Indexing bottles in and out of an inline filler is pretty straightforward. Doing it right, to maximize throughput, requires attention to detail. I often find fillers that because of improper setup or by design are not producing as they should. As with any packaging machine, understanding how it works is the first step to understanding how to make it work better. This paper will explain various indexing architectures.

The most common indexing systems bring the bottles in a single lane to the filler nozzles. Two air cylinders are used to extend fingers across the conveyor to stop the bottles. The upstream, inlet, finger is called the index gate. The downstream, discharge, finger is the fill gate. The purpose of the fill gate is to position the bottles under the filling nozzles. The purpose of the index gate is to hold the empty bottles back while the filled bottles leave the filling area.

200 milliseconds, one fifth of a second, doesn’t sound like much. It might be costing you hundreds of thousands of bottles a year that you could otherwise sell.

Have I got your attention?

An 8-head inline filler, running 8 cycles per minute, has a cycle time of 7.5 seconds. During an 8-hour shift, it will cycle 3,840 times to produce almost 31,000 products. Over a year, 250 shifts, it will produce about 7.75 million bottles.

If 200 milliseconds are added to the cycle time, production drops to 3,696 cycles per shift. Annual output drops to 7.4 million bottles.

200 extra milliseconds cost 350,000 bottles of product that could have been sold for money.

Still think 200ms is no biggie?
The simplest way to control these air cylinders is with a single solenoid valve. The fill gate is normally extended, blocking flow. The index gate is normally retracted. When the solenoid valve is actuated, the fill gate retracts and the index gate is extended. A timer allows sufficient time for the filled bottles to clear the fill gate then activates the solenoid valve shifting the 2 gates. After allowing enough time for the empty bottles to get into position, the filling cycle begins again.

The controls on this system are simple, 2 timers and a solenoid. Unfortunately, it is also slow.

Indexing time can be calculated by the following formula:

\[ T = \frac{L + G}{S} \]

where:

\( T \) = Indexing time

\( L \) = Length of container group

\( G \) = Gap between container groups
S = Container speed in inches per second (Usually conveyor speed)

Let’s look at a group of 8 bottles, each 1.5” in diameter. The conveyor runs continuously at 60 feet per minute or 12 inches per second. There is a 12” gap between bottle groups created while the empty bottles wait for the filled bottles to exit the filler.

L = 12”

G = 12”

S = 12in/sec

Indexing time \( T = \frac{(12+12)}{12} = 2 \text{ seconds.} \)

We can’t do anything about the length of the bottle group, and may not be able to change the bottle/conveyor speed. We can change the size of the gap.

Additional timers and solenoid valve will allow the gates to operate independently. After the fill gate opens, and after a slight delay, the index gate opens admitting the empty bottles. Once a suitable, say 2”, gap has been created, the index gate opens. After an additional delay to allow the last full bottle in the group to pass but before the first empty bottle arrives, the fill gate closes.

Indexing time has been reduced to:

\( T = \frac{(12+2)}{12} = 1.16 \text{ seconds} \)

That’s a gain of 840ms, every cycle.

An issue that can occur with this control scheme is that it relies on time. Bottles may not move smoothly or conveyor speed may change to throw the time delays out of whack.

This indexing system can be further improved with a sensor and control to count the exiting bottles. The fill and index gate actuate as above. As the filled bottles exit, the sensor counts and, upon seeing the 8th bottle closes the fill gate. The replacement of the timer with a sensor makes it less prone to timing errors. This may make it possible to reliably reduce the gap and index time.
The gap can be eliminated completely using a starwheel for indexing. These may be unpowered or powered.

This unpowered starwheel has an air cylinder which releases the starwheel to make a single revolution then relocks it. The starwheel has 8 pockets allowing 8 bottles to index per cycle. There is no gap between filled and empty bottles at the end of the cycle.

Index time is now:

\[ T = \frac{12+0}{12} = 1 \text{ seconds} \]

A disadvantage of the unpowered starwheel is that it relies on conveyor friction to push the bottles through. This may not work reliably with smaller or lighter weight bottles.

The solution is a powered starwheel. A servo motor can be programmed to make a single revolution and stop. An alternative is a continuously running motor with single revolution clutch and brake.

Another alternative is a powered starwheel that runs continuously. As servo motors and controls have become cheaper and easier to use, this arrangement has become rarer but may still be found occasionally.
The starwheel is cut with a group of pockets, 4 in this photo, and the rest of the circumference blank. Clockwise rotation is shown. It rotates in synchronization with the filler so that as filling finishes, the 4 pockets index the bottles out and in. Since the starwheel is running continuously, it may cause scuffing of some highly-finished bottles. Bottle gap between filled and empty bottles on this starwheel is also zero inches.

Starwheel indexing has a disadvantage of requiring a change part for each bottle size and profile. This reduces the filler's flexibility since it may take several weeks to make a new starwheel for a new bottle.

Filling nozzles are sometimes added to increase throughput. While each additional nozzle will add throughput, it also increases the length of the bottle group. Thus, doubling the number of nozzles may only increase throughput by 50%.

One way to reduce indexing time is via cross-indexing. There are two ways to do this, by moving the bottles sideways or by moving the filler nozzles sideways.
Z-Indexing, moving the bottles sideways, requires 2 conveyor lanes with a center deadplate. Empty bottles enter the filling area on the back lane. They are pushed sideways onto the center deadplate and filled. As they are filling, the next set of empty bottles is being admitted to the back lane. On completion of fill, the empty bottles are pushed under the nozzles, pushing the filled bottles onto the front lane where they can exit the filler.

Index time for the 8 bottles is now:

\[ T = \frac{(1.5+0)}{12} = 0.125 \text{ seconds} \]

An alternate means of accomplishing the same goal is to use a dual lane conveyor. Bottles are indexed in and out of the filling station on each lane as described above. The filler nozzles are mounted on a mechanism that allows them to shift from lane to lane. As bottles are filling in one lane, the other is indexing for the next fill. Indexing time depends on how fast the nozzles may be shifted from lane to lane. About 1.5” travel in this case.

Some bottles will not lend themselves to indexing with fingers. Oval bottles may tend to twist as they accumulate, misaligning with the nozzles.
Other bottles may have an inverse taper, smaller at the bottom than the top. This can cause them to fan out and fall over.

Some fillers, because of the nozzle design may require separation between bottles.

Timing screws can resolve these issues. A timing screw for bottle indexing will have a normal infeed with increasing pitch. The difference with other timing screw applications is that, after achieving the desired separation, the screw remains at a constant pitch to position the bottles under the nozzles. Indexing is done by rotating the screw the same number of revolutions as bottles under the nozzles.

On a 4-head filler, the screw will make 4 revolutions and stop, 6 revolutions on a 6 head and so on.
An interesting wrinkle on timing screws is the use of a dwell screw. This is a timing screw with 1 pitch cut vertical for about half a revolution. The effect is to momentarily pause the bottle while the screw continues running. One filling application where this was used was dispensing a drop of fragrance into a detergent bottle that was filled at high speed on a rotary filler.

Generally, it is better to leave the conveyor running continuously while filling. However, leaving it running, with unstable bottles, may cause them to jiggle and not align well with the nozzles. If filling very heavy products, say gallons of water, the weight of the bottles may cause excessive tension on the conveyor chain and excessive pressure on the fill gate. Some plastic bottles, like the gallon water bottle, can be fairly soft. The conveyor chain, if left running, may cause the back pressure of the filled bottles to crush those near the filler discharge.
Conclusion

Indexing looks simple and is. Getting the details right, both in the initial design of the system and in setup and operation can make the difference between selling 350,000 products and not.

Sometimes 200ms can be a long, long, time.

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