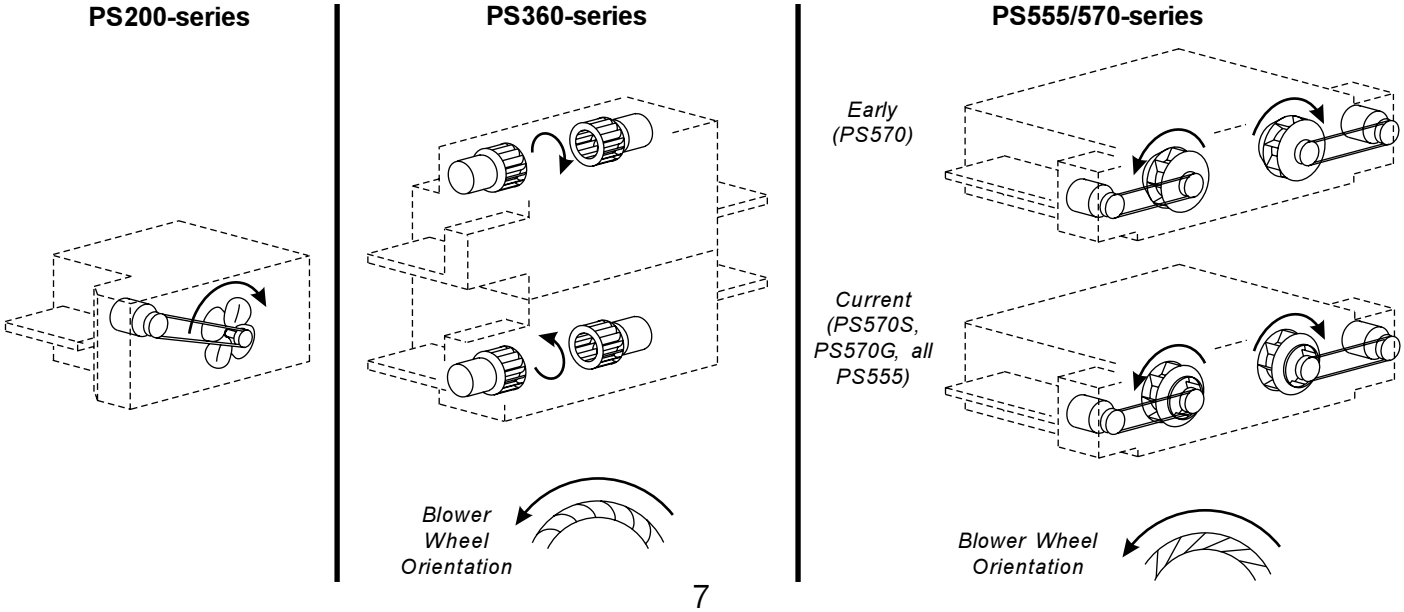
II. BLOWERS AND BLOWER SPEED

A. *PS200-series ovens*

PS200-series ovens have a single blower motor mounted inside the machinery compartment, with a pulley on the end of the motor shaft. A belt connects this pulley to another on the shaft of the blower fan. The air velocity can be changed by using a larger or smaller pulley on the motor shaft, and changing the length of the belt to match the new pulley. See Figure 1.

However, note that there are only two approved belt/pulley combinations for PS200-series ovens; one for 60Hz ovens, and one for 50Hz ovens. Field modifications to these approved combinations are not permitted unless under the specific directions of the Middleby Technical Service Department. Any changes to convection air delivery MUST be made using the air fingers.

Figure 1
Blowers, belts and pulleys



B. *PS360-series ovens*

PS360-series ovens feature two blower motors. A blower wheel is fastened onto the end of the motor shaft. In order to adjust the amount and speed of heated air that is directed by the blower wheels, it is necessary to change the size of the wheels and/or change the speed of the motor. See Figure 1.

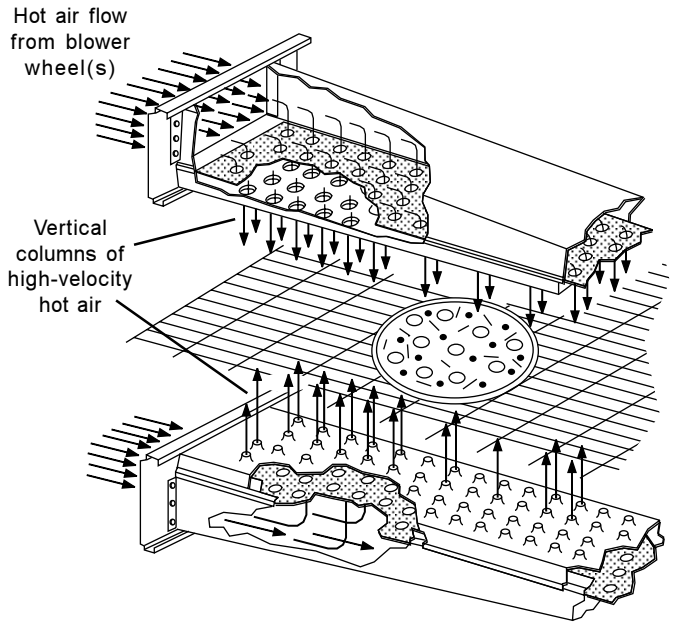
Each PS360-series oven model has a specific combination of blower motor and blower wheel. Field modifications to these approved combinations are not permitted unless under the specific directions of the Middleby Technical Service Department. Any changes to convection air delivery MUST be made using the air fingers.

C. *PS555/570-series ovens*

PS555/570-series ovens have one blower motor mounted inside each of the end compartments of the oven, with a pulley on the end of the motor shaft. The oven has two blower wheels; a belt connects each motor pulley to a pulley on the end of one of the blower wheel shafts. The air velocity can be changed by using a larger or smaller pulley on the motor shaft, and changing the length of the belt to match the new pulley. See Figure 1.

Some customers have a specific belt/pulley combination approved by Middleby Marshall, while others use a "standard" configuration. Field modifications to these approved combinations are not permitted unless under the specific directions of the Middleby Technical Service Department.

Figure 2
Air finger operation



III. AIR FINGERS

A. Description and Function

Air fingers direct the heated air from the blowers into vertical jets that are directed at the top and bottom of the conveyor belt. Each air finger configuration has been tested to optimally cook a specific customer's product. As a rule, air finger configurations should NOT be changed from customer specifications without direct instructions from the Middleby Technical Services Department.

Middleby uses two main types of air fingers:

- PS300/350 and early PS310/360 ovens used a shutter-type air finger assembly. The finger is assembled from a manifold, inner plate and outer plate. The inner plate is assembled from two separate plates, each with a series of holes, that are riveted together. The plates can be repositioned relative to each other to restrict the air flow through the holes as necessary. These fingers are no longer in general use, but may still be found in older ovens in the field. See Figure 3.
- All current ovens use an air finger which is composed of a manifold, inner plate, and outer plate. No adjustments are necessary or possible to these fingers, but a wide variety of styles is available to meet different customers' baking needs. See Figure 4.

Figure 3
PS300/350 air finger with shutter plate

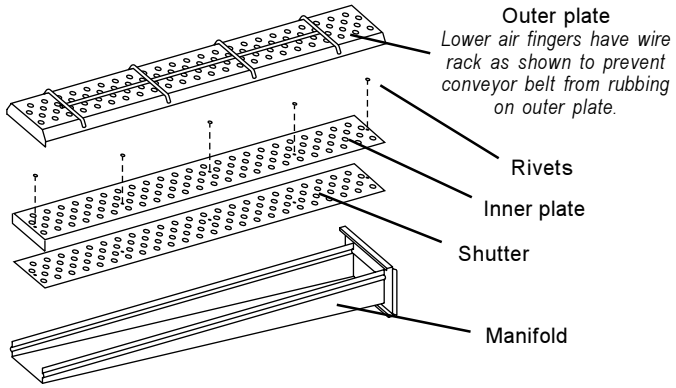
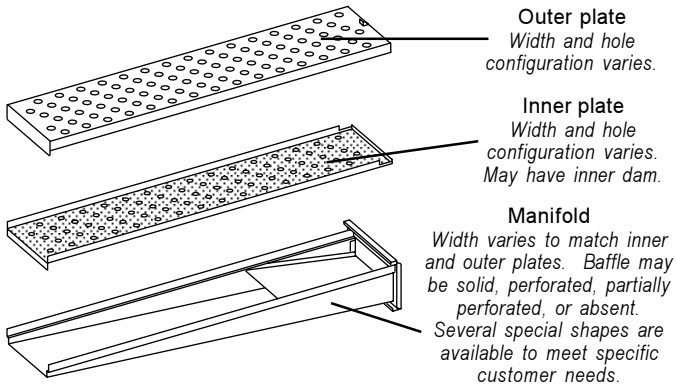


Figure 4
Current standard air finger (all oven models)



B. Configuration and Alignment

To ensure proper baking of the product, the air flow MUST be properly aligned as it exits the air fingers.

Because air finger configurations are tested at the factory for a specific customer's product, severe bake problems related to the air fingers are rare. If you encounter a problem, check the following:

1. Check that the air fingers are properly assembled, cleaned and free of obstructions. For the standard air fingers shown in Figure 4, a variety of styles are available for each of the three components. It is often possible to assemble these components incorrectly, as they are designed to be modular. This will affect the quality of the bake.

   If you need information on the correct air finger configuration of the oven, check the following:

   - *3D air finger label or card.* Many current ovens will have a three-dimensional drawing on the front panel of the oven that shows the correct air finger configuration, as shown in Figure 5. Other ovens may have this information on a laminated card attached to the oven.
   - *Internal air finger chart.* All Middleby ovens have a chart similar to the one shown in Figure 6 attached inside the machinery compartment door. Note that if the air finger configuration has been updated since the oven was installed, this chart may no longer be correct.
   - If there is no label present on the oven, and the chart inside the machinery compartment is incorrect, contact Middleby Technical Service for assistance.

2. Check that the bake time and temperature settings of the oven match the customer's specifications. Most customers have an acceptable range for bake time and temperature to allow for local variations in altitude, humidity, etc.
3. If these checks fail to correct the problem, you should perform a test bake to pinpoint the type of baking problem that is present.

C. Performing a Test Bake

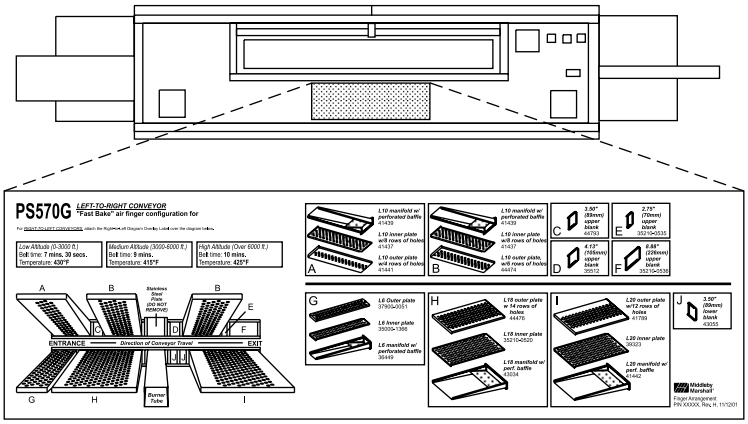
Before you attempt to correct any problem, please <u>CONFIRM THAT THERE IS ACTUALLY A PROBLEM.</u> It is extremely difficult to tell if an oven is baking unevenly by simply looking at a pizza with ingredients, especially if the pizza is a large combination-type. Often, the ingredients and toppings themselves can cause an uneven bake.

The best way to check for an uneven bake is to make a test bake with a consistent, "predictable" product and then read it. We recommend using the customer's dough (for a pizza product) OR a commercially-available pancake mix (for customers with a variety of products). The pancake mix is generally more sensitive to variations in temperature and thus provides more accurate results than the dough test.

When interpreting the results of the test, <u>consistently</u> uneven baking on the top of the product may indicate a problem with the upper air fingers. Likewise, <u>consistently</u> uneven baking on the bottom of the product may indicate a problem with the lower air fingers.

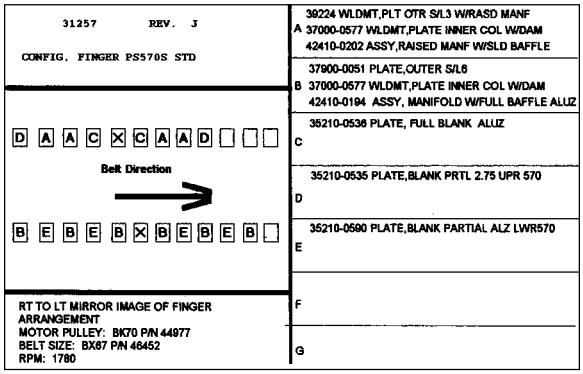
The most common bake problem is a "front-to-back" bake issue. This problem occurs when the "front" of the conveyor belt (towards the window) receives more heat than the rear, or vice-versa. This results in uneven baking for the product based on where it is placed on the conveyor.

Figure 5
3D air finger label (if present)



NOTE: Labels of this type are not used on all ovens. Label placement and design will vary based on customer preference.

Figure 6
Internal air finger chart



NOTE: All ovens use a chart of this type inside the machinery compartment.

Changes to the air finger configuration after oven installation MAY NOT BE INDICATED.

To perform the test bake:

1. Select identical pans for the test. Choose the pans based on the width of the conveyor; you should space the pans in line completely across the conveyor without having them touch each other. For instance, for a 32" /813mm-wide conveyor, you could use three 10"/ 254mm pans or two 15"/381mm pans.

   You will need enough pans to have three complete rows. This eliminates the possibility of a single row distorting the results. If necessary, the test can be run with only 1 row of pans, but the results are not as reliable.

2. For a pancake batter test, mix the pancake batter as instructed by the manufacturer. Pour the batter EVENLY into the test pans to a depth of 1/4" (6mm). You may use any type of pancake mix that is available, AS LONG AS YOU USE THE SAME TYPE THROUGHOUT THE TEST.

   For a dough test, have the customer make up a thin crust dough in each pan. The dough should be of a consistent thickness in each pan and should be no thicker than 1/4" (6mm). Thicker doughs will provide too great a "cushion" and will distort the test results.

3. Place the pans side-by-side on the conveyor. The front and rear edges of the pans should be aligned so that it is easier to see if there is a front-to-back bake problem. DO NOT stagger the rows of pans diagonally. Also, check that the pans do not touch each other; this can transfer heat to the test product and distort the results.

4. Run the products through the conveyor at the customer's normal bake time and temperature settings.

5. "Read" the results of the test. Each pan of product should have the same coloration.

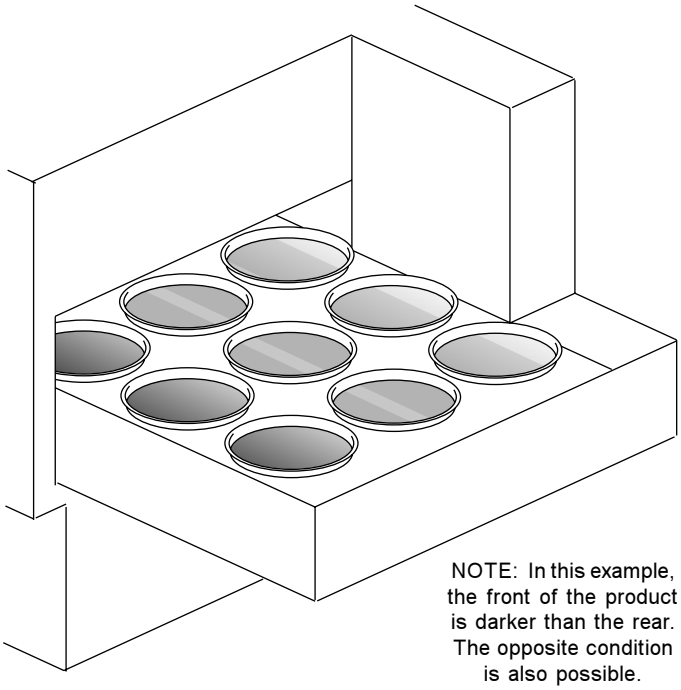
   If you used pancake batter, the sugar in the mix will brown very rapidly if over-baked. This highlights an out-of-balance oven.

   If the product lightens or darkens slightly from front-to-back in only one row, there is probably not a significant front-to-back bake problem. If the product is noticeably lighter or darker at the front or back in ALL of the rows of pans, there is a front-to-back bake problem. See Figure 7.

   Also, remember that consistently uneven baking on the top of the product may indicate a problem with the upper air fingers. Likewise, consistently uneven baking on the bottom of the product may indicate a problem with the lower air fingers.

   - If the oven has the current standard air finger type, you should contact Middleby Technical Services for assistance.
   - If the oven has the PS300/350-style air fingers with a shutter plate, it is possible to adjust the positions of the air shutters to correct a front-to-back bake problem. Proceed to Step D, "PS300/350 Air Finger Shutter Adjustment."

Figure 7
Front-to-back uneven bake



NOTE: In this example, the front of the product is darker than the rear. The opposite condition is also possible.

D. PS300/350 Air Finger Shutter Adjustment

Before attempting to properly balance a Middleby Marshall oven equipped with shutter fingers, you should understand the principles of operation of this type of finger.

The oven moves approximately 2000 ft.³ of air per minute. When this large amount of air is moved through the plenum and fingers it rushes through the plenum and to the end of the air finger. This creates a back pressure of air inside the finger and tends to deliver more air onto the product at the front of the air finger.

The inner plate has a separate shutter plate riveted to it at a slight angle. Since there is more pressure at the end of the fingers (front of the oven) than at the plenum (rear of the oven), the shutter plate is angled to restrict the air flow near the front of the oven. This creates a proper balance permitting an even amount of air to exit out of the holes across the width of the conveyor. See Figure 8.

Before adjusting the shutters, it is necessary to determine if the finger is providing a balanced air delivery across the width of the conveyor. This is the purpose

of making a test to "read" the bake.

1. Remove all upper air fingers from the oven.

   NOTE: As the air fingers are removed, use a felt pen to mark all parts of the fingers. This includes the manifold, inner plate and outer plate. If a blank or choke plate is used, mark that plate also. Fingers are marked in the order shown below, as viewed from the front of the oven. If there are upper and lower oven cavities, you should mark the fingers for the upper oven with a "U" and those for the lower oven with a "L."

   ***VERY IMPORTANT:* When the ovens were shipped from the factory, all of the shutters were pre-adjusted for their location within the oven. All parts of the fingers must be marked as explained above and reassembled into their original position.**

2. Check the size of the openings at the front of the shutter plates by inserting a drill into the opening. The factory setting is a #46 drill (0.081"/2.06mm).

3. Drill out the four 1/8" pop rivets that are located toward the front of the fingers. See Figure 8.

   NOTE: DO NOT drill out the rivet at the back of the air finger. This is the pivot for the shutter.

4. If the product is lighter at the front of the oven, increase the opening by 1/16"/1.59mm. If the product is darker at the front of the oven, decrease the opening by 1/16"/1.59mm.

   The best way to check the size of the openings is to use numbered drills as a gauge. An orifice drill set is ideal for making this adjustment. For example, to increase the opening by 1/16", you would use a #30 drill (0.1285"/3.26mm), which is approximately 1/16" larger than the original setting measured with the #46 drill (0.081"/2.06mm).

   Be sure that the measurement is taken at the largest point of the opening. See Figure 8.

5. While holding the new adjustment, clamp the two shutter plates together (two pairs of vice grip pliers are ideal) and drill holes for new pop rivets.

   NOTE: Most of the old rivet holes can be reused if the old hole is simply elongated. However, if the hole is not properly elongated, the new rivets may pull the plates out of adjustment when they are installed.

   ***IMPORTANT:* Aluminum 1/8" pop rivets are ideal for use here. They are much easier to drill out than stainless steel rivets.**

6. Repeat these steps to adjust all upper air fingers. Then, reinstall the fingers into the oven.

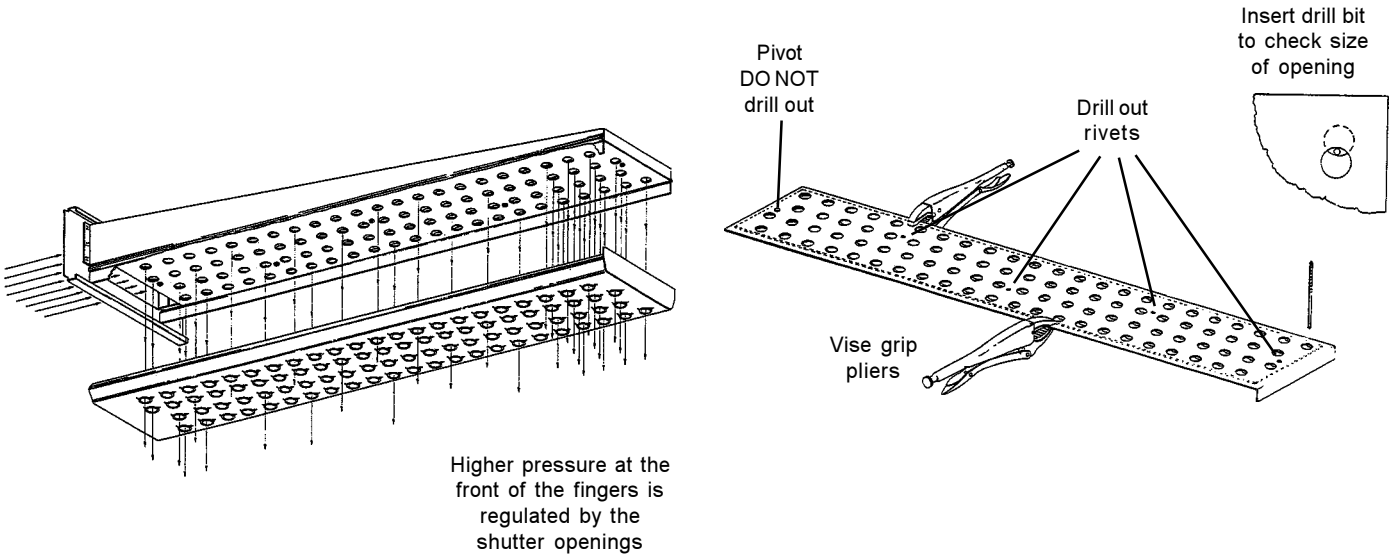
7. Perform another test bake.

   IMPORTANT: This test bake must be an exact duplicate of the first test bake. If you change any of the conditions you will change the results.

   - If the test indicates an even bake, your adjustment is complete.
   - If the test indicates that the bake is still uneven, you will need to repeat the adjustment procedure until an even bake is obtained. By keeping the tests identical, you should be able to determine how much more the shutter plates should be opened or closed to achieve a balanced bake without removing the fingers for a third time.

   VERY IMPORTANT: After attaining a proper adjustment of the fingers, each air finger should be marked with a metal stamp showing its position inside the oven. This will eliminate future problems of operators mixing the adjusted fingers when cleaning the oven.

Figure 8
PS300/350-style air finger with adjustable shutter plate



IV. OVEN CAPACITY

Oven capacity is generally not a service issue. However, when reporting a service problem, customers may use terms relating to capacity, such as bake time, belt time, time of delivery, etc. This information is provided as a reference for understanding these terms.

A. Conveyor Speed and Bake Time

Middleby Marshall conveyor ovens display the Conveyor Speed on the Thumbwheel (or on the display of the Digital Speed Controller, as appropriate for the oven model). Conveyor Speed is also called Bake Time.

Conveyor Speed (Bake Time) is a *leading edge to leading edge* measurement. That is, it is the elapsed time from the leading edge of the product entering the bake chamber to the leading edge of the product leaving the bake chamber. See Figure 9.

B. Belt Time

Belt Time is a measurement used by several customers. It is a *trailing edge to trailing edge* measurement. That is, it is the elapsed time from the trailing edge of the product entering the bake chamber to the trailing edge of the product leaving the bake chamber. See Figure 10.

Note that belt time is equal in length to conveyor speed (bake time), although the time is measured during a different period of the baking process.

C. Time of Delivery (TOD)

Time of delivery (TOD) is a *leading edge to trailing edge* measurement. That is, it is the elapsed time from when the leading edge of the product enters the bake chamber to when the trailing edge of the product leaves the bake chamber. See Figure 11.

Figure 9 - Conveyor Speed (Bake Time)

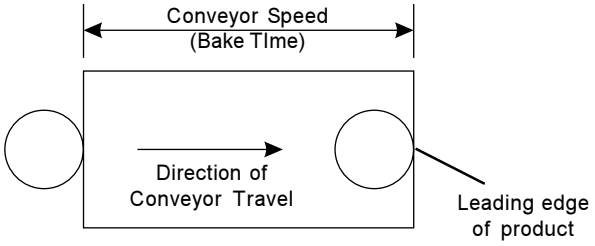


Figure 10 - Belt Time

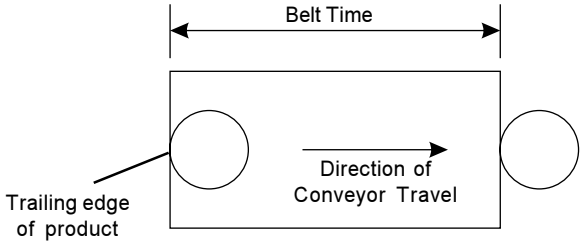
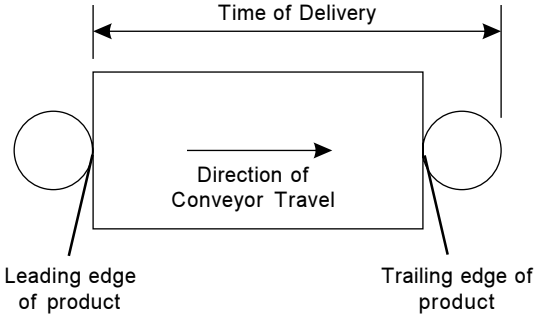


Figure 11 - Time of Delivery



D. Formulas for Determining Time of Delivery (TOD) and Oven Capacity per Hour

1. *Time of Delivery (TOD)*

$$\text{Time of Delivery (TOD)} = \frac{\text{Conveyor Speed}}{\text{Bake Chamber Length}} \times (\text{Bake Chamber Length} + \text{Product Diameter})$$

Example: PS570S Oven, 7:00 Bake Time, 16” Product Diameter = $\frac{7 \text{ mins.}}{70”} \times (70” + 16”)$ = **8.6 mins. (8:36)**

2. *Oven Capacity/Hour*

$$\text{Oven Capacity/Hour} = \frac{(\text{Bake Chamber Length} + \text{Product Diameter}) \times \text{Bake Chamber Depth}}{\text{Product Diameter}^2} \times \frac{60 \text{ min./hr.}}{\text{TOD}}$$

Example: PS570S Oven, 7:00 Bake Time, 16” Product Diameter = $\frac{(70” + 16”) \times 32”}{256 \text{ in.}^2} \times 6.98$ = **75 pizzas/hr.**